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Leaf litter production and decomposition dynamics in four agroforestry tree species of western Himalayas

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Abstract

Litter fall and its subsequent decomposition in the soil are two essential ecosystem processes. In order to determine the soil fertility improvement potential of a tree species, it is necessary to evaluate litter production, its temporal variation, and rates of decomposition and nutrient cycling. In this study, we examined patterns of litter fall production and decomposition four agroforestry tree species (*Celtis australis, Grewia optiva, Bauhinia variegata and Ficus roxburghii*) from western Himalayas, India. Average litter fall was 2190 kg/year/ha and varied significantly among species. Leaf litter production in a year was maximum in case of *Grewia optiva* statistically at par with *C. australis* whereas *F. roxburghii* recorded minimum amount of annual leaf litter. In a litterbag experiment, all species had fast mass loss in the first six months of decomposition, coinciding with the rainy season. *Celtis australis* had significantly higher decomposition rate than all other species whereas *F roxburghii* exhibited slowest rate of decomposition. We recommended *C. australis* and *G. optiva* for soil fertility improvement because of their fast growing characteristic, high litter production and rapid decomposition. However where the objective is to use the leaf litter as mulch for protection against soil and water erosion as well as moisture retention, *F. roxburghii* will be more suitable because leaf biomass will be remained as mulch for longer period.

Keywords: Multi-purpose species, leaf litter, decomposition rate

Introduction

Farmers have been raising and/or allowing trees in their crop fields in one or other forms since ages to meet multi needs of households. In recent times this practice was coined agroforestry. Amidst global climate change agroforestry has got more importance beyond livelihood security and recently for mitigation of climate change by way of sequestering C in both standing biomass and soil. Agroforestry provides many direct and indirect services to the mankind. Directly, it meets the requirement of fuel, fodder, food, furniture, farm implements, employment etc. of each farm household and also other households. Indirectly, it enriches soil, provides shelter, increases biodiversity, sequester C, prevent soil erosion, conserve water etc. For soil enrichment, trees capture nutrients from deeper layers and add to the surface soil through leaf shedding (litter fall) and incorporation of pruned biomass. It is believed that agroforestry promotes a more efficient cycling of nutrients than traditional agriculture system (Smiley and Kroschel 2010) [14]. Litter fall and pruned biomass consequent upon the decomposition release nutrients and results cumulative build up and/or sustain soil fertility. Litter fall is a fundamental process in nutrient cycling and it is the main means of transfer of organic matter and mineral elements from the vegetation to the soil surface (Regina *et al.*, 1999) [11]. Litter is a general term for senescent plant parts. Litter contributes to forest and agro-ecosystem mainly by nutrient and carbon turnover during litter decomposition and thus maintaining biogeochemical cycling in the ecosystems. Litter usually improves soil quality through the addition of organic matter, which enhances the soil's water holding capacity, water filtration, biodiversity, activity of soil microorganisms, and nutrient. More than half of the nutrients taken up by plants return to the soil through several ways, among which decomposition of litter contributes the majority and the nutrient release patterns are related

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to climatic condition and litter quality (Khietwtam and Ramakrishnan 1993) [6]. Litter cover acts as a protective layer for maintaining soil physical properties like retention of soil moisture (Ginter *et al*., 1979) [2], buffering against soil temperature and compaction change (MacKinney, 1929) [7], and soil conservation from erosion or leaching (Mo *et al*., 2003). It also provides habitats and substrates for soil fauna (Attignon *et al*., 2004) and flora (Ruf *et al*., 2006) [12]. Magnitude of soil enrichment depends upon the amount of litter fall and quality of the litter added. Both higher amount and quality of litter added in the system adds more nutrients and *vice versa* (Yadav *et al*., 2008) [20]. Among litter types, leaf litter contains comparatively higher concentrations of nutrients and returns the major source of nutrients to the soil. Litter fall depends upon nature of tree species, climate and tree management practices etc. resulting varying build up in soil fertility. Hence, to understand the processes and mechanism of soil enrichment in tree based cropping systems, it is imperative to study the quantification of litter fall, their decomposition and nutrient addition. Although intensive studies on litter dynamics, and soil enrichment in forest ecosystems have been carried out worldwide, but multipurpose trees, especially grown in farming situations have received very little attention. However, the prime challenge of better management and sustainable production within agroforestry practices depends on the selection of tree species having efficient nutrient return capabilities through the decomposition of litter which influences the nutrient cycling and formation of soil organic matter. Therefore, the aims of the present study were to examine and compare leaf litter production and decomposition dynamics degradation of *G. optiva*, *C. australis*, *B. variegata* and *F. roxburghii.*

Material and Methodology

Litter fall collection

The quantification of litter production was estimated by placing the 4 to 5 litter traps (Each 1 m^2area) with a perforated net covering the base bottom under the canopy of each tree. Litter fall was collected monthly during one year (December to November). Subsequently, the collected material was separated by species and components: leaves, reproductive structures (flowers, fruits and seeds) and twigs. Only the litter samples were air dried in the laboratory and sub-samples were kept at 80°C for 48 h to determine the dry mass (Swamy and Proctor, 1994) [15].

