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Decomposition and Nitrogen Dynamics of Tree Pruned Biomass Under *Albizia Procera* Based Agroforestry System in Semi Arid Region of Bundelkhand, India

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Abstract

Albizia procera is the native and most common agrisilvicultural / agrosilvopastutal tree species of Semi arid regions of Central India. This study focused on pruned biomass decomposition and subsequent nitrogen release from different component viz, leaves, petiole and pod under different pruning regimes of six-year old *A. procera* in agroforestry system. Fresh pruned biomass (leaves, petiole and pods) of *A. procera* was collected from field and oven dried. Samples of 5.0 g of each component of the tree were transferred to nylon mesh bags (20x20 cm, 2 mm mesh size), placed at 5-cm depth. The bags were randomly kept on the soil surface below respective tree canopies in experimental field and retrieved monthly up to 6 month. Pod pruned biomass decomposed at faster rate followed by leaves and petiole. Pod showed the highest decomposition coefficient (k) under agroforestry system. A similar pattern was observed for loss of N. Nitrogen release form pruned biomass of *A. procera* followed the trend: pod >leaves > petiole. Decay rate coefficients were significantly and positively correlated with hemicellulose, N and P concentration of pruned leaves, petiole and pod with strong correlation in pod (r = 0.780). It is further interpretive that decay rate coefficients were significantly and negatively correlated with lignin, lignin/N, C/N, C/P and ADF. The air temperature, soil moisture and soil temperature were found significantly ($P<0.05$) related with percent weight loss of all component in all land uses during decomposition. The objective of this experiment was to characterize the biomass decomposition pattern and quantify the amount of nitrogen added through pruning of *A. procera.*

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Keywords

Albizia procera, Biomass decomposition, Nitrogen dynamics and Substrate quality.

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Introduction

Agroforestry practices are recommended to achieve soil conservation and it is a sustainable option in improving the livelihood as well as creating opportunities for the rural people of semi arid region of bundelkhand[1]. Most of the tree species recommended are fast-growing, leguminous species which can be pruned to a desirable height at appropriate frequencies. These pruning which consist of leaves and immature stems are added to the soil between crop rows. Therefore, while acting as a physical barrier to trap eroding soil, the trees also act as a source of mulch material to the soil. Gradual decomposition and nutrient release from added pruning could enhance the organic matter and nutrient status of the soil[2,3] and influence the yield of the associated agricultural crop[4,5]. Tree species used in agroforestry differ in their ability to enhance soil fertility through addition of pruning[6,7]. This is because of the inter-species variation in biomass of pruning produced per year[2], their nutrient contents[8] and the rates of decomposition and nutrient release[7,9]. The rates of decomposition and nutrient release from added pruning are determined by the climatic factors such as rainfall and temperature regimes[9,10,11] and by litter quality as determined by its lignin, polyphenol and nitrogen contents[5,11]. Biomass decomposition and nutrient release play an important part in selection of tree species for agroforestry because of the need to regulate the pattern of nutrient release and synchronize it with the nutrient demand of the associated agricultural crop[2,12].

Albizia procera is the native and most common agrisilvicultural /agrosilvopastutal tree species of Semi arid regions of Central India. Being a fast growing legume species and having an immense potential for introduction in different types of soils and climatic conditions, it is planted in various states by the Forest Departments and also by farmers under Agro-forestry programmes. It fixes nitrogen through symbiotic bacteria present in root nodules and thus enhances and soil fertility. The present investigation aimed to analyze the impact of *Albizia procera* based agroforestry on improving soil organic carbon status and nitrogen availability.

Therefore, the objective of this experiment was to characterize and compare the patterns and amounts of biomass decomposition and nitrogen loss from *Albizia procera* in different land use in the semi arid region of Central India.

