J. Bamboo Rattan (2022) 21(4):166-177
https://doi.org/10.55899/09734449/jbr021402 www.jbronline.org

RESEARCH ARTICLE

Litter dynamics and nutrient flux in endemic bamboo species *Dendrocalamus stocksii* plantations in moist semi-arid zones of peninsular India

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Received: 8 December 2022/Accepted: 5 March 2023
Published online 2 July 2023

Abstract: The study was undertaken to understand litterfall, litter decomposition and nutrient release pattern of popularly grown bamboo species, *Dendrocalamus stocksii,* in the moist semi-arid agro-climatic zone of Karnataka, India. The litter production and decomposition were studied using the standard litter trap and bag techniques. The total annual litter production in 2017 was 6.03 Mg ha^{-1} $year^{-1}$ for Gottipura and 5.81 t ha^{-1} $year^{-1}$ for Nallal. Litter production was continuous, but the quantity of litter produced varied with season and month. Nutrient concentrations in monthly litter samples varied. Peak litter fall was concentrated during the hot-dry period (February-May) as 62.8 per cent at Gottipura and 52.2 per cent at Nallal site. The collected litter from the litter traps was dominated by leaf litter. Litter production followed a similar pattern for both locations, with a major peak in March 2017, it was found that both types of litter and filter paper had an initial rapid phase of decomposition followed by a slower phase. The increase in percentage nutrient content in litter samples found in litter bags collected month -wise have been attributed to the high temperature and increased rates of mineralization assisted by soil microbes over the low immobilization rate.

Keywords: D. stocksii, litter fall, litter decomposition, nutrient release

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Introduction

Dendrocalamus stocksii is an endemic multi-purpose bamboo species with steady consumer demand. Multi-locational trials of this species in various agro-climatic zones revealed that it is highly adaptable in semi-arid, sub-humid and humid tropical environments, with increased chances of popularisation. In recent times, there has been considerable increase in interest on this multiuse species for cultivation in home gardens, farm boundaries, block plantations and other agroforestry practices. The time necessary for decomposition is directly linked to the decay coefficient (k). The environmental variables (temperature and moisture) and resource quality (lignin, nitrogen-condensed and soluble poly-phenol concentrations) heavily influence the rates of litter decomposition (Anderson and Swift, 1983; Swift *et al*., 1979; Nath and Das, 2008). In bamboo plantations, the rate of decay observed was comparatively low as compared to other tropical forests (Shanmughavel, 2004; Deb *et al*., 2005). The total estimated litter production for *B. bamboos* was around 17.8 Mg ha^{-1}, (Shanmughavel *et al*., 2000).

Nothing goes to waste in bamboo. Bamboo produces tonnes of litter per year, which can be used for in situ composting. Leaf litter is one of the significant sources of soil organic matter in an ecosystem, and it acts as the energy source for heterotrophic organisms. The mineralisation of nutrients in leaf litter helps in nutrient recycling, whichhelp in improving soil fertility. The physical which help environment, in which decay takes place, nature and abundance of decomposers, organic matter present and chemical quality of the litter primarily influences the decomposition rate of litter. (Li-Hua *et al*., 2014; Shanmughavel *et al*., 2001;

Sujatha *et al*., 2003; Watanabe *et al.,* 2013; Jijeesh and Seetha Lakshmi, 2016). However, such studies are very much limited in *D. Stocksii* especially under moist semi-arid tropical climate.

In the study conducted by Jagadesh (2012), the total litter fall (leaves and twigs) varied considerably between species and locations. The *Dendrocalamus asper* in Kodagu (humid tropics) was also substantially higher than in Bangalore (semi-arid). Litter fall pattern in *Guadua angustifolia* plantations (400 plants/ha) varies with the growth and agro-climatic region. In the humid tropics of Coorg, Karnataka, the annual litter fall (twigs, leaves and -1 -1 culm sheath) accounts for 68.37 Mg ha, whereas it was 44.79 Mg ha for a 5-year-old plantation at the same density when grown in a semi-arid region of Hoskote, Bangalore.

Litter Dynamics –Litter fall and patterns of decomposition

Magnitude of litter fall, litter chemistry and the turn-over of nutrients through litter decay depend on the climate, species and literature, season, and soil fauna. Studies on the pattern of litter fall, decomposition and nutrient cycling help us understand the dynamics of litter and the nutrient in land-use systems involving fast-growing species, especially in bamboo farming. (Jagdish, 2012). In different bamboo species, litter decomposition studies were carried out.

Annual bamboo litter production in four bamboo species was studied in Kerala, and maximum litter fall was found in February and December, following a bimodal distribution pattern with high peaks. In the order of *Thyrsostachys oliveri>Bambusa balcooa >Bambusa bambos>Ochlandra travancorica* was the litter fall accumulation (Jijeesh, 2013). In *Ochlandra travacorica* in Kerala, part of Western Ghats, Sujatha *et al*., (2003) reported that it took three months to decompose by 50 percent and to decompose 95 per cent by 13 months.

