Leaf Litter Decomposition and Nutrient Release from Cordia Africana Lam. and Croton Macrostachyus Del. Tree Species

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Abstract
The objective of this study was to investigate the nutrient content of abscised leaves of *Cordia africana* Lam. and *Croton macrostachyus* Del. tree species and the extent to which they decompose to release these nutrients. Abscised leaves were collected from trees of these species and were evaluated by litter-bag technique for a period of 3 months. Nutrient return from each selected species showed that leaf of *C. macrostachyus* had significantly higher ($P < 0.05$) P but lower C compared with the leaf of *C. africana*. N concentration in the leaf of the study species did not show significant variation. Leaves of *C. africana* had significantly ($P < 0.05$) higher concentration of lignin and significantly higher lignin:N and C:N than *C. macrostachyus*. *C. macrostachyus* showed more rapid mass loss and nutrient release than *C. africana.* 50% of the biomass applied was lost during the first 6-7 weeks in *C. macrostachyus* and 9-10 weeks in *C. africana.* The half lives of N and P were 6-7 and 8-9 weeks, respectively, in *C. macrostachyus*. In *C. africana*, however, the half-lives were 13-14 and about 19 weeks for N and P, respectively. Generally, leaves with higher initial lignin, lignin:N and C:N ratios had lower decomposition and mineralization rates.
Key words: *Cordia africana, Croton macrostachyus,* litter, decomposition, nutrient.

1. INTRODUCTION

Transfer of nutrients and energy from living biological components to the soil is closely related to litterfall and is the starting point for nutrient cycling. Litterfall constitutes a major portion of nutrient cycling between plants and soils, thus reflecting constraints on internal fluxes of C, N and P at ecosystem scale (Mc Groddy et al., 2004; Berg and Laskowski, 2006).

Decomposition of litterfall which produces organic matter is an important factor for soil formation as well as nutrient cycling processes (Onyekwelu et al., 2006; Pandey et al., 2007). Decomposition is primarily influenced by the environmental conditions in which decay takes place, the chemical quality of leaf litter, and the nature and abundance of decomposing organisms present (Polyakova and Billor, 2007). Many studies have shown that there exist considerable variations in leaf litter decomposition rates among species (Koukoura et al., 2003).

The process of litter decomposition plays a vital role in regulating ecosystem carbon storage and nutrient cycling (Wardle, 2002; Santiago, 2007). The nutrient dynamics of litter related to the decomposition rates directly determine the nutrient status of an ecosystem, thereby exerting crucial control on vegetation productivity (Knorr et al., 2005; Van Der Heijden et al., 2008). The initial phase of decomposition is characterized by rapid loss of hydrosoluble compounds, high microbial activity and leaching/release of nutrients (Loranger et al., 2002; Nyberg et al., 2002). Some studies also suggested that in the initial stage of litter decomposition, N can be a good predictor of decomposition rate, whereas in later stages, chemical compounds such as lignin can play a more important role (Liu et al., 2007).

Under the traditional agroforestry system in Ethiopia, tree species such as *C. africana* and *C. macrostachyus* are commonly grown in association with crops. They have significant contribution in traditional agroforestry system in improving physical and chemical properties of soil and crop yield. Both species are less vulnerable to drought compared with eucalypts that are regarded as drought tolerant and grow fairly comparable to the eucalypts if moisture is available (Dechasa Jiru, 1999; Gindaba et al., 2004a).

However, these species that are used for soil fertility improvement in the high altitude areas of Northern Ethiopia have not been given much research attention and are still lacking. Therefore, the objective of this study was to investigate the nutrient composition of abscised leaves of *C. africana* and *C. macrostachyus* tree species and the extent to which they decompose to release these nutrients.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in Lalibela, Ethiopia which lies between 12° 02' N Lat, 39° 02' E Long; elevation 2500 m above sea level and has an average temperature less than 20 °C. Geographically, the area exhibited deep gorges, valleys, plateau hills and mountains. The mean annual rainfall of the area is 675 mm. Livestock is the major source of income in the area. The soils are grouped under the sandy clay loams with alluvial parent rock. The most common tree and shrub species are *Eucalyptus* species, *C. africana* Lam., *C. macrostachyus* Del., *M. lutea, A. senagalensis, Dodonea,* and *P. africana* (Abraham et al., 2013).