Materials and Methods

Study Site and Plant Material

The study was conducted in six year old *A. procera* based agroforestry system at research farm of National Research Centre for Agroforestry, Jhansi, Uttar Predesh, India. The experimental field is situated at 25^0 27' North latitude and 78^0 35' East longitudes, 271 m asl in the semi arid region of the Central Indian Plateau. Average annual rainfall of the region is 806 mm, about 80 % of which occurs between June to September with intermittent dry spells. The mean monthly temperature is generally high, with high degree of variation between a maximum 39.8 ^{0}C in May and June and minimum temperature of 5.8 ^{0}C in December and January. In summer, temperature occasionally reached up to 48 ^{0}C. The mean monthly evaporation in the region is highest in April- June (9.40-15.2mm) and it ranges from 1.90-6.00 mm during other months of the year. The soil in the experimental field is Parwa representing inter-mixed black and red soil group of bundelkhand region (U.P.), India, falling under the soil order *Alfisol*. It is medium in texture, moisture retentive and workability, prone to crust whenever drought spell exceeds 2-3 weeks even under mild evaporation situation.

The experiment field was established as agri-silviculture (crop + tree) system in July, 2000 with *Albizia procera* as the tree component. *A. procera* was planted in at spacing of 8m x 4m in plot size of 576 m^{-2} (18 trees plot^{-1}) with three replications. Under *A. procera* blackgram – mustard crop sequence were taken as intercrop. In Kharif season (Black gram) the trails were fertilized with 20 kg /ha N, 40 Kg/ha P and in rabi season (mustered) 60 Kg/ha N, 40 Kg/ha P and 40 Kg/ha K were applied. Inter crop black gram is rainfed in both pruning regime, therefore mustard is irrigated twice a year (1st at flowering and 2nd at siliquae formation).

Biomass Decomposition and Nutrient Analysis

Fresh pruned biomass (leaves, petiole and pods) of *Albizia procera* was collected from field and oven dried at 72 ^{0}C till constant weight. The standard litterbag technique[14] was employed for characterizing litter decomposition dynamics.

Samples of 5.0 g of each component of the tree were transferred to nylon mesh bags (20x20 cm, 2 mm mesh size). The bags [270(3x3x5x6)] were randomly kept on the soil surface below respective tree canopies in experimental field. Each month, 5 bags for each biomass component of *A. procera* were collected from the floor of the different land sues. The biomass samples thus drawn were washed under a fine jet of water using a fine mesh screen to remove all the adhered soil particles, dried at 72 ^{0}C to constant weight, weighed and ground in a Wiley Mill to pass through a 1mm mesh screen. Samples were analyzed for N analysis.

Data Analysis

To evaluate nutrient release pattern, nutrient remaining in the decomposing biomass were estimated by equation[15]

$$\% \text{ Nutrient remaining} = (C/C_0) \times (DM/DM_0) \times 10^2$$

Where,

C = Concentration of nutrient element in decomposition litter at the time of sampling

C_0 = Concentration of nutrient element at the beginning of the study

DM = Mass of dry matter at the time of sampling

DM_0 = Initial dry matter of the biomass kept for decomposition

The decay rate coefficient (k) of the decomposing pruned biomass of different component for the entire study period was calculated through the negative exponential decay model[16] as represented by the equation:

$$X / X_0 = e^{-kt}$$

Further, following Olson (1963), the time required for 50 (half life) % weight losses was estimated from k values using the equation:

$$t_{50} = \ln (0.5) / -k = -0.693 / -k$$

Similarly, time taken for 95% decay can be estimated as follows

$$t_{0.95}=2.9957/k$$

The effect of land use of *Albizia procera* on decomposition, nutrient dynamics and cumulative impact on soil properties was tested by means of ANOVA using the General Linear Model of SYSTAT Ver.9 (SYSTAT Inc. 1998).

Results

Decomposition and Decomposition Coefficient

Average weight loss pattern in decomposing different components of pruned biomass of *A. procera* is shown in fig 1, 2 and 3. Weight loss pattern in six months under different land uses followed the trend: cropping > Fallow > *A. procera* + cropping for leaves; Cropping > *A. procera* + cropping > Fallow for the petiole and *A. procera* + cropping > Cropping > Fallow for pod. Data is further showen (Table 1) that for 95 per cent decay, pruned biomass leaves, petiole and pod is to took 568, 767 and 831 days; 969, 1046 and 1094 days; 414, 432 and 445 days, respectively, correspondingly under *A. procera* + cropping, cropping and fallow.

