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LEAF LITTER DECOMPOSITION PATTERN OF TREES

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ABSTRACT

Experiment was conducted to study the leaf litter decomposition and nutrient release pattern of seven multipurpose trees *Tectona grandis, Eucalyptus tereticornis, Dendrocalamus strictus, Terminalia bellirica, Cassia fistula, Casuarina equisetifolia, Terminalia arjuna* were evaluated using litter bag technique. Results showed that, weight loss and decay rate higher in *T. grandis* (25.92%) followed by *D. strictus* (23.08%), *T. arjuna* (22.12%) and least in *C.equisetifolia* (20.51%). Litter nutrient (N, P, K), days elapsed and climatic factor (rainfall, temperature and humidity) of the study site were found to influence the rate of decomposition and significantly correlated to each other. Nutrient release pattern found higher in *T. grandis* and gradually followed by *D. strictus* > *T. arjuna* > *T. bellirica* > *C. fistula* > *E. tereticornis* > *C. equisetifolia*. Initial days of leaf litter decomposition and nutrient release faster and after that gradually slow down due to the influence of climatic parameter. Hence, rainfall, humidity, temperature and microclimate seem to be control the decomposition more effectively and strongly than any other combination of climatic variables.

INTRODUCTION

The litter comprises of the upper decomposed material and its production in natural forests as well as in plantation have one of the most important aspects of nutrient cycling in an ecosystem and are also essential for maintenance of ecosystem's process. The dead organic matter on the forest floor is the vital link between the autotrophs and heterotrophs (Singh, 1969). Litter also reduces bulk density, increase water holding and cation- exchange capacity of the soil and serves as reserve store of plant nutrient. The nutrient content and their cycling between the biological and the physical environment has gained unprecedented importance in the recent years and their disruption may cause serious setback to the dynamic behavior of an ecosystems.Litter decomposition is one of the key biogeochemical processes in forest ecosystems (Swift *et al.*, 1979). The rate of litter decomposition is largely a determining factor for productivity of forest ecosystems as plant nutrients became available for recycling within the system during the process. It is estimated that the nutrients released during litter decomposition can account for 69-87% of the total annual requirement of essential elements for forest plants (Waring and Schlesinger, 1985). Litter decomposition is influenced by environmental factors and physiochemical properties of the parts such as stem wood leaves, root etc. of the species studied and the decomposer organism present in the soil (Vesterdal,1999).Three factors which are site environmental condition (particularly climate), litter quality and the soil biota are known to control litter decomposition processes (Gholz *et al.*, 2000; Trofymow *et al.*,2002; Parton *et al.*, 2007; Gartner and Cardon, 2004; Bardgett, 2005; Austin and Vivanco, 2006).Thus, it was demonstrated among seven different tree species *Tectona grandis, Eucalyptus tereticornis, Dendrocalamus strictus, Terminalia bellirica, Cassia fistula, Casuarina equisetifolia* and *Terminalia arjuna* in the arboretum of college farm. To do this the litter bag method was adopted, using bags with a large mesh that allowed activity both by macro and micro-organisms (Olson, 1963).In present study observed that variation in the rate of leaf litter decomposition and nutrient release pattern with climatic as well as physical structure of litter and microbial activity in soil significantly correlated to each other.

MATERIALS AND METHODS

Location

The present investigation was carried out in 18 years old plantation of seven different tree species (*T.g*) *Tectona grandis,* (*E.g*)*Eucalyptus tereticornis,*(*D.s*) *Dendrocalamus strictus,* (*T.b*)*Terminalia bellirica,*(*C.f*)*Cassia fistula,*(*C.e*)*Casuarina equisetifolia* and (*T.a*) *Terminalia arjuna* raised in the Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari Campus, Navsari (Gujarat). Geographically, Navsari (Gujarat), India is situated at 20.95° North Latitude and 75.90° East Longitude and at an altitude of 11.98 meters from above mean sea level (MSL). The experimental site is located just 12 km away in the east from the Arabian Seashore of historical Dandi, India.