Litter studies in *Ficus benghalensis* has been tried with a standard technique of surface and subsurface litter bag. Decomposition and release of nutrient of leaf litter showed that the decay rate in sub-surface placing was marginally higher than in the surface (22.5 % of the initial litre mass remaining after one year of breakdown while 28 percent of initial litter mass remaining for surface placement. The litter quality and climatic and edaphic conditions (monthly rainfall and soil moisture) have affected the rate of decomposition. Litter mineralisation was in the order K>N>P (Dhanya *et al*., 2013).

Fig 1. Litter fall studies; Close up view of circular litter traps installed (A); Storing of dried litter bags in laboratory (B); Separating twig and leaf litter (C)

A study carried out in the Munnar tea gardens, Kerala, found that *Grevellia robusta* (silver oak) trees contributed a significant amount of nutrients to the soil nutrient pool in the form of lopping, through fall and stem flow (Nitrogen 75 kg, Phosphate 4 kg, Potassium oxide 40 kg, Calcium 95 kg, Magnesium 40 kg and Sulphur 38 kg per hectare per year). Besides enriching the soil nutrient pool, leaf litter decomposition increases the soil humus content resulting in improved soil physico-chemical and biological properties (Niranjana and Viswanath, 2010).

Materials and Methods

Litter fall determination

Litter traps were placed in D. *stocksii* plantations at Gottipura and Nallal field station of ICFRE-IWST, Bangalore. These traps were designed so that litter is to be retained in the traps once it is trapped. The litter within or outside the trap would not get intermixed either by the wind or small animals or undergo loss from decay due to the collection of water within them. The litter collected in each of the traps were collected at monthly intervals.

One-year litter fall data were recorded from five clumps from Nallal and five clumps from Gottipura with four litter bags at each four cardinal directions (North, South, East and West). The litter quantification was conducted from January 2017 to December 2017. The average periodic litter production measurements were made using specially designed circular traps (collection area: 0.18 m^2). The traps were fixed about 20-30 cm above the ground level by three pegs at the corners (Jamaludheen and Kumar, 1999; Shanmughavel *et al*., 2000). The litter collected in each of the traps were removed at monthly intervals. Periodically collected litter was brought to the laboratory, separated into leaf and twig components and oven-drying at 60 °C to a constant weight. The oven-dry weight was taken, and the mean litterfall was calculated. Litter from four traps per clumps is calculated as litter from 1m^2. It was extrapolated for 1 ha.

The oven-dried litter (leaf and twig litter) samples of both litter fall and litter decomposition experiment collected at different intervals of months were ground. They were passed through a 0.5 mm sieve before chemical analysis. Samples were then analysed CHN Analyzer and in ICP- OES (Perkin Elmer - Avio 200). The following digestion procedure was used before analysing samples in ICP-OES. About 0.5 g of sample was weighed and digested using 3 ml Hydrogen peroxide and 5 ml nitric acid. Again, digested using 2 ml Hydro-fluoric acid and made up with 25 ml. From this, 1ml pipetted and made up to 25 ml. From this again, 1ml pipetted and diluted to 25 ml. The litter analysis was undertaken for both litters - fallen litter and decomposition litter.

Litter decomposition

To carry out the litter decomposition experiment, the freshly fallen and senescent leaves were collected during the peak period of litter fall and air-dried for five days under laboratory conditions. The composite litter was separated into leaf and twig litter. The standard litter bag technique was employed for characterising litter decomposition dynamics (Bocock and Gilbert, 1957; Jamaludheen and Kumar, 1999; Shanmughavel *et al*., 2000). Twenty grams of leaf litter, twig litter and filter paper (control) samples were put into nylon mesh bags (dimensions: 20 cm x 20 cm: 2 mm mesh size), and the mouths of the bags were stitched with nylon threads to avoid loss of sample. One hundred and forty-four bags were prepared for the period of 12 months for each litter component considering four bags (replications) to be retrieved at a monthly interval. The bags were then placed in the soil of the bamboo-based agro-forestry systems in June 2018 in strips to facilitate easy retrieval. The bags were placed in a manner such that contact was established with the soil and were covered in the soil to avoid.

Fig 2 . Sub-surface placement of litter, twig and filter paper samples for decomposition experiment

disturbances by animals. Four bags from each litter component, including control, were carefully retrieved from the soil (12 bags/month) and returned to the laboratory at monthly intervals. The bags were gently rinsed with water to remove the soil and other extraneous materials. The residual litter mass removed from the bags were oven dry at 80 °C and weighed after extending the fine roots and macro arthropods penetrating the mesh.