Table 1: Decomposition parameters of different components of pruned biomass of *Albizia procera*

Decay parameters	Land uses		
	***A. procera* + crop**	**Cropping**	**Fallow**
	Leaves		
Decay constant	0.0046	0.0058	0.0050
t_{50} (days)	131	177	192
t_{95} (days)	568	767	831
t_{99} (days)	949	1277	1385
	Petiole		
Decay constant	0.0031	0.0034	0.0033

t_{50} (days)	223	242	253
t_{95} (days)	969	1046	1094
t_{99} (days)	1616	1744	1823
	Pod		
Decay constant	0.0071	0.0070	0.0068
t_{50} (days)	96	100	103
t_{95} (days)	414	432	445
t_{99} (days)	690	720	741

Pearson Correlation Coefficient Between Pruned Biomass Substrate Quality and Decomposition Coefficients

Interpretation of data (Table 2) revealed that decay rate coefficients were significantly and positively correlated with hemicellulose, N and P concentration of pruned leaves, petiole and pod with strong correlation in pod (r = 0.780). It is further interpretive that decay rate coefficients were significantly and negatively correlated with lignin, lignin/N, C/N, C/P and ADF of pruned leaves, petiole and pod with strong correlation in pod.

Table 2: Pearson correlation coefficient between substrate quality (Pruned biomass) and decomposition constant (k) averaged across the different land use

Quality parameter	Leaves K	Petiole K	Pods K
C	-0.370*	0.183	0.341
N	0.596**	0.598**	0.780**
P	0.531**	0.178	0.646**
Lignin	-0.622**	-0.617**	-0.724**
C/N	-0.593**	-0.602**	0.747**
Lignin/N	-0.614**	-0.605**	-0.757**
ADF	-0.551**	-0.286	-0.647**
Cellulose	0.282	-0.218	-0.746**
Hemi cellulose	0.591**	0.539**	0.312**
L/LC	-0.594**	-0.594**	0.617**
C/P	-0.575**	-0.103	-0.633

* Significant at P < 0.05, ** P < 0.01

Pearson Correlation and Linear Regression Between Pruned Biomass Weight Loss and Environmental Factors Under *A. Procera* Based Different Land Uses.

The effect of climatic factors on the decomposition rate was evaluated by correlating percent weight loss of pruned biomass (Table 3). Percent weight loss of leaf pruned biomass was positively correlated with air temperature and was significant (P<0.05) only in *A. procera* unpruned + crop. However, the soil temperature and soil moisture was positive and significantly (P<0.01) correlated with percent weight loss of leaf pruned biomass respectively in all land uses. Percent weight loss of petiole showed positive and significant (p<0.01) correlation with soil moisture and soil temperature in all land uses, while air temperature was significant only in *A. procera* unpruned + crop. Furthermore, soil moisture and soil temperature were also significantly (P<0.01) correlated with percent weight loss of pod, in all land uses.

Table 3: Pearson correlation coefficients between pruned biomass weight loss and environmental factors under *A. procera* based different land uses.

Environmental factors	Pearson Correlation		
	Leaves	Petiole	Pod
***A. procera* unpruned + crop**			
Air Temperature	0.76*	0.76*	0.76*
Soil Moisture	0.94**	0.92**	0.94**
Soil Temperature	0.90**	0.89**	0.91**
Cropping			
Air Temperature	0.75	0.75	0.77*
Soil Moisture	0.93**	0.94**	0.93**
Soil Temperature	0.90**	0.90**	0.91**
Fallow			
Air Temperature	0.70	0.75	0.73
Soil Moisture	0.94**	0.94**	0.94**
Soil Temperature	0.87*	0.90**	0.88**

* Significant at P < 0.05, ** P < 0.01

Linear regression for the significant effect of climatic factors on percent weight loss (Table 4) was analyzed. The air temperature, soil moisture and soil temperature were found significantly (P<0.05) related with percent weight loss of all component in all land uses during decomposition.