Weather and climate

Climatically, this region is typically tropical, characterized by fairly hot summer, moderately cold winter and more humid and warm monsoon with heavy rain. The average annual precipitation was 1599 mm. with maximum and minimum mean annual temperature 35.45°C and 15.9°C respectively, then higher relative humidity in morning was 92.5% and minimum 75% and evening time was higher 83.5% and minimum 36% respectively (Fig. 1).

Soil types

The clay content ranges from 42 to 50 percent, pre-dominated with montmorillonite type of clay mineral. It includes deep moderately drained clayey soils, classified as deep black soil. It is medium in fertility and has high water holding capacity (Kaswala and Despande, 1983).

Technique used

Decomposition studies were done using litter bag technique with each sample containing 10 g of mature (after litter fall) litter was filled in nylon bags of size 20 × 20 cm as used by Olson (1963). The bags were sealed on all sides; many holes of size 2mm were made in each bag and placed in soil at a depth of 2 cm for decomposition studies. 39 bags of each species were laid out in three replications. All the bags were placed randomly in the field on same day. Samples were taken at one fortnight (15 days interval) interval starting from the first month during July, 2009. Cumulative seasonal weight loss was calculated for each of the species. The values were pooled and correlation between climate and decomposition as well as nutrient release was established. Samples were immediately brought to the lab. After removing the extraneous materials like arthropods, fine roots and other soil particles, the samples were carefully washed under running water and finally rinsed with distilled water. The contents of the bags were transferred to paper bags and oven dried at 70°C for 48 h and then recorded the mass residues and powdered using a precision balance. Nitrogen content was determined in fresh litter and the residues sampled at fortnight intervals by Micro-Kjeldahl method, Phosphorus by Spectrophotometer method and Potassium by Flame photometer method as per Jackson (1967).

Statistical analysis

Decomposition constant (k) of the leaf litter were estimated following by Olson (1963).

$$\text{In}\ (X_t/X_0) = -\,kt$$

Where

X_0 = weight of litter at time 0, X_t = weight of litter at time t, t - time (usually in year), k - decomposition rate constant. Pearson's correlation co-efficients of mean days weight loss of litter with weather parameters in the experimental plot were worked out following Panse and Sukhatme (2000).

RESULTS AND DISCUSSION

Initial chemical composition

Initial nutrient composition of leaf litter showed variation among the multipurpose tree species. The highest nitrogen concentration was estimated in *T. arjuna* (0.502%) and followed by *E .tereticornis* (0.384%), *C.equestifolia* (0.351%) and maximum potassium concentration was in *T. arjuna* (0.378%) and least in *C.equestifolia*(0.150%) along with lowest concentration estimated of Phosphorus in all tree species as well as higher concentration found in *T. bellirica* (0.140%) and *T.grandis* (0.132%)(Table-1).

Weight loss pattern

Loss of dry matter (Percentage of original mass) and actual weight loss per fortnight (15 days interval) percentage, regarded as litter decomposition rate are the two parameters which have been used to describe the results on weight loss pattern. Although weight loss continued throughout the study period relatively higher weight loss occurred within rainy seasons. It is seen from the data presented in Figure-2 showed that significantly maximum weight loss percentage from first 15 days interval (July) to 195 days (January) interval was recorded in *T.grandis* with (25.922%),which was followed by *D. strictus* (23.083%), *T.arjuna* (22.12%), *T. bellirica* (21.23%), *C.fistula* (21.03%),*E. tereticornis* (20.61%) and least in *C.equestifolia* (20.51%) respectively(Fig. 2).Among different time of sampling first 15 days of July recorded significantly highest weight loss percentage in *T. grandis* with (33.00%) followed by *D. strictus* (27.00%) and least in *C.equestifolia* with (23.00%) (Fig. 2). Initially the decomposition was rapid, followed by a much slower decomposition rate toward the last phase of

Table 1: Initial chemical composition (%) in leaf litter of multipurpose tree species

Nutrient (%)	*T.g*	*E.t*	*D.s*	*T.b*	*C.f*	*C.e*	*T.a*
Nitrogen	0.295	0.384	0.278	0.228	0.243	0.351	0.502
Phosphorus	0.132	0.120	0.038	0.140	0.090	0.101	0.100
Potassium	0.353	0.281	0.362	0.303	0.222	0.150	0.378