2.2 Leaf collection and decomposition

In this particular study, a total of eight isolated trees of *C. africana* Lam. and *C. macrostachyus* Del. (four of each species), located in the same soil type, same landscape position, and approximately with similar age were selected with no tillage, fire, or inorganic fertilizer use in the past years. Abscised leaves of these trees species were collected by shaking branches and picking them from the ground. Samples were air dried and were oven dried at 65 °C for 24 hours, and a portion of each sample was grounded into powdered form to pass through the mesh screen for chemical analysis while part of it was used for the decomposition study.

Leaf litter decomposition was studied using the standard litter-bag technique described by Swift and Anderson (1989). Batches of 10 g of oven-dried leaf litters were placed separately inside 20 x 20 cm plastic mesh litter bags with 2 mm mesh size. The litterbags were returned to the corresponding (study) site and randomly placed on the soil surface, in randomized block design, and exposed to natural weathering conditions and soil borne decomposers by placement just under the natural litter layer in the research site. 12 samples from each species were placed in the three plots (replicates) of four sample litter bags situated within each plot. From each plot, one sample bag of each species was randomly collected every three weeks after placement of bags for about 12 consecutive weeks. Hence, in total, 24 sample bags (2 species x 3 replicates x 4 sample bags) were installed. After this, all attached materials were removed from the bag, carefully cleaned of roots and debris, and finally were oven-dried at 80 °C for 24 h to achieve a constant weight and for further chemical analysis.

2.3 Chemical analyses

The oven-dried litter samples were ground and sieved through a 0.5 mm mesh and analyzed for total C, N, P, and lignin. C content was measured using the dry combustion method (Nelson and Sommers, 1982). N concentration was determined by the micro-Kjeldahl method by digesting 0.5 g samples in 10 ml concentrated H_2SO_4, using a catalyst mixture ($CuSO_4$, K_2SO_4 and selenium powder) and distillation. P was determined in digested samples colorimetrically using the ammonium molybdate stannus chloride method (Olsen and Sommers, 1982). Lignin was determined by the methodology stated by Van Soest and Robertson (1985).

The decomposition constant (*k*) of leaf litter was estimated with a single exponential decomposition model by the equation (Olson, 1963): $W_t/W_o = e^{-Kt}$

Where W_0 is the original mass of leaf litter, W_t the amount of leaf liter remaining after time t, t the time (year), e is the base of natural logarithm, and k is the decomposition rate (year^{-1}).

2.4 Statistical analyses

All statistical computations were made using JMP-5 statistical package. One-way analysis of variance (ANOVA) was used to test variations. Means were compared using Tukey's Honestly Significant Difference tests and were tested at alpha 0.05 for significant differences.

3. RESULTS

3.1 Leaf litter nutrient content

The results obtained for the leaf nutrient composition revealed that there were significantly ($p < 0.05$) different between the treatments. Comparisons of potential C, N and P nutrient return from each selected species showed that leaf of *C. macrostachyus* had significantly higher ($P < 0.05$) P but lower C compared with the leaf of *C. africana*. N concentration in the leaf of the study species did not show significant ($P < 0.05$) variation (Table 1). Leaves of *C. africana* had significantly ($P < 0.05$) higher concentration of lignin and significantly ($P < 0.05$) higher lignin:N and C:N than *C. macrostachyus* (Table 1)

3.2 Decomposition and nutrient release

The analysis of variance of the mass loss and nutrient release from the leaves of *C. africana* and *C. macrostachyus* revealed that there were highly significant ($P < 0.001$) differences between the species (Figure 1). *C. macrostachyus* showed more rapid mass loss and nutrient release than *C. africana.*

Fifty percent of the biomass applied was lost during the first 6–7 weeks in *C. macrostachyus* and 9-10 weeks in *C. africana.* The half lives of N and P were 6-7 and 8-9 weeks, respectively, in *C. macrostachyus*. In *C. africana*, however, the half-lives were 13-14 and about 19 weeks for N and P, respectively. Thus, the rates of nutrient release (*k*-value) became clear when the half-life was computed.

4. DISCUSSION

4.1 Leaf litter nutrient content

A study on evaluating the leaf litter nutrient content is important to understand the underneath soil condition (Moore et al., 2006). This is because litterfall is a major pathway for the return of dead organic matter and nutrients held in it from the aerial parts of the plant communities to the surface of the soil (Attiwill and Adams, 1993).

In the present study, *C. macrostachyus* had significantly higher ($P < 0.05$) P but lower C compared with the leaf of *C. africana* may be due to the inherent characteristics of the species. Other researchers also stated that structural differences in leaves of plants present a possible source of variability in the amount of leaves reaching to the soil under plant canopies and the amount of nutrients in the soil (Vesterdal et al., 2008).

