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Dynamics of leaf litter decomposition of four tree species of arid western Rajasthan under varying soil moisture regimes

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Abstract: *Dynamics of decomposition of leaf litters of Acacia senegal, Dalbergia sissoo, Acacia tortilis and Colophospermum mopane were studied from June 2010-April 2011 at research farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner (Rajasthan). The mass loss of leaf litters varied significantly with time, species and moisture content. Among different tree species, the mass loss of leaf litter followed the order A. tortilis> A. senegal > D. sissoo> C. mopane at both moisture levels (Field Capacity and 50 % field capacity). The wider C:N ratio (55: 1), high lignin (34.1 %) and lower N content (0.99 %) of C. mopane as compared to A. tortilis , A. senegal and D. sissoo resulted in lower decomposition rate of C. mopane as compared to the other species. The high lignin in C. mopane binds strongly to organic-N in litter, hence making its litter resistant to decomposition. The differences in decomposition rates among A. tortilis, A. senegal and D. sissoo litters can be attributed to variation in their N content and C:N ratio because lignin did not differ much among these litters. For all species, the decomposition data best fitted the exponential decay function. Accordingly, decomposition rate constants (k) for C. mopane were significantly lower than other species. Between the two moisture levels, the decay rate coefficient for each species were more in soils maintained at field capacity as compared to 50 % field capacity. The half lives or time required for 50% decay at field capacity soil moisture was lowest (54 days) for Acacia tortilis and highest (81 days) for litter of C. mopane. For 99% decay, litter of A. tortilis, C. mopane, D. Sissoo, A. senegal would require 390, 588, 510 and 485 days at field capacity and 495,746,675 and 568 days at 50 % field capacity, respectively.*

Key words: *Acacia senegal, Dalbergia sissoo, Acacia tortilis, Colophospermum mopane , arid, Litter decomposition*

In the arid ecosystem of north-western Rajasthan, a great emphasis is being laid on the development of arid lands through alternate land use systems comprising perennial tree species as one of the main components. The perennial component of these systems play a great role in most part of the soil- C sequestrated and nutrient cycling through decomposition of leaf litterfall. The litter decomposition of these species in the soil is of primary importance. If the decomposition and nutrient mineralization of litters of these species are lower, it may slow down the rate of ecosystem nutrient cycling.

The prime importance of any perennial component in arid zone lies in its fodder value but some of the tree species involved in development of agroforestry models have differential selectivity for cattle as their feed. The species like *Prosopis cineraria, Calligonum polygonoides, Lasiurus sindicus, Cenchrus ciliaris* etc. have high selectivity, whereas *Colophospermum mopane*, *Acacia senegal, Acacia tortilis, Dalbergia sissoo* have low selectivity for cattle feeds. The low selectivity or rejection of these species by the cattle or other animals may increase their abundance in the ecosystem. Hence, their decomposition and nutrient release in soil becomes utmost important for ecosystem functioning. The foliage biomass produced by these species enhance soil fertility by recycling the nutrients through litter fall, pruning or importing nutrients through

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biomass transfer systems [12]. Intensive studies on litter dynamics in forest ecosystems have been carried out worldwide [4, 11, 19, 22, 23]. But the litter decomposition of tree species grown in farm fields/ silvipastoral systems have not received due attention. Currently, no information is available on the litter decomposition of tree species in western Rajasthan. Hence, the present experiment was carried out to study the litter decomposition and N release pattern of leaf litters of *Colophospermum mopane*, *Acacia senegal, Acacia tortilis, Dalbergia sissoo* under field conditions.

MATERIALS AND METHODS

Site description

The study was conducted from June 2010 to April-2011 at research farm of Central Arid Zone Research Institute, Regional Research Station, Bikaner, India (latitude 28.03^{0}N, longitude 73.19^{0}E) in between the tree stands consisting of four tree species (*Acacia senegal, Acacia tortilis, Colophospermum mopane and Dalbergia sissoo*). The average rainfall of the region is 275 mm with 57 % coefficient of variation. Mean monthly maximum and minimum temperature ranged from 21 to 43 ^{0}C and 6 to 29 ^{0}C, respectively, in which the mercury touches 47^{0}C in summer and dipping down to freezing point in winter. The soils of the site was alkaline, non-saline, loamy sand with pH=8.3 and EC_2=0.22 dS m^{-1}. The average soil water content at field capacity was 12.1% (w/v) in upper 0-15 cm soil profile.

