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Research article

Foliage litter decomposition of agroforestry shrub species in Dello-menna District of Bale Zone, Southeast Ethiopia

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In agroforestry land use system soil productivity is maintained via the decomposition of tree/shrub species biomass input mainly foliage's litter material. The quality of foliage litter material could be considerably varied among species. Hence, better soil management decision in agroforestry land use system remains on identification and use of the desirable species biomass input based on their decomposition characters. A study was conducted to evaluate the decomposition pattern of foliage litter materials of three agroforestry shrub species grown in Dello-menna district of Bale zone, Southeast Ethiopia. In the study single exponential model was employed to determine the decay rate of decomposing litter materials as the dependency of degradation rate on some litter chemical quality indices examined by using Pearson's correlation coefficient. Results showed that the fastest decomposition rate was 0.037 day-1 for S. sesban followed by 0.017 day-1 for C. cajan and the least 0.014 day-1 for F. macrophylla. The explained variation in rate of decomposition among the tested species was found to be due to the effects of some litter chemical quality parameters. Accordingly lignin, cellulose, lignocelluloses index and C/N ratio were reported as impeding parameters whereas phosphorus and nitrogen identified as facilitators. Indeed, among the species S.sesban was recommended as the most suitable species for short term soil fertility management purpose. However, the accelerated decomposing character of S.sesban foliage litter may limits its potential for long-term build-up of soil fertility. Alternatively F.macrophylla majorly and C.cajan in some case can be considered for long-term build-up of soil organic matter.

Keywords: Cajanus cajan, Flemingia macrophylla, Incubation period, Sesbania sesban

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Background and Justification

Decomposition is one of the most important processes that accounts for nutrient recycling on planet of earth (Jianru, 2013). In tropical agroforestry land use system soil fertility improvement achieved via the decomposition of tree/shrub species biomass input mainly foliage litter. The qualities of foliage litter materials considerably varied among species. Thus, better soil management decision in agroforestry land use system remains on identification and use of the desirable specie's foliage litter material based on their decomposition characteristic. Rapid decomposition characteristics are associated with high quality litter materials and conversely, the slow refer to the low quality (*Palm et al., 2001*). High-quality material could be used for short-term soil fertility correction whereas low materials used for long-term maintenance of soil organic matter.

The process of litter decomposition controlled by many factors; the chief among them are litter quality (chemical constituents) and climatic factors such as rainfall and temperature regimes (Mubarek *et al.,* 2008). Under small scale environmental condition the chemical parameters; nitrogen (N), phosphorus (P), lignin, cellulose, hemicellulose, Lignocellulose index (LCI) and C/N are better controlling factors of decomposition (Mafongoya *et al.,* 1998). However, these chemical constituents are widely variable across species, stage of growth, plant part and environmental conditions under which the species are grown (Olalekan, 2017).

Senescent material dominates as an input in natural forest and agricultural system whereas inputs in agroforestry land use include both fresh and senescent plant materials. Essentially, deliberately pruned foliage material is the usual practice in agroforestry land use system of than natural litter fall (Nair *et al.,* 1999; Sarkar *et al.,* 2016). Foliage materials contain higher concentration of nutrient and perceive better potential to improve soil fertility than any other senescent plant materials (Hossain *et al.,* 2011). Despite these facts, an attempt of monitoring the decomposition pattern of deliberately collected foliage biomasses of agroforestry species is very scarce. Therefore, this study was planned to evaluate the decomposition pattern of foliage litter materials of three agroforestry shrub species grown in Dello-menna district of Bale zone, Southeast Ethiopia. The objectives of the study are:

- To study the decomposition pattern of the three species foliage litter material
- To study the effect of foliages litter chemical composition on rate of decomposition

MATERIALS AND METHOD

Study Area

The experiment was conducted at the research sub-site of Sinana agricultural research center, located in Burkiti kebele of Dello-Menna district. The research site is located about 2.5 km in the North of the administrative town of Dello-menna district lying 6º 24' 42.45" N and 39º 49' 55" E.