The residual litter mass remaining in the litter bags and their corresponding nutrient contents were also analysed. The residual moss loss over time was computed using the negative exponential decay model (Olson, 1963) represented by the following equation:

$$\frac{X}{X} = e^{-kt}$$

Where X_0 is the initial dry weight in gram, X is the dry weight remaining at the end of the sampling interval (g) interval (gram), *e* is the base of the natural logarithm, k is the decay rate coefficient, and t is the time interval in months. The time required for 50 ($t_{0.5}$) and 90 ($t_{0.9}$) percent decay was calculated from the k-values using the equation

$$t_{0.} = \frac{0.693}{-k} \quad \text{and} \quad t_{0.9} = \frac{5}{-k}$$

The total stock of nutrients in litter was calculated by multiplying the concentration (%) with that of dry matter. However, per content nutrient remaining in the litter bag was investigated as Bockheim *et al.,*(1991)

$$\text{Percentage Nutrient remaining} = \frac{C}{C_0} \times \frac{X}{X_0} \times 100$$

Results and discussion

Litter production

The present study examined the litter production, decomposition, and nutrient release dynamics of *D. stocksii*. The total annual litter production by *D. Stocksii* was 6.03 Mg ha^{-1} year^{-1} at Gottipura and 5.81 Mg ha^{-1}year^{-1} at Nallal. Litter production was continuous, but the quantity of litter produced varied by season and month. Nutrient concentrations in monthly litter samples varied with nutrient type.

Table 1. Month wise total litter production in *D. Stocksii* in Gottipua and Nallal

Month	2017					
	Gottipura			Nallal		
	Leaf (Mg ha^{-1})	Twig (Mg ha^{-1})	Total (Mg ha^{-1})	Leaf (Mg ha^{-1})	Twig (Mg ha^{-1})	Total (Mg ha^{-1})
January	0.162	0.003	0.166	0.199	0.002	0.201
February	0.595	0.003	0.598	0.615	0.005	0.620
March	1.947	0.002	1.950	0.946	0.004	0.950
April	1.100	0.003	1.104	0.856	0.008	0.864
May	0.325	0.001	0.326	0.611	0.006	0.617
June	0.300	0.001	0.301	0.489	0.002	0.491
July	0.240	0.003	0.243	0.234	0.008	0.242
August	0.284	0.002	0.286	0.361	0.004	0.365
September	0.339	0.002	0.341	0.300	0.002	0.302
October	0.277	0.003	0.280	0.440	0.003	0.443
November	0.275	0.001	0.276	0.253	0.001	0.255
December	0.460	0.002	0.462	0.497	0.002	0.499
TOTAL	**6.306**	**0.027**	**6.333**	**5.801**	**0.047**	**5.849**
MEAN	0.525	0.002	0.528	0.483	0.004	0.487
SD	0.512	0.001	0.512	0.240	0.002	0.241
SE (±)	0.148	0.000	0.148	0.069	0.001	0.070

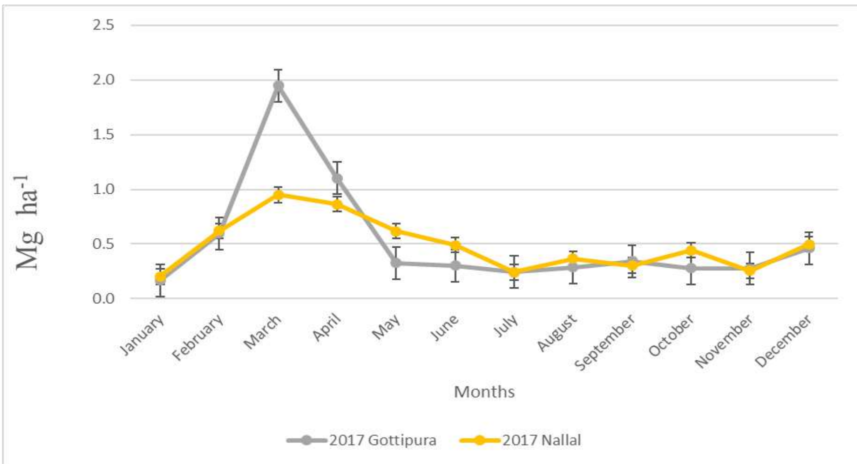

Fig 3. Monthly mean litter production of *D. Stocksii* in Gottipua and Nallal.

Seasonal variation in litter production showed a uni-modal trend with a distinct peak during the summer season (February-May).The collected litter from the litter traps was found to be dominated by leaf litter. Litter production followed similar pattern for both locations, with a major peak in March 2017.

Both in the case of Gottipura and Nallal, total litter and leaf litter fall pattern are significantly and positively correlated with maximum temperature and radiation. Positive correlation indicates that as the maximum temperature increases litter fall also increases. The linear mixed effect model (Ahirwal *et al.*, 2021) revealed a significant effect of precipitation on annual litter fall patterns, while aridity and precipitation significantly influence litter decomposition rate. Our study concluded that tropical forests have greater annual litter fall and k-values but subtropical forests have higher litter quality. Their study suggested environmental factors and forest types instead of litter quality in the Indian Himalayan Region mainly control litter decomposition. The outcome of the study will be useful to predict the forest carbon and nutrient cycle in future climate change scenarios.