Organic matter decomposition

We used the litterbag method to determine the decomposition rate of leaves of each species (Wieder and Lang 1982) [19]. We focused on leaf litter rather than twigs because it represented a substantial portion them for determining their chemical composition. Leaf litter constitute 50–80 % of total litter in terms of biomass produced (Sundarapandian and Swamy 1999) [16], it has higher nutrient concentrations and decomposes faster than twigs and other wood materials thus accelerating the cycling of nutrients in the soil. Freshly senesced leaves of each species were gathered and the senesced leaves of species were collected and spread separately in a thin layer for drying at room temperature (25–30°C). 20 g sample of each species was placed in bags. The mesh size was 2 mm, small enough to prevent major losses of litter samples yet large enough to permit aerobic microbial activity and free entry of small soil organisms. Each bag was stitched with nylon thread to prevent movement and to ensure good contact between the bags and the soil surface on experimental sites A total of 192 bags for 12 collections (one per month) with four replicates of each species were randomly placed and set in the ground under trees of each species. Four randomly selected mesh bags of each species were collected monthly for 12 months. After collection, the material was removed manually, including plant material (leaves, seeds, grasses, roots) and fauna, if present. The litterbags were washed in a bucket full of tap water, by swirling briefly, and carefully decanted through a 2-mm mesh size sieve to remove extraneous matter. The weight of leaf litter was recorded before and after oven drying at 80°C to a constant weight.

Remaining weight (RW) for each collection date was expressed as a percentage of initial weight as follows

$$RW = (WT1/WT0) \times 100$$

Where RW = remaining weight; WT0 = weight at time 0; WT1 = weight after a given period.

The decomposition rate constant (K) was estimated for each collection date following the exponential model (Olson 1963) that characterizes the weight loss during the decomposition.

$$K = - \int \ln (Xt/X0) \int /t$$

Where X0 = weight (g) of litter at time 0; Xt = weight (g) of litter at time t (days); K = decomposition rate constant.

From K it was possible to obtain the average lifespan of the material sampled, in terms of time of
Decomposition, using the following equation (Olson 1963):

$$T(0.5) = - \ln_{(0.5)} / k_{t(0.5)} = 0.6931/k.$$

The time (t) necessary for 99 % organic matter loss as obtained by using the following equation (Olson 1963)

$$t(0.99) = \ln_{(1-0.99)/} k.$$

Table 1: Some characteristics of tree species under study

Tree	Family	Litter production (Kg/ha/year)	Age	Growth characteristic
Grewia optiva	Tiliaceae	2548^{ab}	20	Fast growing
Celtis australis	Ulmaceae	2250a	18	Fast growing
Bauhinia variegata	Caesalpiniaceae	2105c	22	Fast growing
Ficus roxburghii	Moraceae	1860d	25	Moderate growing

Table 2: Dry weight loss and decay constant in different trees

Tree	Dry weight lost in one year (%)	Decay constant (K value)	$T_{0.5}$	$T_{0.95}$
Grewia optiva	87.65 ab	2.12 ab	0.32	1.41
Celtis australis	89.75 a	2.30 a	0.30	1.30
Bauhinia variegata	71.30 c	1.64 c	0.42	1.82
Ficus roxburghii	65.35 d	1.05 d	0.66	2.85