Collection of litterfall and analysis

The senescent leaves of four tree species viz. *Acacia senegal, Acacia tortilis, Colophospermum mopane* and *Dalbergia sissoo* were collected from each tree and were brought to the laboratory for estimation of moisture. Sub samples were taken and oven dried at 70^{0}C to constant weight for further analyses of total carbon (C_{tot}), total nitrogen (N_{tot}), lignin, cellulose and ADF . C_{tot} was analyzed by CHN analyzer, N_{tot} by standard Kjeldahl digestion after acid digestion [8]. Acid detergent fiber (ADF), cellulose and lignin were estimated by using the method given by Van Soest *et al.* [21].

Experimental set up

Litter decomposition was studied by *Litterbag technique* [1]. Two sets of 60 nylon litterbags (1mm mesh) of each species containing 20 g leaf litter (whole plant material without grinding on dry weight basis) were positioned at 10 cm. deep in the soil in between the tree rows with two moisture levels (1) Field capacity (FC) and (2) 50% Field capacity in micro plots. Soil moisture was maintained by replenishing the deficit amount of water by sprinkling the water. The soil moisture was determined by using TDR reading. To ensure the soil moisture reading of TDR, the gravimetric soil moisture content was also determined (0-15 cm) frequently during the course of decomposition as well. The litterbags were fixed with iron nails. To assess the pattern of decomposition, five litter bags of each species from both the treatments (40 litterbags in all) were retrieved randomly on each sampling date at monthly interval. After removing any extraneous material from litter bags, they were dried at 70^{o}C for 48 hours till constant weight reaches and analyzed for weight loss.

Determination of mass loss and decomposition constants

Percent mass and nutrients remaining on dry weight basis were fitted to the exponential model of Olson [14] and the decomposition rate constant (K) was determined as follows:

$W_t = W_0 \, e^{-kt}$

Where:

W_t = Mass remaining after time (t)

W_0 = Initial mass or nutrient pool

k = decomposition rate constant

t = time (week)

The decomposition rate constant (k) was estimated as the slope of the linear regression of the natural log (Wt/Wo) against time [7]. Time required for 50% (t_{50}) and 99% weight loss (t_{99}) was calculated by using the equations:

t_{50}= 0.693/k

t_{99} =5/k

RESULTS AND DISCUSSIONS

Initial chemistry of leaf litter

The C, N and C/N ratio of the leaf litter showed that among different tree species, *Colophospermum mopane was* lowest in nitrogen and highest in C/N ratio. Lowest C/N ratio was observed in *Acacia tortilis.* Total N concentration in the leaf litters varied from a minimum of 0.99% in *C.mopane* followed by *D. sissoo* (1.51%), *A. senegal* (1.76%) and maximum of 2.18% in *A. tortilis* (Table 1). The lignin content (34.1%) was maximum in the *C. mopane* and minimum in *A. senegal* (12.6%). There was no much variation in lignin content of *A. senegal* and *A. tortilis.* However, cellulose content of *A. tortilis* (22.1%) was higher than *A. senegal* (10.7%).

Table 1
Initial characteristics of leaf litters of *A. tortilis, A. senegal, C.mopane* and *D.sissoo* used in decomposition experiments (Values are mean ± S.E.)

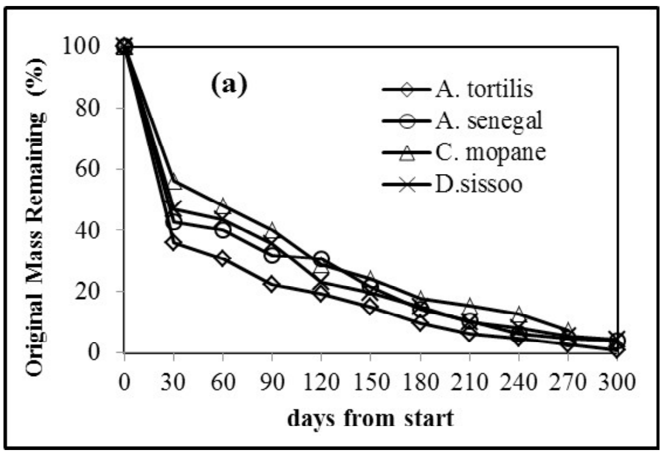
Parameters	*A. tortilis*	*A. senegal*	*C.mopane*	*D.sissoo*
C_{tot} (%)	44.3 ± 0.58	42.5 ± 0.82	49.8 ± 0.62	49.1 ± 0.76
N_{tot} (%)	2.18 ± 0.03	1.76 ± 0.06	0.99 ± 0.06	1.51 ± 0.06
C:N ratio	20.3 ± 0.51	24.2 ± 1.18	50.5 ± 3.26	32.9 ± 1.63
ADF (%)	35.66 ± 2.25	23.37 ± 1.55	39.75 ± 1.32	28.32 ± 2.37
Lignin (%)	13.53 ± 0.99	12.65 ± 0.38	34.12 ± 0.16	16.16 ± 1.35
Cellulose (%)	22.13 ± 1.33	10.72 ± 1.40	5.63 ± 1.22	12.16 ± 1.89