Table 2: Effect of time of sampling on decay coefficient (-k), R^2, and half-life ($t_{0.05}$) in different multipurpose tree species

Trees	Parameter	-k	$T_{0.05}$	R^2
T. grandis	DM	0.0171	40.7	0.7213
	N	0.0573	12	0.8808
	P	0.0488	14.2	0.864
	K	0.052	13.3	0.9485
E. tereticornis	DM	0.0133	52.19	0.9599
	N	0.0299	23	0.9403
	P	0.0415	16.7	0.8753
	K	0.0386	17.9	0.9171
D. strictus	DM	0.0155	46.2	0.9336
	N	0.0475	14	0.8837
	P	0.0456	15.2	0.9227
	K	0.0505	13.7	0.9064
T. bellirica	DM	0.0137	50.58	0.9722
	N	0.0375	18	0.7648
	P	0.043	16.1	0.8462
	K	0.0422	16.4	0.9508
C. fistula	DM	0.0136	50.9	0.9556
	N	0.0371	18.6	0.9548
	P	0.0407	17	0.866
	K	0.0412	16.8	0.8472
C. equisetifolia	DM	0.0132	52.5	0.9826
	N	0.0202	34	0.9218
	P	0.04	17.3	0.8138
	K	0.0312	22	0.8712
T. arjuna	DM	0.014	49.5	0.9486
	N	0.0422	16	0.9653
	P	0.042	16.5	0.9122
	k	0.0434	15.9	0.8885

DM - Decomposed material, N - Nitrogen, P - Phosphorus, K - Potassium

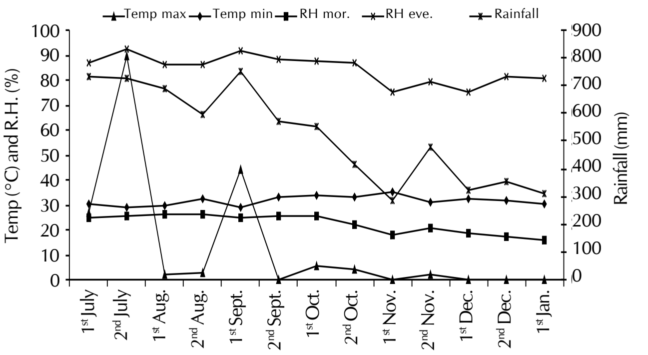

Figure 1: Meteorological data recorded during the experimental period 1st fortnight of July 2009 to 1st fortnight of Jan 2010 (mean)

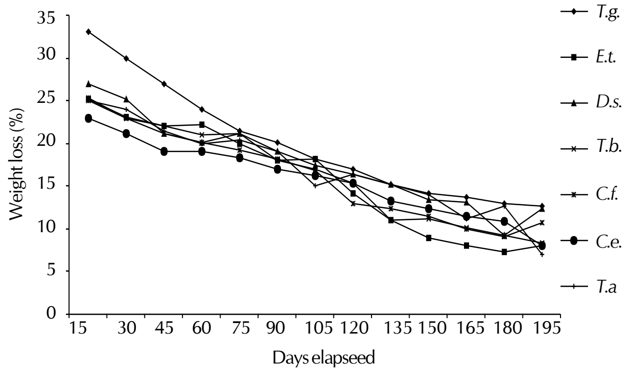

Figure 2: Effect of time of sampling on weight loss (%) in different multipurpose trees

decomposition due to the high content of fast decomposable components such as sugars, amino acids and proteins. In the later stages, decomposition rates tend to decrease due to the accumulation of recalcitrant components such as lignin, tannins and cellulose (Zaharah and Bah, 1999; Thonnissen *et al*. 2000; Hada *et al*. 2004; Lupwayi *et al*. 2004). The decomposition was constant (-k) and they decomposed found higher in *T.grandis* with (0.0171 $k_{DM}^{-15\ days}$) and 40.7 days taken to 50% decay followed by *D. strictus* (0.0155 $k_{DM}^{-15\ days}$), *T. arjuna* (0.014 $k_{DM}^{-15\ days}$), *T. bellirica* (0.0137 $k_{DM}^{-15\ days}$), *C. fistula* (0.0136 $k_{DM}^{-15\ days}$), *E. tereticornis* (0.0133 $k_{DM}^{-15\ days}$) and least in *C. equestifolia* (0.0132 $k_{DM}^{-15\ days}$) and varies from 46.2 to 52.5 days taken to 50% decay respectively(Table-2). The edaphic and climatic factors apparently had more influence on residue decomposition than the chemical and biochemical composition. We suggest that the effects of tree constituents on the decomposition process should be more carefully evaluated in future studies involving heterogenic material and that temperature and humidity should be controlled. Thonnissen *et al*. (2000) observed that the effects of residue chemistry and biochemistry on decomposition rates varied widely between season and locations.