The result of this study also showed that P content was low (Table 1) in the fallenleaf of the two species as compared to N and C nutrients which could be mainly because it is not so readily cycled from plant surfaces to the soil. This result is in agreement with the observations of Read and Lawrence (2003); Ca´rdenas and Campo (2007) who described that P is one of the most tightly cycled major plant nutrients and usually more than half of the P in deciduous leaves is retranslocated back to the trees before leaf abscission. Aerts (1996) also reported that most perennials reabsorb 40-65% of P from leaves abscission, permitting this nutrient to be recycled internally and used in the construction of new tissues.

4.2 Decomposition and nutrient release

At a global scale, litter decomposition rate is mainly determined by climate; at a particular climatic region, litter quality (including leaf toughness, N, P concentration, lignin content, etc.) plays the most important role in determining litter decomposition rate (Aerts, 1997). Numerous studies have well documented that N is one of the most common factors limiting litter decomposition as it determines the growth and turnover of microbial biomass mineralizing the organic C (Talor et al., 1989). The present study did confirm that litter decomposition rates were positively correlated with litter N.

Early decomposition is often determined by the availability of limiting elements such as N and P, whereas in late stages carbon loss has been related to elements required to decompose recalcitrant components such as lignin that accumulate in the remaining litter (Gusewell and Gessner 2009; Berg et al., 2010). Liu et al. (2007) also suggested that in the initial stage of litter decomposition, N can be a good predictor of decomposition rate, whereas in later stages, chemical compounds such as lignin can play a more important role. Thus, variables controlling the early decomposition stage and nutrient release could differ from those influencing the proportion of slow decomposing litter and therefore the buildup of soil organic matter and carbon sequestration. Occasionally, the same variable could have counteractive effects on the early and late stages of decomposition (Hobbie et al., 2012).

In the present study, leaves of *C. africana* and *C. macrostachyus* species had similar N concentration but were having different decomposition rate. The slower decomposition of *C. africana* leaves could be because of the presence of higher lignin concentrations and ratios of lignin:N and C:N (Table 1) than in *C. macrostachyus.* Similarly, Palm (1995); Jama and Nair (1996) also reported that, the higher the initial concentrations of lignin and initial ratios of lignin:N and C:N in the leaves, the slower the rate of decomposition and release of nutrients. Palm (1995) estimated that if the lignin concentration in the leaf material is >15% there is likely to be reduced or delayed N release. The result from this study is in agreement with the estimate, i.e., *C. africana* with >15% lignin showed much lower decomposition and N mineralization (Figure 1).

The present study also confirm the previously reported pattern that the litter with high quality (characterized by higher N concentration and lower C/N ratio) can decompose faster in comparison with low quality litter (Sanchez, 2001; Su et al., 2004). Thus, suggesting that N concentration can be a good predictor of decomposition rate in the initial stage of litter decomposition. Nitrogen inputs from litter decomposition contribute to meeting N requirement of decomposers in the initial stage of decomposition and produce a stimulating effect on the decomposition (Vestgarden, 2001).

In other studies, P is immobilized at the initial stages of decomposition and subsequently released (Staaf and Berg, 1982; Maheswaran and Attiwill, 1987). However, this immobilization phase did not occur in this experiment. The present study also confirmed previous findings regarding trees such as *C.macrostachyus* whose leaves decompose rapidly (Gindaba et al., 2004b) may not significantly buildup soil organic C, but could supply nutrients in the short term for uptake by crops.

In conclusion, there were significant differences in leaf litter nutrient composition and leaf litter decomposition rate between the two species included in this experiment. *C. macrostachyus* had higher mass loss and nutrient release while *C. africana* had significantly higher concentration of lignin and significantly higher lignin:N resulting less decomposition rate and nutrient release. Generally, tree species of *C. africana* and *C. macrostachyus* play a great role in maintaining soil fertility and provide various products and services to the farmers. Thus, the continued use of these species in the agricultural setting of the study area and other areas in the Ethiopian highlands is recommended.