Mass loss pattern

Dynamics of residual biomass retention with time has been shown in Fig. 1(a) and 1 (b). The results obtained showed that the decomposition pattern seemed to be almost in single phase. This seems to be uniform moisture maintained during the course of experiment. The mass loss of leaf litters varied significantly with time, species and moisture content. There were highly significant differences among tree residues in all sampling months. Among different tree species, the mass loss of leaf litter followed the order *A. tortilis*> *A. senegal* > *D. sissoo*> *C. mopane* at both moisture FC and 50% FC. In the first month, percent dry matter remaining in *C. mopane* and *D. sissoo* was significantly higher than *A. tortilis*. This indicates that loss of soluble materials in *C. mopane* and *D. sissoo* was lower than *A.tortilis* by 21.1% and 15.2%. Richards [17] reported that nitrogen exerts a strong influence in the early stages of decomposition. It affects the physiological adaptation of the organisms associated with decomposition. Hence, the leaf litters with high N contents (low C-to-N ratios) decomposes more rapidly, particularly during the early stage of decomposition, than litter with low N contents [6, 20]. In the present study, the N content of *C. mopane* (0.99%) was lowest as compared to other species *viz. A. tortilis* (2.18%) , A. senegal (1.76%) and *D. sissoo* (1.53%) which resulted in lower decomposition rate of *C. mopane* as compared to the other species. Another reason for lower rate of decomposition in *C. mopane* could possibly be due to presence of recalcitrant materials such as lignin [10]. Melillo [13] reported that lignin content of the litter exerts more control over the rate of decomposition as compared to nitrogen. The high lignin in *C. mopane* (34.1 %) bind strongly to organic-N (e.g. amino acids and proteins) in litter, hence making its litter resistant to decomposition [15]. The differences in decomposition rates between *A. tortilis, A. Senegal and D. sissoo* litters can be attributed to higher N content because lignin did not differ much between these two litters. The instantaneous rates of decomposition were calculated as per cent weight loss per day. Relatively highest rate of decomposition was observed during the first month of incubation. The correlation coefficients describing the remaining mass with time were highly significant (P<0.01).

Decay coefficients and time projections for litter decomposition

The decay rate coefficients (k) of the decomposing litters of MPTs and nutrient loss for the entire study period, time required for 50% (half life) and 99% decay are presented in Table 2. For all species, the decomposition data best fitted the exponential decay function ($W_t=W_0\ e^{-kt}$). Accordingly, mass loss rate constants (k) for *C. mopane* was significantly lower than other species. The fast decrease in initial dry matter in the early month of decomposition could be attributed to the leaching of water-soluble material by watering [16]. Earlier studies indicated that both physical leaching and microbial metabolism of water-soluble material, lead to mass loss in the early stages of decomposition [2,3]. Between the two moisture levels, the decay rate coefficient for each species were more in soils maintained at field capacity as compared to 50 % field capacity.



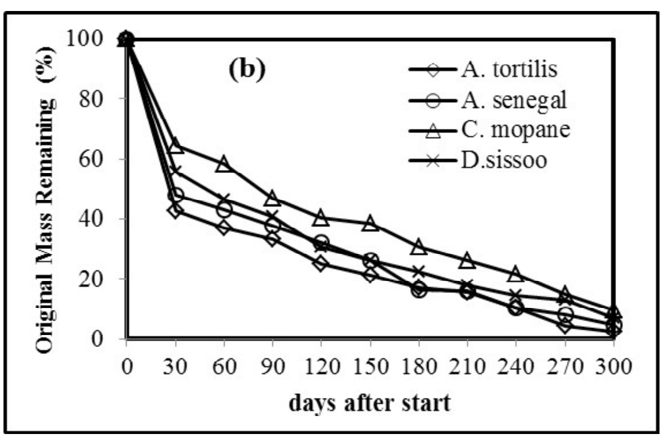


Figure 1 : Mass remaining (as percent of initial) through time for leaf litters of various MPTs incubated at (a) 100% Field capacity (b) 50 % Field capacity