Nutrient release pattern

Nitrogen (N)

Nutrient release from the decomposing leaf litter also varied considerably. N release was maximum during first 15 days interval to 195 day found in *T.grandis* with (53%) followed by *D. strictus* (47%), *T.arjuna* (43%), *T. bellirica* (39%), *C.fistula* (37%),*E. tereticornis* (33%) and least in *C.equestifolia* respectively (Fig. 3). The rate of N release followed the same trend as mass loss. During initially first to second 15 days interval found higher N release in *T.grandis* (0.290%) and least in *C. equestifolia* (0.350%) respectively and after that gradually slow down (Fig. 3). The initial release or decline in concentration can be attributed to leaching of the soluble form of nitrogen, while the second phase can be attributed to binding of N to lignin and polyphenols in the tissues, as suggested by Palm and Sanchez (1990). As decay advanced, mineralization resulted in the decline of the elements in residual litter, and this accounted for its release (Isaac and Nair, 2006). The N release (k_n) varied from 0.0573 to 0.0202 $k^{-15days}$ during first 15 days interval to 195 days (Table-2). The N release (k_n) found higher in *T.grandis* (0.0573 $k_n^{-15days}$) and taken 12 days to released 50% nutrient and *C. equestifolia* taken higher 34 days to release 50% nutrient compare to other tree species *viz*. *E. tereticornis* (0.0299 $k_n^{-15days}$) and *C. fistula* (0.0371 $k_n^{-15days}$) taken 18.6 to 23 days to release 50% nutrient(Table-2). Zaharah and Bah (1999) observed a similar behaviour of *Gliricidia sepium*, which released half of the initial N content in the initial stage.

Phosphorus (P)

Table 3: Correlation analysis between weight loss percentage and days elapsed, environment (temperature, relative humidity and rainfall) factor

Correlation	*T. g*	*E. t.*	*D. s.*	*T. b.*	*C. f.*	*C. e.*	*T. a.*
Days elapsed	- 0.967**	-0.978**	-0.968**	-0.985**	-0.978**	-0.990**	-0.971**
Maximum temperature	0.790*	0.920**	0.827**	0.922**	0.873**	0.894**	0.838**
Relative humidity morning	0.678*	0.790*	0.720*	0.800*	0.749*	0.740*	0.700*
Relative humidity evening	0.871**	0.913**	0.883**	0.944**	0.920**	0.900**	0.881**
Total rainfall	0.610*	0.531	0.646*	0.570*	0.582*	0.575*	0.595*

Critical value (2-tail, 0.05) = ±0.55108, ** = Highly significant, * = Significant

T.g. - Tectona grandis, E.t. - Eucalyptus tereticornis, D.s. - Dendrocalamus strictus, T.b. - Terminalia bellirica, C.f. - Cassia fistula, *C.e. - Casuarina equisetifolia* and *T.a. - Terminalia arjuna.*

Table 3a: Correlation analysis between weight loss percentage and nutrient release (N, P and K)

Correlation	*T. g.*	*E. t.*	*D. s.*	*T. b.*	*C. f.*	*C. e.*	*T. a.*
Nitrogen	0.982**	0.862**	0.936**	0.969**	0.926**	0.957**	0.934**
Phosphorus	0.967**	0.906**	0.927**	0.851*	0.904**	0.892**	0.903**
Potassium	0.969**	0.921**	0.947**	0.899**	0.944**	0.763*	0.896**

Critical Value (2- tail, 0.05) - ±0.55108, ** - Highly significant, * - Significant

