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NUTRIENT LOCKING IN BIOMASS AND SOIL OF *MUNROCHLOA RITCHIEI* AND OCHLANDRA *SETIGERA*, TWO ENDEMIC BAMBOO SPECIES OF WESTERN GHATS

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ABS**TRACT**
The present study was conducted to determine nutrient locking in biomass and soil of *Munrochloa ritchiei* and *Ochlandra setigera* natural populations situated in the Nilambur Forest Division of Kerala. The storage of N, P, K, Ca and Mg in the standing biomass of the *M. ritchiei* was 196.5±87.8, 1988.1±902.9, 977.6±542.1, 48.1±15.8 and 23.2±8.7 kg ha^{-1}, respectively. The soil nutrient status under the bamboo stand indicated that the total N, P and K content of the soil up to a depth of 60 cm was 30.3±1.3, 81.03±4.01 and 22.97±1.30 t ha^{-1} respectively and that of Ca and Mg was 2.775±0.634 and 1.92 ±0.34 t ha^{-1} respectively. Studies on nutrient status of the plant and soil revealed that the total nutrient stored in the plant parts was in the order Stem > Rhizome > Leaves+ Branches> Root. The nutrient storage in the standing biomass stock was in the order P > K > Ca > N > Mg. In *O. setigera,* the total nutrients locked in the biomass components were 306.5±116.2 (N), 2085.9±698.0 (P), 658.8±228.7 (K), 52.1±16.1 (Ca) and 38.4±6.8 (Mg) kg ha^{-1}. The total N, P, K, Ca and Mg storage of the soil was 21.671±2.238, 83.308±5.106, 7.902±0.148, 1.598±0.702 and1.132±0.269 t ha^{-1} respectively.

Key words: Bamboos, Nutrient status, soil nutrients, aboveground biomass, belowground biomass

INTRODUCTION
India is endowed with abundant resources and species diversity of bamboos and endemism in Indian bamboos is of very high order. More than 50% of the bamboo species found naturally occurring in India is endemic to the country. Southern Western Ghats of India is known for its bamboo diversity with a high degree of endemism. Out of the 22 naturally occurring bamboo species in this area, 17 are reported to be endemic. *Munrochloa ritchiei* (Munro) M. Kumar &Ramesh and *Ochlandra setigera* Gamble are perennial, gregarious sympodial bamboo species endemic to the Western Ghats. *M. ritchiei* is distributed in northern Kerala, Karnataka, and Maharashtra, growing up to an altitude of 200-1100 m. This genus is represented only with a single species and endemic to Western Ghats of India (Kumar and Ramesh 2008). Various uses of this species include the furniture, lathi making, support for betal plants, for making baskets, umbrella handles and walking sticks, etc. It is marked as conservation dependent as per the IUCN standards and needs appropriate conservation and management strategies. *Ochlandra setigera* Gamble is a small straggling bamboo species with culms reaching a height of 5−8 m, a diameter of 1.5−2.2 cm, and an internodal length of 23−35 cm. Its distribution is restricted to Malappuram and Palakkad districts of Kerala state and in Gudallur of Tamil Nadu at elevations of 600−1000 m (Kumar 2011).

Bamboos can play a major role in maintaining and improving the nutrient status of the soil. Most of the bamboo plantations are located in nutrient- poor marginal lands and bamboo can grow in relatively nutrient- poor soil and efficiently make use of the available nutrients and build up the fertility of the soil around the clumps (Singh and Singh 1999). Bamboo plantation with short rotations coupled with intensive management and rapid growth rate are also characterized by high rates of nutrient removal in the harvested biomass (Kumar *et al.* 2005). The associated high nutrient export potential, especially with whole culm harvesting may deplete the nutrient capital in the system. Estimating the bamboo biomass and nutrients can help in the determination of nutrient removal through harvest and also in formulating suitable nutrient management strategy for sustainable production in natural strands as well as plantations (Upadhyaya *et al.* 2008). Studies relating the nutrient status in biomass and soil in bamboos are essential but studies are lacking in many bamboo species. Earlier studies on estimation of the nutrient status of the bamboo stand are based on the leaf analyses (Kleinhenz and Midmore 2001). The nutrient inputs from other bamboo components such as culms, branches, and roots were ignored. Hence, the present study was framed to estimate the nutrient stocks in biomass and soil of two bamboo species *M. ritchiei* and *O. setigera.*