Table 2. Correlation of litter production pattern of *D. Stocksii* with climatic parameters in Gottipura

Climatic parameters	Leaf (Mg ha^{-1})	Twig (Mg ha^{-1})	Total (Mg ha^{-1})
Rainfall	-0.365^{ns}	-0.072^{ns}	-0.365^{ns}
Maximum Temperature	0.672**	0.292^{ns}	0.673**
Minimum Temperature	0.193^{ns}	0.172^{ns}	0.194^{ns}
Radiation	0.629**	0.255^{ns}	0.630**

Ns non-significant; ** Significant at 0.01 level

Table 3. Correlation of litter production pattern of *D. Stocksii* with climatic parameters in Nallal

Climatic parameters	Leaf (Mg ha^{-1})	Twig (Mg ha^{-1})	Total (Mg ha^{-1})
Rainfall	-0.349^{ns}	-0.035^{ns}	-0.348^{ns}
Maximum Temperature	0.672**	0.380^{ns}	0.673**
Minimum Temperature	0.203^{ns}	0.283^{ns}	0.205^{ns}
Radiation	0.637**	0.325^{ns}	0.638**

Ns non-significant; ** Significant at 0.01 level

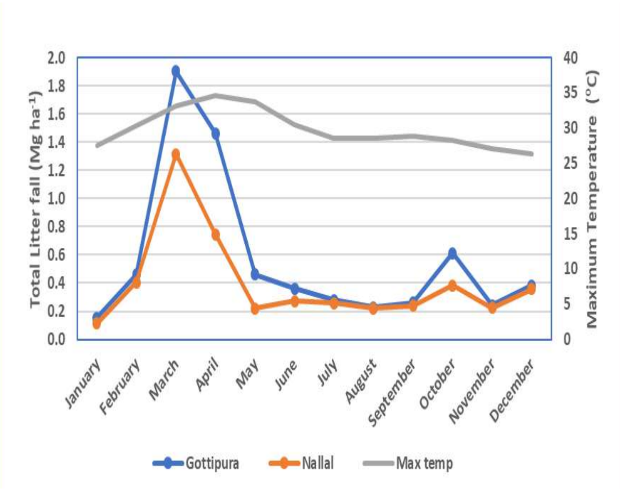

Fig 4. Total litter fall pattern of *D. Stocksii* at Gottipura and Nallal with respect to maximum temperature (^{o}C)

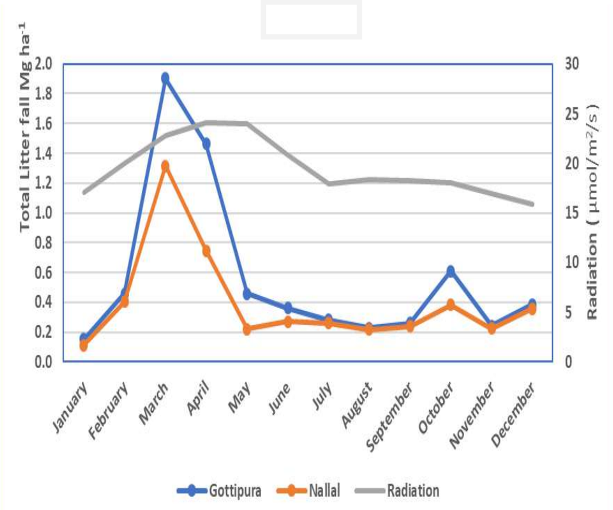

Fig 5. Total litter fall pattern of *D. Stocksii* at Gottipura and Nallal with respect to radiation

All nutrients except Ca in twig nutrients were found to be uninfluenced by climatic parameters. Calcium in twig is negatively influenced by maximum and minimum temperatures and radiation. Deb and Arunachalam (2005) demonstrated cell-wall degradation and nutrient release pattern in decomposing leaf litter *of Bambusa tulda Roxb.* and *Dendrocalamus hamiltonii Nees*. in bamboo-based agroforestry system in north-east India that calcium will be got released with cell wall decomposition undeterred by maximum and minimum temperatures and radiation.

Table 4. Correlation of leaf and twig nutrient contents of *D. Stocksii* with respect to climatic parameters

Leaf/twig	Nutrients	Rainfall	Max temp	Minimum Temp	Radiation
	N	-0.223^{ns}	0.263^{ns}	-0.1^{ns}	0.215^{ns}
	P	-0.371^{ns}	-0.363^{ns}	-0.554^{ns}	-0.385^{ns}
	K	0.573^{ns}	-0.214^{ns}	-0.003^{ns}	-0.206^{ns}
Leaf	Ca	-0.548^{ns}	-0.176^{ns}	-0.307^{ns}	-0.156^{ns}
	Mg	-0.51^{ns}	0.171^{ns}	-0.402^{ns}	0.144^{ns}
	Si	-0.345^{ns}	0.272^{ns}	-0.034^{ns}	0.268^{ns}
	B	0.372^{ns}	-0.398^{ns}	0.071^{ns}	-0.367^{ns}
	N	-0.171^{ns}	-0.211^{ns}	-0.504^{ns}	-0.217^{ns}
	P	-0.139^{ns}	-0.388^{ns}	-0.419^{ns}	-0.412^{ns}
	K	-0.009^{ns}	0.115^{ns}	0.095^{ns}	0.132^{ns}
Twig	Ca	-0.054^{ns}	-.819**	-.681*	-.810**
	Mg	-0.307^{ns}	-0.438^{ns}	-0.416^{ns}	-0.408^{ns}
	Si	0.156^{ns}	-0.533^{ns}	-0.152^{ns}	-0.48^{ns}
	B	0.168^{ns}	0.121^{ns}	0.349^{ns}	0.136^{ns}

ns non-significant; ** significant at 0.01 level

Table 5. Decay constant and time required for decomposition of various litter types for *D. stocksii* at 50 % and 90 % decomposition.