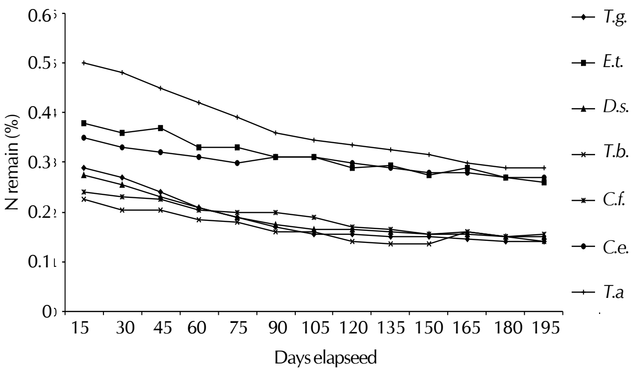

Figure 3: Effect of time of sampling on Nitrogen remain (%) in different multipurpose trees

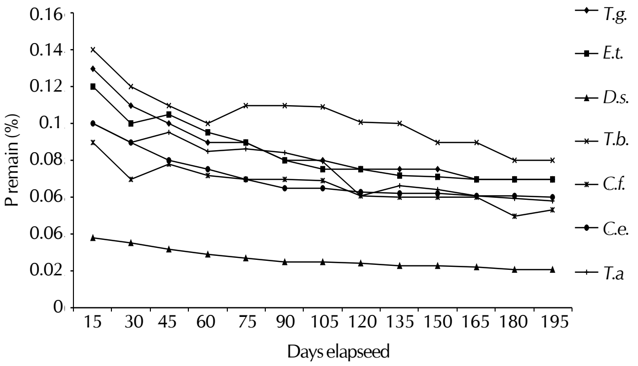

Figure 4: Effect of time of sampling on phosphorus remain (%) in different multipurpose trees

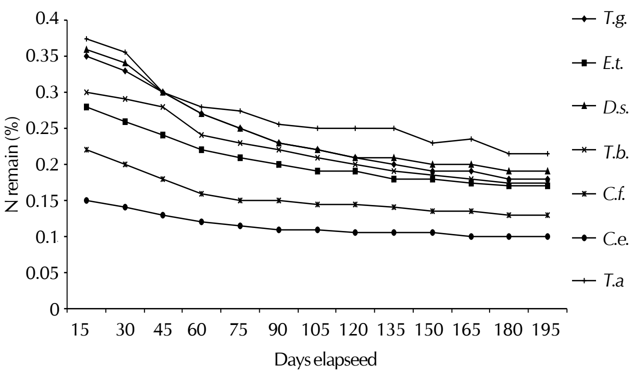

Figure 5: Effect of time of sampling on Potassium remain (%) in different multipurpose trees

It is evident Fig. 4, that significantly maximum phosphorus release from first 15 days interval of July to 195 days (January) was recorded in *T.grandis* (47%) followed by *D. strictus* (44.8%), *T. arjuna* (43%), *T. bellirica* (42.86%), *C. fistula* (42%), *E. tereticornis* (41.7%) and least in *C. equestifolia* (40%)respectively (Fig. 4). During first to second 15 days interval found higher P release from leaf litter and after that gradually slow down. Maximum P release found in *T. grandis* (0.132 - 0.11%) and least in *C. equestifolia* (0.100%) after that all tree species show P release process slow down (Fig 4). The P release rate (kp) varied among tree species from 0.0488 to 0.040 $kp^{-15days}$. Maximum P release rate (kp) found in *T.grandis*(0.0488 $kp^{-15days}$) and taken 14.2 days to release 50% P nutrients followed by *D. strictus* (0.0456 $kp^{-15days}$), *T. arjuna* (0.042 $kp^{-15days}$), *T. bellirica* (0.0430 $kp^{-15days}$), *C. fistula* (0.0407 $kp^{-15days}$), *E. tereticornis* (0.0415 $kp^{-15days}$) and least in *C. equestifolia* (0.040 $kp^{-15days}$)respectively taken time to 50% P release from (15.2 days to 17.3 days) respectively(Table-2). Oliveira *et al.* (2003) reported similar $t_{1/2}$ P values of 16.1 days for *A. pintoi*. Unlike K, generally considered the nutrient with highest release rate, P participates in cell constituents, e.g., phospholipids, nucleic acids and DNA and RNA structures, and is also part of the ATP molecule (Ha *et al.*, 2007). Phosphorus release is not directly related to rainfall, but to the total inorganic P content and soluble P in the residues, and to the effective action of microorganisms on the organic fractions (Giacomini *et al.*, 2003).