MATERIALS AND METHODS
The present study was conducted in the natural populations of *Munrochloa ritchiei* and *Ochlandra setigera* located inthe Nilambur Forest Division (11° 34' 57.6'' N and 76° 15' 32.6' E) of Kerala. *Munrochloa ritchiei* is naturally distributed at Nellikutha Forest Station of Vazhikadavu Forest Range and that of *Ochlandra setigera* (*Neomicrocalamus setigerus* (Gamble) is located at Vazhikadavu Forest Range. The study area has a warm humid climate, receiving rain from the Southwest and

Northeast monsoons. Monthly averages of daily maximum temperatures during the study ranged from 29.4 to 35.6ºC with the hottest period in March and the minimum temperature ranged from 20.0 to 25.5ºC with the lowest temperature in January. Average monthly rainfall ranged from 0.0−459.7 mm with the highest rainfall occurring in June. Relative humidity ranged from 58−85% with higher values during June and July. As the distribution of both bamboo species was scattered, three plots of 25 m x 25 m dimension, which contains at least 40 clumps were selected. The destructive sampling method was employed for the estimation of biomass of both the bamboo species. Three bamboo clumps were destructively sampled for each species. After harvesting, samples of above and belowground plant parts were divided into culm, branch+leaf, rhizome and root and their respective fresh weight was taken in the field in five replications. Sub-samples were oven-dried at 65 °C to a constant weight. Oven dry weight was scaled up to compute biomass per hectare basis.

To determine the nutrient concentration in biomass components, five samples each of the components were collected per plot. The samples for nutrient analysis were oven-dried to constant weight at 70°C. The samples were ground in a Wiley mill and kept for analysis. Meanwhile, the soil samples were taken from the pits dug up to 60 cm depth at three different levels (0-20, 20-40 and 40-60 cm) at the centre of sample plots. The collected soil samples were labeled, tagged, and brought to the laboratory for analysis. The air-dried samples were sieved through 2 mm sieve and kept for analysis. Nutrient concentration of biomass components and soil was determined on sub-samples in five replications (3x5= 15 replications). Nitrogen was estimated using Euro vector (EA 3000) CHNS Elementar analyzer and phosphorus by using Skalar San++ Auto analyzer. Potassium was estimated using flame photometer (ELICO) and calcium and magnesium by Atomic Absorption Spectrophotometer (VARIAN) (Jackson 1973).

The plant nutrient status of bamboo was calculated as the product of nutrient concentration in different clump components and their biomass yield. The nutrient storage of the soil was estimated as the product of nutrient concentration, bulk density and soil depth. The bulk density was determined as per the method suggested by Blake and Hartge (1986)

Statistical analysis

One way analysis of variance conducted to compare the treatments and the means were compared using the least significant difference.

RESULTS

Standing stock biomass

The total standing stock biomass of *M. ritchiei* was 70.6±37.9 t ha^{-1} and it was distributed in the components as leaves+branch (6.5±1.1 t ha^{-1}), stem (35.3±25.5 t ha$^{-1)}$, rhizome (30.3 ±15.7 t ha^{-1}), root (1.4±1.0t ha^{-1}). The distribution of biomass in different components of *O. setigera* was, stems (40.0±12.8 t ha^{-1}), leaves+branches (6.5±1.1t ha^{-1}), rhizome (30.3±15.7t ha^{-1}) and root (1.4±0.8 t ha^{-1}) and the total standing stock biomass was 73.4±30.3 t ha$^{-1.}$ In both the species the biomass accumulation was highest in aboveground components. The rhizome also significantly contributed to the total biomass but the contribution of roots was nearly 2% only.

Nutrient storage in bamboo stands

Perusal of the results indicated that *M. Ritchie and O. setigera* were able to accumulate substantial amount of nutrients in standing stock biomass. Nutrient concentration in biomass components of *M. ritchiei* varied significantly (p=0.01). The nutrient with the highest concentration was K and its value ranged from 0.44 to 0.91%. The nitrogen concentration ranged from 0.10 to 0.43%, Pfrom0.11 to 0.26%, Ca from 0.02 to 0.09% and Mg from 0.03 to 0.22% (Fig. 1).With regard to biomass components,leaves branches recorded the highest concentration of K, Ca and Mg. The highest N concentration was recorded in culms and P was at maximum concentration in rhizomes. Except for P, the roots recorded the lowest concentration of the nutrients.