Table 4: Linear Regression between pruned biomass weight loss and environmental factors under *A. procera* based different land uses.

Environmental factors	Regression	P	Leaves Regression	Petiole P	Pod Regression	P
***A. procera* unpruned + crop**						
Air temp.	Y=23.43+0.95 * A	< 0.08	Y=52.36+0.33 * A	< 0.08	Y=19.14+0.52 * A	< 0.08
Soil Moisture	Y=33.75+1.11 * B	< 0.01	Y=55.97+0.38 * B	< 0.01	Y=24.77+0.61 * B	< 0.01
Soil Temp.	Y=22.77+0.88 * C	< 0.01	Y=52.17+0.30 * C	< 0.02	Y=18.65+0.49 * C	< 0.01
Cropping						
Air temp.	Y=3.51+2.13 * A	< 0.08	Y=46.86+0.62 * A	< 0.09	Y=20.28+0.49 *A	< 0.07
Soil Moisture	Y=26.50+2.51 * B	< 0.01	Y=53.53+0.74 * B	< 0.01	Y=25.74+0.57 * B	< 0.01
Soil Temp.	Y=1.75+1.98 * C	< 0.01	Y=46.19+0.59 * C	< 0.01	Y=19.94+0.46 * C	< 0.01
Fallow						
Air temp.	Y=23.34+1.44 *A	< 0.12	Y=42.59+0.85 * A	< 0.09	Y=21.68+0.50 *A	< 0.10
Soil Moisture	Y=37.78+1.84 *B	< 0.00	Y=51.64+1.02* B	< 0.01	Y=26.92+0.62 * B	< 0.00
Soil Temp.	Y=20.97+1.39* C	< 0.02	Y=41.70+0.80 * C	< 0.02	Y=21.03+0.48 * C	< 0.02

A = Air Temperature, B = Soil Moisture, C= Soil Temperature

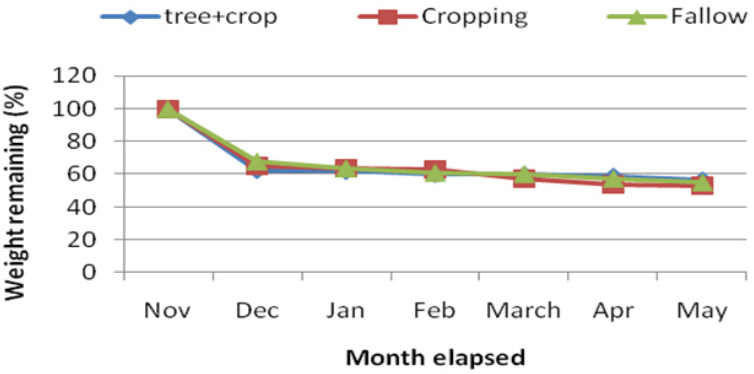

Fig. 1: Per cent weight loss of leaf pruned biomass remaining under *A. procera* based land uses

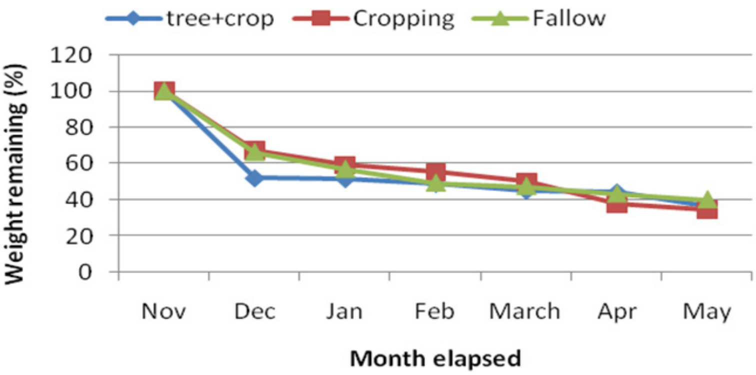

Fig. 2: Per cent weight loss of petiole pruned biomass remaining under *A. procera* based land uses