Potassium (K)

The rapid loss of K observed in this study from the first 15 days interval to fourth 15 days interval was probably due to removal of soluble K by excessive watering after burying the litterbags. Many studies indicated that K can be leached in the early stages of decomposition (Musvoto *et al.*, 2000). Maximum potassium release from first 15 days interval of July to 195 days (January) was recorded in *T. grandis* (49.01%) followed by *D. strictus* (47.52%), *T. arjuna* (43.13%), *T. bellirica* (42.25%), *C. fistula* (42%),*E. tereticornis* (39.51%) and least in *C. equestifolia* (33.34%)respectively (Fig. 5). Initial phase of decomposition was found rapid loss of K from litter in *T.grandis* (0.350% to 0.270%) and least in *C. equestifolia* (0.150% to 0.120%) respectively(Fig. 5).The K decline rate (kp) varied from (0.052 $kp^{-15days}$) to (0.0312 $kp^{-15days}$) respectively and time taken from (13.3 days to 22 days) to release 50% K content. Maximum K decline rate (kp) was found in *T.grandis* (0.052 $kp^{-15days}$) followed by *D. strictus* (0.0505 $kp^{-15days}$), *T.arjuna* (0.0434 $kp^{-15days}$), *T. bellirica* (0.0422 $kp^{-15days}$), *C. fistula* (0.0412 $kp^{-15days}$), *E. tereticornis* (0.0386 $kp^{-15days}$) and least in *C. equestifolia* (0.0312 $kp^{-15days}$) respectively (Table-2). The high potential for potassium leaching from plant residues in the early stages of this study is consistent with literature. The high loss of initial K observed here was reported earlier (Isaac and Nair, 2005). Because K is not a structural element, it is susceptible to high initial loss by leaching (Staaf, 1980). Other studies also reported that, K release is not affected by chemical composition because this cation is not incorporated in the organic compounds in the plant tissue and therefore easily leached from residues (Saini, 1989)

Relationship between weight loss, days elapsed and environmental factors

Physical environment had a significant role in weight loss percentage of different tree species. It includes the climatic parameters like temperature, rainfall and relative humidity. Climatic variations were one of the most important determinates in the decomposition process. The climatic conditions were markedly different during the various seasons of the fortnight. It was observed from these correlation data that days elapsed were negatively higher in magnitude than their corresponding environmental factor (temperature, relative humidity and total rainfall) in most of the cases. The data regarding days elapsed correlation showed in Table 3, that all weight loss percentage had highly significant and negatively correlated with treatment *T. grandis* (r = -0.967), *E. tereticornis* (r = -0.978), *D. strictus* (r = -0.968), *T. bellirica* (r = -0.985), *C. fistula* (r = -0.978), *C. equestifolia* (r = -0.990) and *T. arjuna* (r = -0.971) respectively (Table-3). Understanding the distribution of fungi associated with leaf litter decomposition in relation to optimum climatic patterns is crucial, as it will provide useful insights into the future changes of biodiversity and functioning in warmer and wetter climates along climatic gradients Tokumasu (2001). In case of minimum temperature, weight loss percentage had non-significant correlation with all treatments under study due to slow functional activity of micro-organism . Whereas in case of maximum temperature correlation, weight loss percentage had highly significant positive correlation with all treatment *T. grandis* (r = 0.790), *E. tereticornis* (r = 0.920), *D. strictus* (r = 0.827), *T. bellirica* (r =0.922), *C. fistula* (r = 0.873), *C. equestifolia* (r = 0.8947) and *T. arjuna* (r = 0.0.838) respectively (Table 3).The data regarding relative humidity (morning) correlation showed that weight loss percentage had highly significant positive correlation with all treatment *T. grandis* (r = 0.678), *E. tereticornis* (r = 0.790), *D. strictus* (r = 0.720), *T. bellirica* (r = 0.800), *C. fistula* (r = 0.749), *C. equestifolia* (r = 0.740) and *T. arjuna* (r = 0.700) respectively (Table-3). Whereas in case of relative humidity (evening) correlation weight loss percentage had highly significant positive correlation with all treatment *T. grandis* (r = 0.871), *E. tereticornis* (r = 0.913), *D. strictus* (r = 0.883), *T. bellirica* (r = 0.944), *C. fistula* (r = 0.920), *C. equestifolia* (r = 0.900), and *T. arjuna* (r = 0.881) respectively (Table 3). However in case of total rainfall correlation, weight loss percentage had significant positive correlation with treatment *T. grandis* (r = 0.610), *D. strictus* (r = 0.646), *T. bellirica* (r = 0.570), *C. fistula* (r = 0.582), *C. equestifolia* (r = 0.575) and *T. arjuna* (r = 0.595) and *E. tereticornis* (r = 0.531) showed non-significant correlation respectively (Table-3). Parton *et al.*, 2007; Gartner and Cardon, 2004; Bardgett, 2005; Austin and Vivanco, 2006 reported similar work correlation between leaf litter decomposition and abiotic factors and also observed rapid decomposition rate in rainy season and after that gradually slow down.Although, in the initial phase the decomposition rate was rapid, but it was followed by slow phase of decomposition during winter. In winters, low temperature and rainfall may have resulted into low activity of decomposers. Wiegert and McGinns (1975) reported slow rate of decomposition during winter.