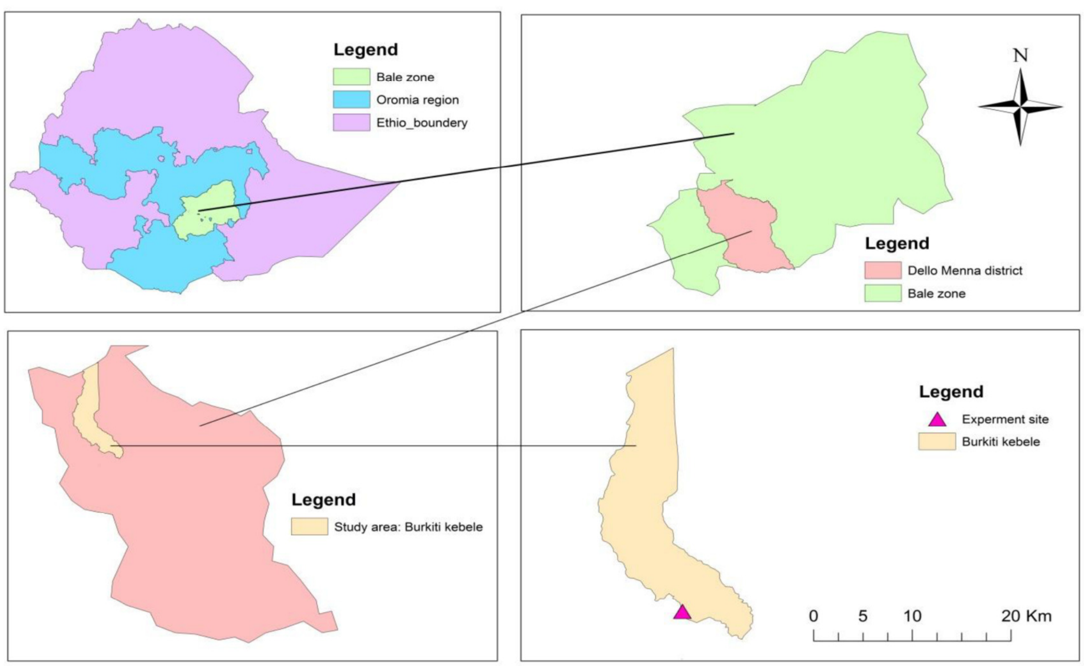

Figure 1: Location of the study area

Nit sol is the dominant soil in the area, and characterized by its color reddish brown clay towards the higher altitudes and tends to red-orange sandy soil towards the lower altitudes.

Experimental Procedure

Foliage collection and sample preparation

The collection and preparation of foliage biomass was undertaken following a standard sampling procedure of woody perennial plant tissue technique (Benton, 1998). With this the most recent and fully developed live foliage biomass of the species were collected. This was foliage exposed to full sunlight just below the growing tip on main branches or stems, prior to or at the time of the species begins their reproductive stage. Accordingly three replicate leaf samples were collected and air dried for three subsequent days (Jiregna *et al.,* 2004). The dried foliage biomasses of 60 g were placed in nylon litter bags with a mesh size of 2mm.

Experimental design and treatment arrangement

The experiment was installed by using factorial in RCBD design. The species types (*C. Cajan, S.sesban* and *F.macrophylla*) were used as main factor and incubation period (15, 30, 45, 60, 75, and 90 days) sub-factors with three replications. All the treatments were allocated to each of the 3 blocks making a total of 54 litter bags. As decomposition is faster in the sub-soil of than soil surface litter bags were placed beneath the soil at depth of 0 - 15cm (Nair *et al.,* 1999).

Litter bag collection and data management

The litter-bags were recovered randomly block wise every 15 days of interval for three consecutive months. The bags were placed inside a paper envelope with a label (three replications) after they were recovered and transported to the laboratory. Samples were air dried and cleaned from attached soil particles carefully by hand and hair brush and then oven dried at 70°C until constant weight (Jiregna *et al.,* 2004). The oven dried samples were separately weighed as this enables to understand the mass loss pattern of litter residues. Accordingly the percentage of ash free dry matter remained at different sampling period was determined using the following function (Hossain *et al*., 2011):

$$\text{Mass remaining (\%)} = \frac{\text{DMt}}{\text{DM0}} * 100 \qquad \text{equation (1)}$$