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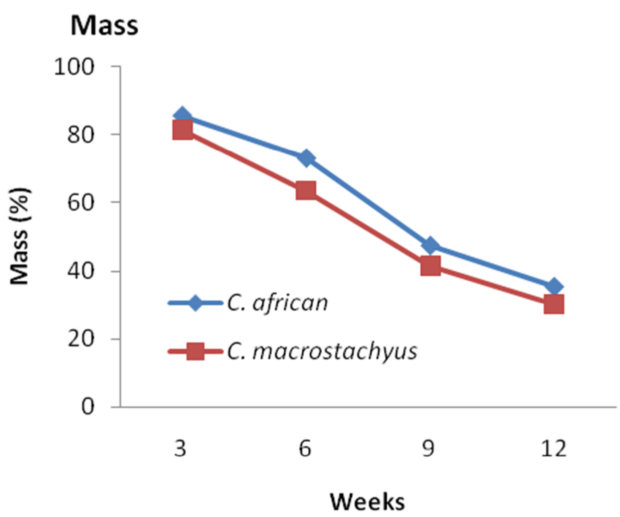
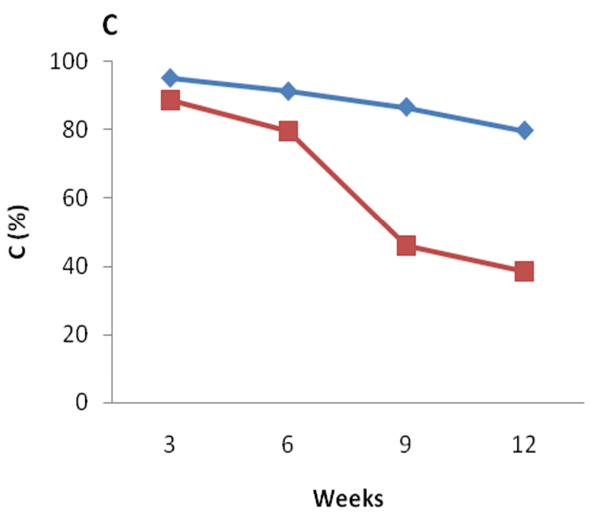
Table 1: Major nutrients in abscised leaves of *C. africana* and *C. macrostachyus* from the study area.

Nutrients (mg g-1)	*C. africana*	*C. macrostachyus*
C	433.38 ± 0.79a*	430.45 ± 0.35b
N	11.10 ± 0.23a	11.36 ± 0.05a
P	1.70 ± 0.03b	2.54 ± 0.03a
Lignin	17.91 ± 0.57a	10.64 ± 1.03b
C:N	39.16 ± 0.82a	37.89 ± 0.15b
Lignin:N	1.62 ± 0.04a	0.94 ± 0.33b

*Means followed by the same letter are not significantly different at $P \leq 0.05$ as determined by Tukey Honest Significant Difference (HSD) test. Values are expressed as mean ± standard error.





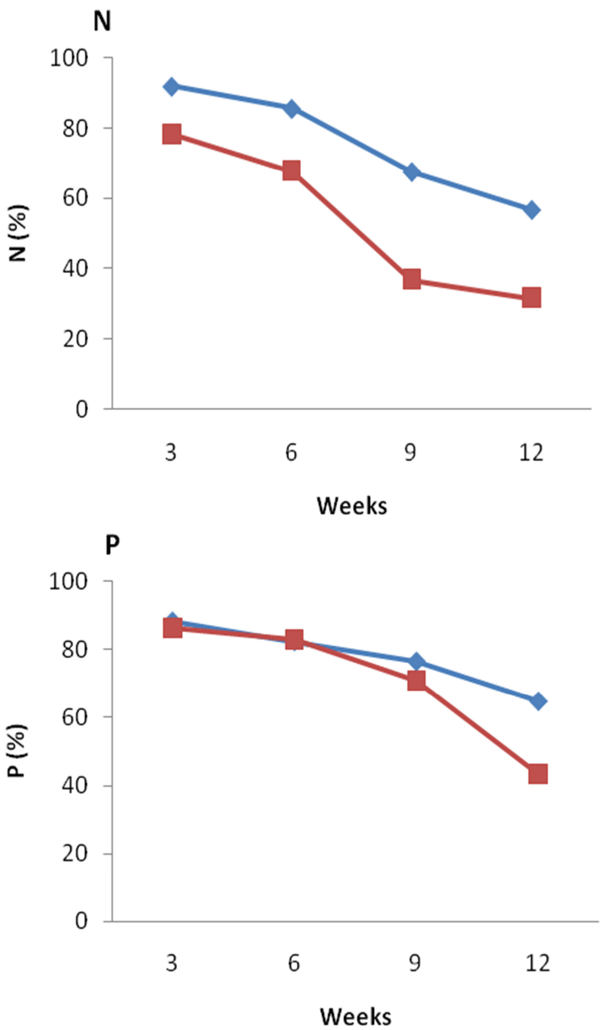


Figure 1. Mass and nutrients remaining during 12 weeks of decomposition of absciesed leaves of *C. africana* and *C. macrostachyus*