	k-value	$T_{0.50}$	$T_{0.9}$
Leaf litter	0.0097	71	515
Twig litter	0.0087	80	575
Total litter	0.0091	76	549
Filter paper	0.0028	248	1786

Table 6. Fitted equations for litter decomposition of *D. stocksii*

	Fitted equation	R^2
Leaf litter	$Y= e^{-0.0097t}$	0.986
Twig litter	$Y= e^{-0.0087t}$	0.973
Total litter	$Y= e^{-0.0091t}$	0.982
Filter paper	$Y= e^{-0.0028t}$	0.983

Litter decomposition

Mass remaining (of the initial mass), the instantaneous decay constant (k) for mass, the time required for 50 per cent ($t_{0.5}$) and 99 per cent ($t_{0.9}$) mass loss for *D. stocksii* litter decomposition study at Nallal is given in Tables 5 -6.

Leaf litter, twig litter and total litter followed near linear patterns of decomposition. In case of filter paper 0 to 85, days, it follows a normal pattern then 85 to 120 days, a stable pattern, and after 120 days, there is a faster rate of decomposition. In case of litter there is a steady decline upto 200 days for litter and gradual decline thereafter while the control showed more or less continuous declining trend. Macro-organisms such as earthworms, flies and snails are involved in the early process of decomposition; subsequently it is often the work of enzymes, bacteria and fungi that aid in the cycling of nutrients back into the soil (Terry, 1967). With time decomposing matter of litter i.e. declining substrate for microbes.

Nutrient Release Pattern

Table 7 Variation in contents of major elements (% nutrient remaining) in *D. stocksii* leaf litter retrieved at monthly intervals during decomposition at Nallal location.

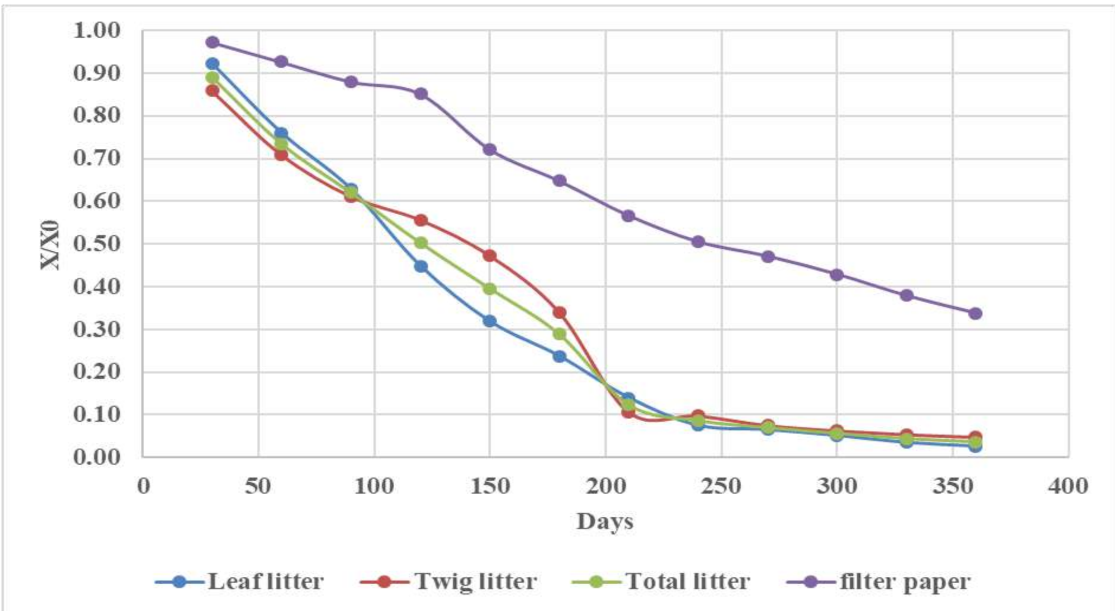

Fig 6. Fitted lines for litter decomposition of *D. stocksii*

Table 7. Variation in contents of major elements (% nutrient remaining) in *D. stocksii* leaf litter retrieved at monthly intervals during decomposition at Nallal location