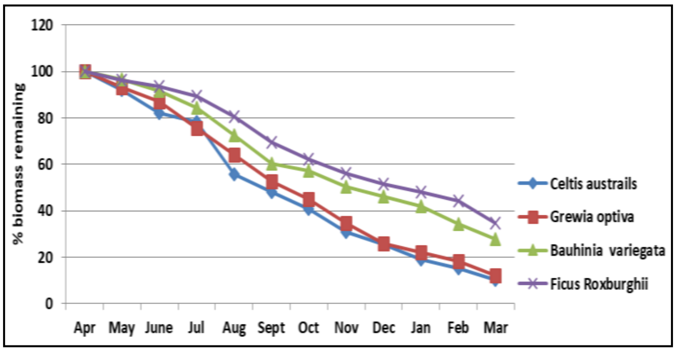

Fig 1: Percent biomass remaining after one year

Result and Discussion

Annual litter fall production

Annual litter production from the four tree species are presented in Table 1. Average litter fall production for all species after one year was 2190 Kg/year/ha there was marked variation in the amount of leaf litter fall across seasons and tree species. Leaf litter fall production differed significantly among different tree species at 5% level of significance. *Grewia optiva* had the highest leaf fall production followed by *C. australis* whereas *Ficus roxburghii* had the lowest amount. *G. optiva* and *C. australis* produced the highest annual litter fall, possibly because both are fast-growing species, and after 20 years they had the highest basal area, cover and crown volume; which correlate with litter fall production. All the species except *Ficus roxburghii* had a uni modal peak in annual pattern of leaf litter fall, but with different seasonal fluctuations. *In G. optiva* the leaves remained green throughout the winter and leaf fall largely occurred during the summer months (April-June). In case of *Celtis australis*, highest leaf litter-fall was recorded in the month of October while the least occurred in the month of February. Leaf fall reached its peak in October for *B. variegata*. Leaf fall in *Ficus roxburghii* followed a bimodal pattern of distribution. Maximum leaf litter fall occurred during October-November, whereas other peak was observed during January-February.

Dry Weight Loss

Table 3 indicated that C. *australis* exhibited maximum Leaf dry weight loss in one year i.e. 89.75% which is statistically at par with dry weight loss in a year in case *of Grewia optiva* (87.65%). Minimum dry weight loss in a year was recorded in *Ficus roxburghii* (65.35%) which is statistically lower than all the other three tree species at 5% level of significance. Similar results were reported by Raijada *et al* (2002) who observed maximum dry weight loss in G. optiva i.e.71% of the original dry weight in one year wheras slowest decomposition of leaf litter was observed in *B. purpurea*, with only half of the initial dry weight decomposing in one year. Litter decay rates were determined on the basis of mean percentage remaining dry weight for the different species at the time of sampling. *C. australis* and *G. optiva*, exhibited relatively fast decomposition rates i.e. (k = 2.30, 2.12 respectively, respectively while *Bauhinia variegata* (k = 1.64) and *Ficus roxburghii* (k = 1.05) showed relatively slower decomposition rates. The half-lives and full-lives (t50and t99) ranged from (0.30 and1.30) for *C. australis* to (0.66 and2.85) for *F. roxburghii*. Differences in decomposition rates can probably be explained by variations in litter quality and in climatic and soil conditions of study sites (Mugendi and Nair 1997) [8]. Litters with low lignin and phenolics and higher nitrogen content are generally considered good quality material for decomposition Lignin is highly resistant to enzymatic attack and physically interferes with decay of other chemical fractions in leaf tissue hence, slows down decomposition process.

Pattern of Litter Decay

Previous studies have shown that litter decay can follow an exponential pattern (Harmon et al 1990; Edmonds and Thomas 1995; Sadasivam and Manickam 1992) [4, 1, 13] or a linear pattern (Issac and Nair 2004; Upadhyay and Singh 1989) [4, 17] depending upon the species studied and conditions (climate, soil, method of application, etc.) under which decomposition takes place. The dry matter loss in leaf litter of all the four species at monthly intervals was analyzed to access the decomposition rate. The percentage of average dry weight remaining differed significantly among different tree species at 5% level of significance Table 3. In all species mass loss during initial six months was rapid, coinciding with the rainy season (May to November). After this period, the mass loss stabilized showing small losses that were similar and continuous. This behavior was similar to as observed with different tree species by various workers (Sundarapandian and Swamy 1999; Goma-Tchimbakala and Bernhard-Reversat 2006) [16, 3]. The rate of decomposition was highest in *C australis* followed by *Grewia optiva* whereas the curve for *Ficus roxburghii* and *B variegata* indicate comparatively slow decomposition. In case of *C australis* only 10.25% biomass (dry weight basis) remained after one year whereas in *F roxburghii* as high as 34.65% leaf litter remained undecomposed in the same period of time. When the objective is to increase soil fertility as soon as possible, the appropriate species according to the results of the study are *C. australis* and *G optiva* because they are fast-growing trees, with a rapid canopy closure and a high litter production which produces large amounts of rapidly decomposing mulch, therefore nutrients can be rapidly released into the soil. However where the objective is to use the leaf litter as mulch for protection against soil and water erosion as well as moisture retention, *F. roxburghii* will be more suitable because leaf biomass will be remained as mulch for longer period.

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