Where DMt is the dry matter at the time of sampling, and DM_0 is the initial dry matter of the litter sample kept for decomposition. The decomposition rate constant (k) of litter residues was estimated following single exponential model (Olson, 1963) as indicated below:

$$\frac{\text{DMt}}{\text{DM0}} = e^{-kt} \qquad \text{equation (2)}$$

Chemical analyses

Chemical analyses of samples were conducted employing standard analytical procedures. Accordingly, cellulose, hemicellulose and lignin contents were determined using three sequential heating fiber extraction methods (Anderson and Ingram, 1993). The extraction was done in the order of neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid determined lignin (ADL). The neutral detergent fiber (NDF) method separated the soluble and insoluble fiber, which provides a measure of total cellulose, hemicellulose and ADL. The acid detergent fiber (ADF) method was used to estimate cellulose and ADL. The difference between NDF and ADF gave an estimate of hemicelluloses. Lignin was extracted from ADL after heated in strong Sulfuric acid (72% H_2SO_4). This was used to fractionate ADL into ash and lignin content. Thereafter Lignocellulosic index (LCI) estimated following Herman *et al.* (2008) mathematical equation as used below whereas total phenol composition extracted by Folin-Denis modified method (Claudia *et al.,*2008).

$$\text{LCI} = \frac{(\text{Lignin})}{\text{Lignin} + \text{Cellulose} + \text{Hemicellulose}} \qquad \text{equation (3)}$$

For the determination of carbon dry ashing of plant tissue technique was used. To do so one gram milled foliage litter biomass was weighed into a crucible and calcinated at 450 °C for 3 hours in Muffle Furnas. In the study fifty percent of the ash free dry matter was considered as organic carbon (Anderson and Ingram, 1993). Moreover, quantities of Phophorus and Nitrogen were determined by Olson (1963) and Kjeldahl distillation method respectively.

Statistical Analysis

The data collected from the experiment was analyzed using Genstat (15th ed.) and Microsoft Excel computerized programs. The method used to compare treatment means was Fisher's least significant difference (LSD) procedure. Moreover, effects of chemical composition on rates of decomposition examined by Pearson's correlation coefficient. Results are declared as statistically different at 5% level of error tolerance.

RESULTS AND DISCUSSION

Decomposition pattern of *C.cajan, S.sesban* and *F.macrophylla* Foliage Litter

Loss of ash free dry matter (percentage of original mass) and litter decomposition rates are the two parameters which have been used to describe the results for decomposition pattern. The result obtained from ANOVA has showed that both parameters were significantly ($p < 0.05$) varied over species and incubation period.

The effect of species on mass loss over 90 day's incubation period

The result has showed that maximum mass loss was reported for *Sesbania sesban* followed by *C.cajan* and *F.macrophylla* respectively over the entire experimental period (fig 2). Mass remained during the first fifteen days ranged from 45.32% in *S.sesban* to 71.44% in *F.macrophylla*. At the same period 60.23% of *C.cajan* foliage dry matter remained which rapidly decreased to 45.39% after the second fifteen days. After 60th day the amount of foliage litter mass remained for *S. sesban* was below 10% (6g) compared to the other two species especially with *F.macrophylla* which was about 30.68% (18.41 g) at the end of study period.