Days	N	C	P	K	Ca	Mg	Si	B
30	102.0	95.9	0.0	0.0	109.2	55.5	162.4	8.8
60	84.6	61.8	0.0	0.0	80.8	46.1	189.8	3.1
90	76.1	53.5	79.9	0.0	78.7	32.4	185.9	14.1
120	53.3	39.1	18.9	0.0	56.5	23.2	78.3	4.3
150	47.9	31.8	8.0	0.0	47.1	26.4	35.0	2.5
180	30.1	19.6	8.8	0.0	19.9	12.6	65.6	9.3
210	15.3	9.9	15.6	0.0	13.9	8.3	34.0	3.5
240	8.2	4.9	5.9	0.0	7.6	4.7	16.9	0.9
270	7.4	3.8	7.9	0.0	5.6	3.4	15.3	1.0
300	5.8	2.6	4.4	0.0	4.0	1.9	17.4	1.7

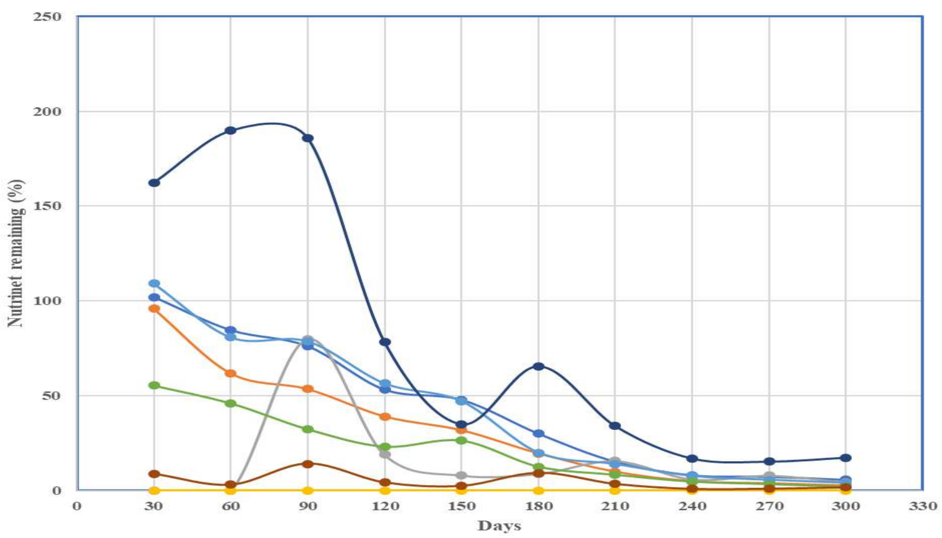

Fig 7. Variation in contents of major elements (% nutrient remaining) in *D. stocksii* leaf litter retrieved at monthly intervals during decomposition at Nallal location

The relative proportion of residual nutrient contents remaining in the leaf litter at the end of one-year period was highest for Si (17.4 %), N (5.8 %), P (4.25 %) and the least for K and B as 0 per cent and below detectable limits, respectively. The order of nutrient mineralisation was K>B>Mg>C>Ca>P>N>Si. Potassium, Boron, and Magnesium are highly mobile and move with water in the flow direction, while others are having slow mobility with water but may move with organic solvents. As silicon is with leaf cuticle, dissolution and movement will be very slow. Once the litter is put in place by the microbes of rhizosphere and mycorrhizae take care of its decomposition, mobility and absorption and movement in plants

Table 8. Variation in contents of major elements (% nutrient remaining) in *D. stocksii* twig litter retrieved at monthly intervals during decomposition at Nallal location

Days	N	C	P	K	Ca	Mg	Si	B
30	58.4	83.0	460.2	0.0	80.6	85.4	121.2	4.7
60	40.7	52.5	160.6	0.0	72.8	48.8	139.0	35.7
90	31.6	34.5	27.0	0.0	74.2	59.1	159.6	9.1
120	26.5	25.0	187.5	0.0	58.9	67.6	108.9	150.8
150	18.6	15.2	175.5	0.0	6.2	0.8	310.0	16.4
180	12.6	9.0	584.4	0.0	25.5	29.3	105.7	17.4
210	3.7	2.5	61.7	0.0	9.8	0.9	22.6	3.3
240	3.3	2.1	15.2	0.0	9.6	11.9	21.4	3.0
270	2.4	1.4	26.6	0.0	7.9	9.0	10.4	10.3
300	1.9	1.1	50.5	0.0	8.0	8.8	9.1	1.6

The relative proportion of residual nutrient contents remaining in twig litter at the end of one-year period was highest for P (50.5 %) B (9.6 %), Si (9.1) and least were for K and Ca 0 percent and below detectable limit respectively. The order of nutrient mineralisation was K>Ca>N>C>Mg> B>Si>P.