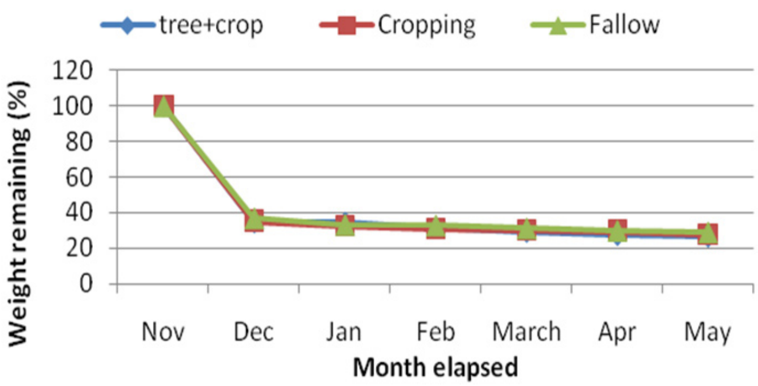

Fig. 3: Per cent weight loss of pod pruned biomass remaining under *A. procera* based land uses

Nitrogen Release

Result shown for N release from decomposing pruned biomass indicate that N content during decomposition increased initially followed by decrease. Figure 4 shows that leaf pruned biomass under cropping released higher N during decomposition followed under *A. procera* + crop and fallow. Petiole decomposition under cropping released 80.6 % N and was in the order: cropping > *A. procera* unpruned + crop (74.7 %) > fallow (64.1%). N content in decomposing pod pruned biomass increased initially. *A. procera* + crop, cropping, fallow, respectively. The corresponding N release from decomposing *A. procera* pod pruned biomass was 90.3, 93.7 and 90.6 percent.

Figure 5 shows that N release from decomposing *A. procera* petiole pruned biomass differed widely among different land uses. Data showed that irrespective of different pruning and land use, N content in decomposing petiole pruned biomass increased initially and decreased finally. The final N content in decomposing petiole pruned biomass under *A. procera* unpruned + crop, cropping and fallow was 0.456, 0.371 and 0.667 per cent, respectively. From N release data (figure-6) it is evident that *A. procera* pod pruned biomass released N at faster rate followed by leaf and petiole. Across component of decomposing biomass, *A. procera* pruned biomass under cropping released maximum N and minimum N release was under fallow.

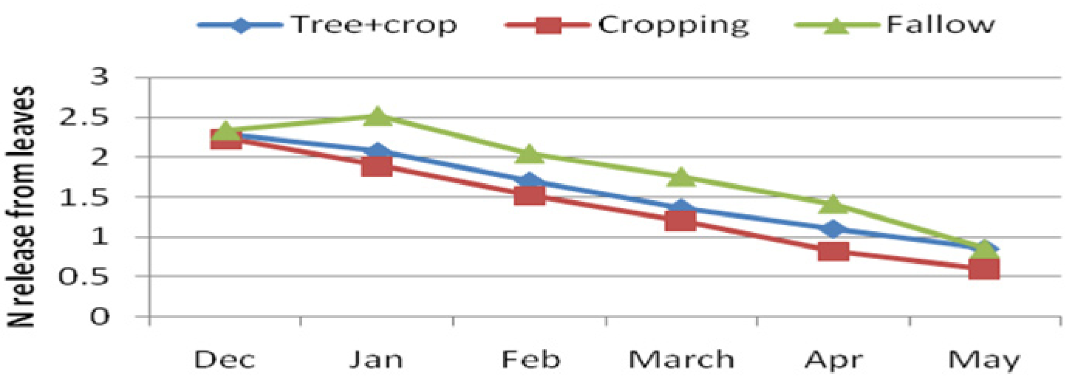

Fig. 4: N release from decomposing leaves biomass of *A. procera* under different land use