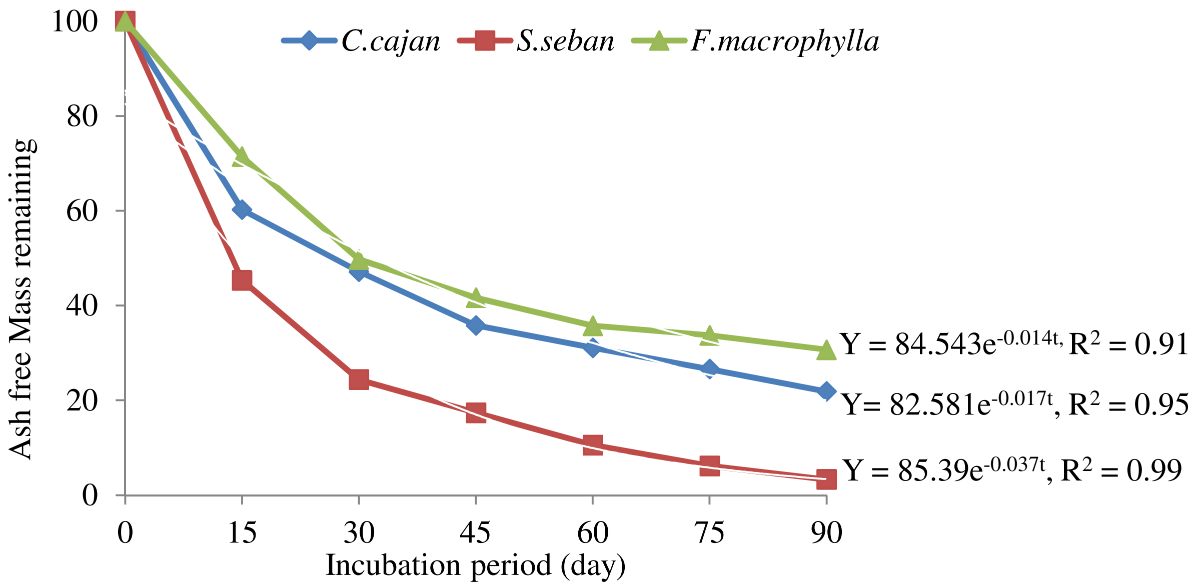

Figure 2: Remaining litter mass during decomposition of foliage litter material over 90 days.

The species exhibited biphasic mass loss trend occurred through an initial rapid phase followed by a slower in the subsequent monitoring period. This has resulted mass loss curve resembled a good fit of exponential decay model (R^2 = 0.91- 0.99). The reason for rapid mass loss in the early stage might be attributed to leaching of water soluble components whereas the slower in the later related to the increment of recalcitrant materials, notably lignin.

Effect of species on rate of decomposition (k_D) over 90 days experimental period

Consistent to the observation made for dry matter loss the subsequent decomposition rate (day^{-1}) of *S.sesban* was found to be the fastest with a range of 0.037 to 0.0528 day^{-1} over each 15 days monitoring period (table 1). Likewise, *C.cajan* and *F.macrophylla* attains more than two fold a slower rates of decomposition of than *S.sesban.* The variation explained between *C.cajan* and *F.macrophylla* not an extreme even a statistical similarity was noticed at some points (30 and 60 days) of monitoring period. This might be due to the slight resembling of foliage morphological character (size, toughness) noticed between the two species of than *S.sesban.* Further, the explained variation in k_D among the species was due to the effect of litter chemical compositions as this was also substantiated by correlation coefficient (table 2).

Table 1: The effect of species on decomposition rates at different stages of decomposition

Species	Incubation period (days) ------------------------------ k_D (day^{-1}) --------------------------------					
	15	30	45	60	75	90
C.cajan	0.0338^b	0.0245^a	0.0228^b	0.0195^a	0.0176^b	0.017^b
S.sesban	0.0528^c	0.0471^b	0.0389^c	0.0376^b	0.0372^c	0.038^c
F.macrophylla	0.02244^a	0.0233^a	0.0195^a	0.01714^a	0.0145^a	0.0131^a
LSD (0.05)	0.0049	0.0031	0.0008	0.0032	0.0023	0.0023

Mean values within in columns followed by the same letters are not significantly different

Overall kD value of the studied species fall within a range of 0.00166 to 0.06033 day^{-1}, which is reported for tropical tree legume foliages litter material (Dubeux *et al*., 2006). However, it is relatively higher than the domestic range reported for *C.cajan* and *Haricoat bean* (Girma *et al.* 2014). According to this finding the mean daily decomposition rate constant of these two leaf litter ranged from 0.0043 to 0.021 inconsistent to 0.014 to 0.037 the present finding. Notwithstanding soil condition and litter quality factors, the observed variation may be due to the effect of moisture availability as the present study was conducted during rainy season opposite of Girma *et al.* (2014) study.