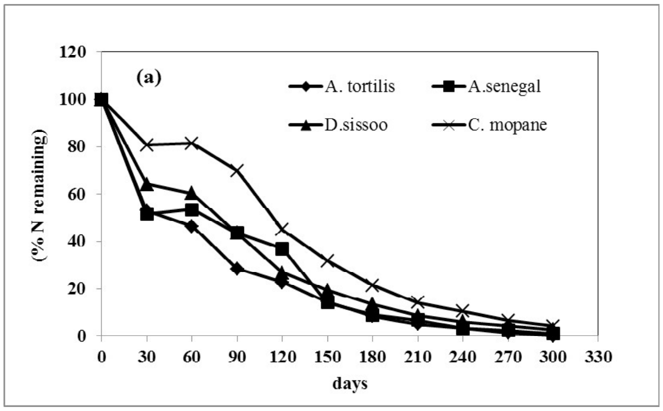
Among the four MPTs, decomposition rates was lowest for *C. mopane* followed by *Dalbergia sissoo*. The half lives or time required for 50% decay at FC soil moisture was lowest (54 days) for *Acacia tortilis* and highest (81 days) for litter of *C. mopane*. For 99% decay, litter of *A. tortilis, C. mopane, D. Sissoo, A. senegal* would require 390, 588, 510 and 485 days at FC and 495,746,675 and 568 days at 50 % FC, respectively.

Table 2
Daily decay rate coefficient (k_D x 10^{-3}) and time (days) required for 50 % decomposition (t_{50}) and 99% decomposition (t_{99}) of leaf litters of various tree species

Species	*Field Capacity*			*50% Field Capacity*		
	k_D x 10^{-3}	t_{50}	t_{99}	k_D x 10^{-3}	t_{50}	t_{99}
Acacia senegal	10.3	67.2	485.4	8.8	78.7	568.1
Acacia tortilis	12.8	54.1	390.6	10.1	68.6	495.0
Colophospermum mopane	8.5	81.5	588.2	6.7	103.4	746.2
Dalbergia sissoo	9.8	70.7	510.2	7.4	93.6	675.6

Nitrogen release dynamics

The release of nitrogen was species specific (Fig 2). Irrespective of tree species, the concentration of nitrogen in the residual mass increased initially and then decreased. The initial increase in N concentration of decomposing litter of all MPTs could be ascribed to microbial immobilization [5,9] and the second phase of decrease to the mineralization of the nutrients from the decomposing litter. Only 0.21%, 1.09%, 2.69% and 4.16% of N remained in the residual litter of *A. tortilis, A. senegal, D.sisoo* and *C. mopane* at FC condition and 1.28%, 2.45%, 4.20% and 8.2% at 50% FC, respectively. Significant differences in the total amount of nitrogen released were observed in different tree species. Release of N was faster under FC conditions as compared to 50% FC [18]. The nitrogen released by various tree species followed the order *A. tortilis*> *A. senegal*> *D.sissoo*> *C. mopane*. The *A. senegal* and *A. tortilis* released highest amount of N followed by *D.sissoo*. Lowest N was released by *C. mopane*. The rates of N release was also related to the initial composition of the litter of trees. Lower nutrient release rates associated with high lignin content.



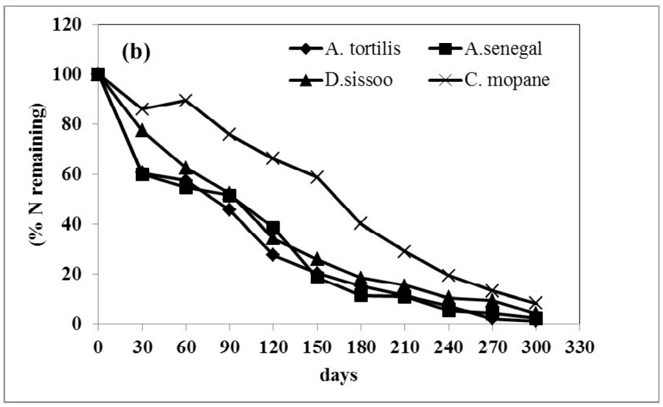


Figure 2: Percent N remaining in the decomposing litter of four tree species at different time intervals at (a) 100% Field capacity (b) 50 % Field capacity

Table 3
Nitrogen mineralization constants (k_N day^{-1}) and time (days) required for 50 % nitrogen release (t_{50N}) and 99% nitrogen release (t_{99N}) of leaf litters of various tree species

Species	*Field Capacity*			*50% Field Capacity*		
	$K_N \times 10^{-3}$	t_{50N}	t_{99N}	$K_N \times 10^{-3}$	t_{50N}	t_{99N}
Acacia senegal	14.7	47.1	340.1	12.2	56.8	409.8
Acacia tortilis	17.0	40.8	294.1	13.5	51.3	370.4
Colophospermum mopane	10.9	63.6	458.7	8.2	84.5	609.7
Dalbergia sissoo	12.0	57.7	416.7	9.9	70.0	505.1

The N mineralization constant (k_N) for *Acacia senegal, Dalbergia sissoo, Acacia tortilis* and *Colophospermum mopane* ranged from 10.9-17.0 in FC and 8.2-13.5 in 50% FC. Compared to other species, *C. mopane* had much lower k_N. C. mopane leaves having high lignin and low N concentration decomposed at a slow rate, and hence revealed slow rate of N release.

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