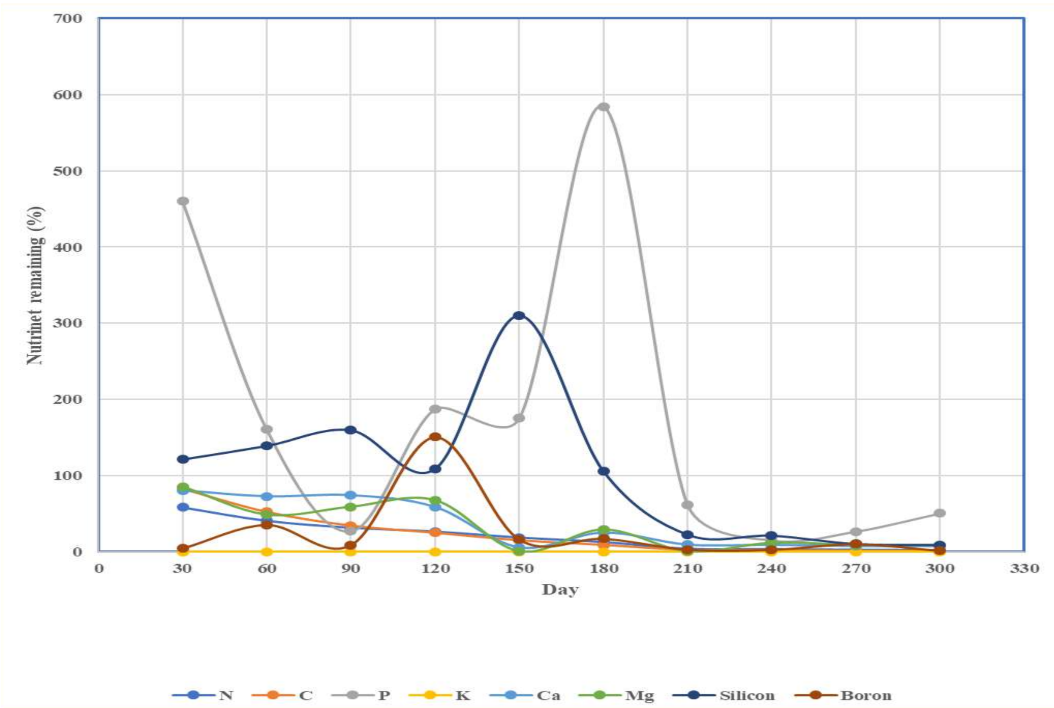

Fig 8. Variation in contents of major elements (% nutrient remaining) in *D. stocksii* twig litter retrieved at monthly intervals during decomposition at Nallal location

Table 9. Variation in contents of major elements (% nutrient remaining) in filter paper kept as control.

Days	N	C	P	K	Ca	Mg	Si	B
30	160.2	91.7	75.1	264.8	133.4	217.8	51.2	0.0
60	117.1	89.9	59.7	167.5	140.8	157.4	74.9	0.0
90	33.4	89.4	74.6	228.0	109.9	185.2	52.9	0.0
120	73.4	80.4	40.9	180.7	51.8	103.7	52.4	0.0
150	49.6	67.6	48.6	109.0	54.0	92.9	35.9	0.0
180	52.6	58.0	45.1	193.6	74.8	126.7	29.8	0.0
210	44.3	52.3	62.1	128.2	64.8	80.7	27.4	0.0
240	49.9	47.8	50.3	63.3	45.2	118.5	99.0	0.0

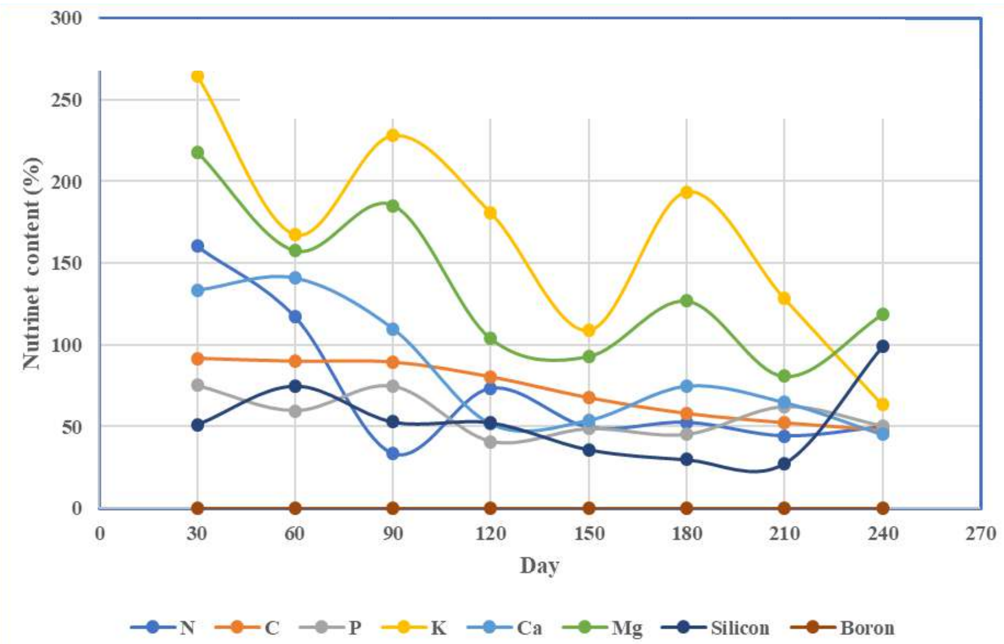

Fig 9. The per cent nutrient remaining in the filter paper retrieved at monthly intervals during decomposition at Nallal location.