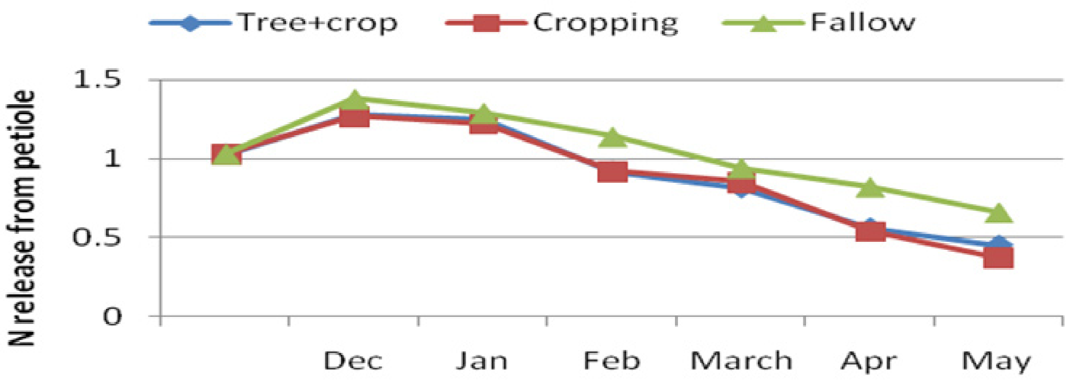

Fig. 5: N release from decomposing petiole biomass of *A. procera* under different land use

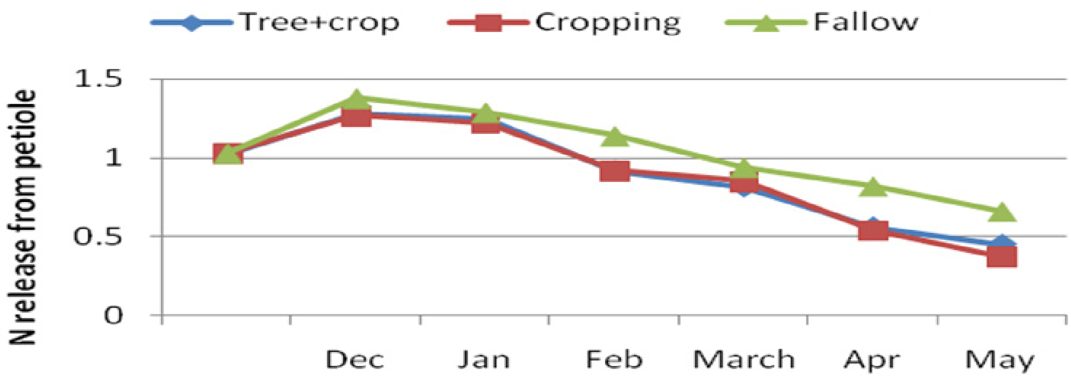

Fig. 6: N release from decomposing pod biomass of *A. procera* under different land use

Discussion

Substrate (litter/biomass) quality, climate and quantity and quality of decomposer organisms are the primary determinants of any biomass decay rates[17,18]. In the present work, the differences in rates of decomposition of different components of litter and biomass of *A. procera* under different land uses could be related to differences in substrate (litter/biomass) quality (Table 2) and variations in micro environment beneath *A. procera* in cropping and fallow. The higher concentration of N and lower C/N ratio in the biomass of *A. procera* was probably responsible for its faster decomposition and lower concentration of N in the petiole of *A. procera* brought slower rate of decomposition. A positive effect of N concentration on decomposition was also reported by several workers[19,20,21,22,23,24]. In *A. procera*, higher rate of biomass decomposition in agroforestry systems than to fallow might be due to high fertility status in agroforestry systems as evident from results of this study and favorable microenvironment for microbial population. Earlier, Anderson and Swift[25] have pointed out that soil of high fertility favour faster rate of decomposition. Conducive microclimate under agroforestry systems might have also played role in faster litter decay as reported by several workers[7,26,27,28].

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