Relationship between weight loss, nitrogen, phosphorus and potassium release

It was observed from these correlation that nitrogen release correlation were higher in magnitude than their corresponding phosphorus and potassium correlation in most of the cases. It is evident from Table-3(a), that nitrogen release correlation showed that weight loss percentage had highly significant positive correlation with all treatment *T. grandis* (r = 0.982), *E. tereticornis* (r = 0.862), *D. strictus* (r = 0.936), *T. bellirica* (r = 0.969), *C. fistula* (r = 0.926), *C. equestifolia* (r = 0.957) and *T. arjuna* (r = 0.934) respectively (Table-3a). Our finding of significant correlations between litter decomposition rates and N- related variables of the litter corroborate the results of other studies, which demonstrated that the N concentrations, or the ratios of N to other foliar compounds, are among the principal factor affecting the rates of liter decomposition in particular climatic condition(Cornelissen, 1996 and Aerts, 1997). Whereas in case of phosphorus release correlation, weight loss percentage had highly significant positive correlation with all treatment *T. grandis* (r = 0.967), *E. tereticornis* (r = 0.906), *D. strictus* (r = 0.927), *T. bellirica* (r = 0.851), *C. fistula* (r = 0.904), *C. equestifolia* (r = 0.892) and *T. arjuna* (r = 0.903) respectively (Table 3a). Significantly positive correlation has also been found between the decomposition rates and the P concentration of the litter (Hobbie *et al.* 2006). However, it has been considered that (i) correlations between nutrient concentrations and litter decomposition rates do not necessarily imply that litter quality controls litter decay and (ii) simple extrapolations of decomposition rates from early stages of decay to long term rates might yield erroneous results (Prescott, 2005). From Table 3a, it revealed that potassium release correlation weight loss percentage had highly significant positive correlation with all treatment *T. grandis* (r = 0.969), *E. tereticornis* (r = 0.921), *D. strictus* (r = 0.947), *T. bellirica* (r = 0.899), *C. fistula* (r = 0.944), *C. equestifolia* (r = 0.763) and *T.arjuna* (r = 0.896) respectively. The different correlated factors which affect the rapidity of decomposition of the litter may be said to be of two main kinds, exterior ones, chiefly the nature of climate and soil and interior ones *i.e.,* the chemical and physical qualities of the litter. In the present experimentation the litter of different species was allowed to decompose. (Isaac and Nair, 2005 and 2006; Mafongoya and Nair, 1977) have reasoned for the differences in litter decomposition. They are of the opinion that incorporation of pruning may improve nitrogen recovery due to fast biomass decomposition.

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