The relative proportion of residual nutrient contents remaining in filter paper at the end of one year period was highest for Mg, Si and least was for B, 0 percent or below detectable limit respectively. The order of nutrient mineralisation was B>Ca>C>N >P>K>Si>Mg.

It was found that both types of litter and filter paper had an initial rapid phase of decomposition followed by a slower phase. The increase in nutrient content can be attributed to rapid mineralisation by microbes, which utilize most of the labile carbon forms as their energy sources and decomposes the easily degradable fractions in the litter. As the easily decomposable forms are exhausted, more resistant microbes takes over the decomposition process, which essentially reduces the reactions rates. Olson (1963) demonstrated that when starting with the same leaf litter type, an increase in or an increase in leaf litter types, will both result in an increase in the rate of litter break down and suggested that an increase in leaf litter types (species) will result in higher rates of decomposition, comparable to an increase in detritivores.

Data analysis reveals that the percentage of nutrients remaining in the little bag increases. A possible reason for this can be leaching of nutrients from soil to litter bag. Soil contains many unavailable phosphates. This is due to the liberation of unavailable P with silicon and organic phosphates from soil under the influence of microbes and organic acids. Phosphorus and silica show a similar pattern. Organic acid will be released during decomposition. So, Silicon and Phosphorus remaining in organic form in the soil also may be solubilised. This can also be a probable reason for increased nutrient content.

The carbon to nitrogen ratio of leaf litter was approximately 80:1 during initial months of decomposition for both types of litter and it reduced to 39:1 and 32:1for leaf litter and twig litter respectively after ten months of decomposition.

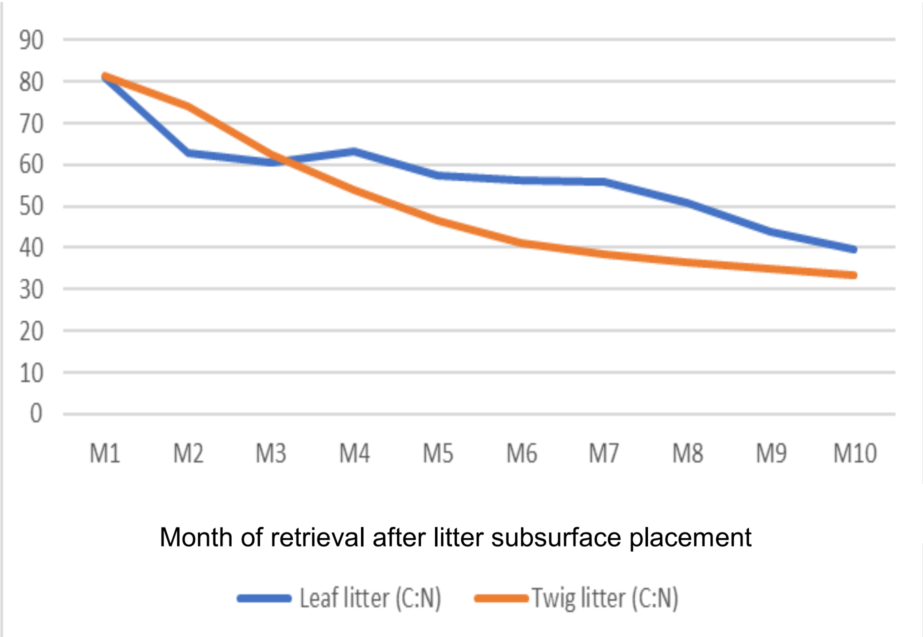

Fig 10. C:N ratio of litter during decomposition process of *D. stocksii*

Conclusion

The current research investigation looked at litter production, decomposition and nutrient release dynamics of *D. stocksii*. The standard litter trap approaches were used to study litter production and breakdown. Decomposition and nutrient release dynamics of bamboo litter will be useful in under-standing the role of bamboo in soil improvement, soil reclamation and habitat restoration efforts. This study was conducted in semi-arid tract of Karnataka.

Litter production was found continual, however, the amount generated fluctuated depending on the season and month. The concentrations of nutrients in monthly litter samples varied per nutrient. Seasonal variation in litter production, with significant peaks during the winter season and the middle of the rainy season. Peak litterfall output occurred during the cool-dry season (February-May). Leaf litter predominated among the litter gathered from the litter traps. Litter production in both places followed a similar pattern. Litter fall pattern was found significantly and positively correlated with maximum temperature and radiation. The order of mineralisation and the relative proportion of residual nutrient concentration was also estimated. The C:N ratio during decomposition of litter during initial and subsequent months provides better under-standing of nutrient release pattern.

Acknowledgement

I gratefully acknowledge the funding agency, the University Grant Commission (UGC) of the Government of India, for providing financial support, to complete my work, in the form of UGC NET-JRF/SRF. The funding and staff support through ICFRE project by Dr N. Ravi, Scientist, Institute of Wood Science and Technology is also thankfully acknowledged. I also thank for the time and effort taken by Dr. Sunanda C, Statistical Consultant on giving suggestions, which helped in the improvement of statistical data analyses and interpretation.

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