The effect of litter chemical composition on rates of decomposition

The relationship between decomposition rate and some litter chemical parameters of *C.cajan*, *S.sesban* and *F.macrophylla shrub* species was examined by Pearson correlation coefficient. The species are found to be influenced by more than one litter chemistry parameters (table 2). As confirmed *C.cajan* and *F.macrophylla* were significantly influenced by lignin (-ve), cellulose (-ve), LCI (-ve), C/N ratio and nitrogen (+ve) whereas *S.sesban* influenced by N (+ve), C/N (-ve), lignin (-ve) and LCI (-ve). However, the magnitudes of their effects vary over the studied species (R^2 = 0.004 - 0.72). Accordingly, lignin, LCI, cellulose and C/N ratio reported as more reasonable parameters in retarding decomposition rates of *C.cajan* and *F .macrophylla* of than *S.sesban* whereas the more nitrogen's decomposition facilitation effect pronounced in the latter species.

Table 2: Relationships between decomposition rate constant (kDc, kDs, kDf) and some litter chemistry parameters of the species foliage litter material

Parameters	Correlation coefficients (r) and regression (R^2)					
	kDc		kDs		kDf	
	r	R^2	r	R^2	r	R^2
Lignin	-0.77***	0.59	-0.58*	0.33	-0.83***	0.68
Cellulose	-0.56*	0.31	-0.45^{ns}	0.20	-0.6**	0.36
Hemicelluloses	0.21^{ns}	0.04	-0.07^{ns}	0.004	0.27^{ns}	0.07
LCI	-0.66**	0.43	-0.50*	0.25	-0. 53*	0.28
Nitrogen	0.79***	0.62	0.92***	0.84	0.63**	0.39
C/N ratio	-0.55**	0.30	-0.30^{ns}	0.09	-0.74**	0.54
Phosphorus	0.63**	0.39	0.32^{ns}	0.10	0.435^{ns}	0.18

*Significant at $P < 0.05$, ** significant at $P < 0.01$, *** significant at $p < 0.001$, ^{ns} not significant. kDc=rate of *C.cajan*, kDs=rate of *S.sesban* and kDf=rate of *F.macrophylla*.

This might be attributed to their initial level of litter chemical quality indices variation observed among the tested species (Wondmagegn and Lisanework, 2019). According to the authors considerably higher amount of cellulose, lignin and LCI reported for *F.macrophylla* where N and P likely reported for *S.sesban and C.cajan respectively*. This supports the hypothesis stating the effect of litter chemical quality indices more pronounced in species characterized by their higher initial level of litter chemistry of than the other.

SUMMARY AND CONCLUSION

A study on decomposition of agroforestry tree/shrub species foliage litter is lacking even if an attempt has been made for some indigenous species. This study was designed to examine the decomposition patterns of three agroforestry shrub species foliage litter grown in Dello-menna district of Bale zone, southeast Ethiopia. The species were *F.macrophylla, S.sesban* and *C.cajan. To do so* fully mature green leaves with petiole (foliage) was collected from all crown parts of mother plants and air dried for three subsequent days. Thereafter the experiment was undertaken in the open field condition using litter-bag technique. In the study the dependency of rates of decomposition on some litter chemical quality indices also examined.

Results confirmed significant ($p < 0.05$) differences in loss of ash free dry matter and rates of decomposition among the species. The amount of foliage litter mass remained at the end of the study varied between 3.3 to 30.08% with mean of 18.32% and overall decomposition rates varying from 0.014 to 0.037 with mean 0.023 day^{-1}. Biweekly (15days interval) rates of decomposition also vary between the species occurring faster rate during the first to the second 15 days, and the slowest (0.013) during the last date of sampling period. This rapid initial breakdown followed by a longer period of slow decomposition process has resulted mass loss curve resembling a good fit of exponential decay model (R^2 = 0.91- 0.99). The study has also added knowledge on the effects of biochemical composition on decomposition rates of foliage litter material. Indeed lignin, cellulose, C/N and LCI identified as impeding parameters whereas N and P were associated with facilitation.

The study proved that foliage litter of *S.sesban* was found as the fastest decomposing material followed by *C.cajan* and *F.macrophylla* respectively. The accelerated decomposition rate of *S.sesban* foliage litter may limit its potential for long-term build-up of soil organic matter. Alternatively, *F.macrophylla* majorly and *C.cajan* in some cases can be considered for such purpose.

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