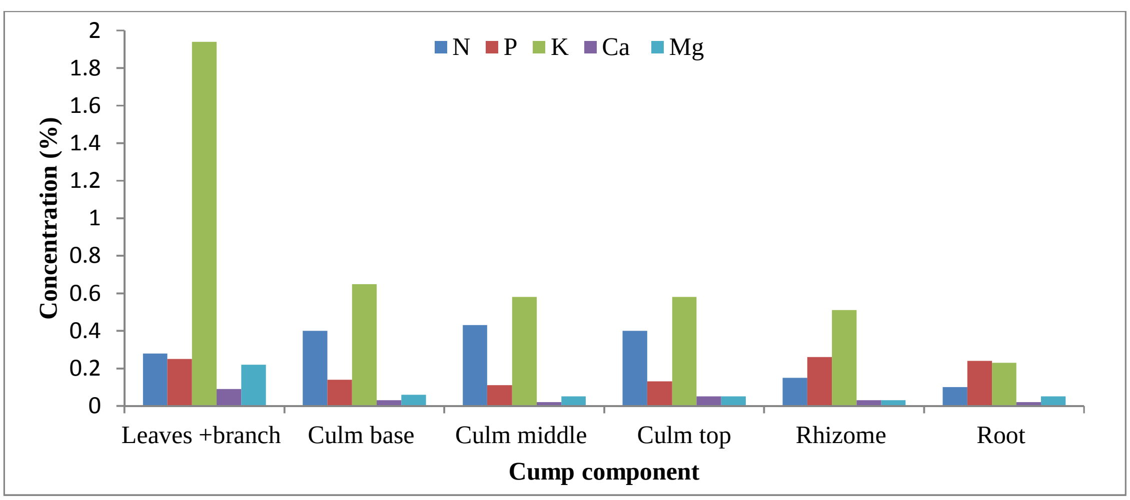

FIGURE 1. Nutrient concentrations in the clump components of *Munrochloa ritchiei*

The nutrient locking in biomass components of *M. ritchiei* also showed significant variation (p=0.01). The total storage of N, P, K, Ca and Mg in the standing stock biomass of the *M. ritchiei* was 196.5±87.8, 198.8±90.9, 977.6±542.1, 48.1±15.8 and 23.2±8.7 kg ha^{-1}, respectively (Table 1). The nutrient storage in biomass components declined in the order Stem> Rhizome> Leaves+ Branches> Root and that of nutrients with some exceptions was K>P> N>Ca>Mg. The P content of the rhizome was comparable to that of stems.

TABLE 1. The nutrient storage in the standing biomass stock of *Munrochloa ritchiei*

Nutrient	Storage (kg ha^{-1}) in				
	Stem	Leaves+branches	Rhizome	Root	Total
N	108.0±31.5b	34.3±4.4b	52.8±13.5b	1.5±1.0c	196.5±87.8a
P	94.9±32.8b	10.3±13.3d	90.1±20.2c	3.6±2.3e	198.8±90.9a
K	748.0±295.1a	50.2±6.5c	175.9±48.5b	3.5±2.3d	977.6±542.1a
Ca	34.7±13.0a	2.5±0.3c	10.6±3.7b	0.3±0.2d	48.1±15.8a
Mg	7.7±5.1b	4.2±0.5d	10.6±4.7c	0.8±0.5e	23.2±8.7a

Values with same superscript within a row did not differ significantly
The values given are mean and standard deviation

The nutrient concentration in various components of *O. setigera* was slightly lower compared to *M. ritchiei*. In *O. setigera,* the highest K concentration was observed in the rhizome and it was the nutrient in the highest concentration in all biomass components. Nitrogen concentration in the biomass components ranged from 0.12 to 0.67 % and the highest concentration was recorded in culm top whereas the highest P concentration (0.40%) was recorded in the rhizome. Ca and Mg concentration was observed in highest concentration in leave+culm (Fig. 2). The roots recorded the lowest concentration of the all the nutrients. Analysis of variance revealed significant difference nutrient concentration of N, Ca, Mg at one per cent level and P at five per cent level and no significant differences was observed in K among the biomass components.

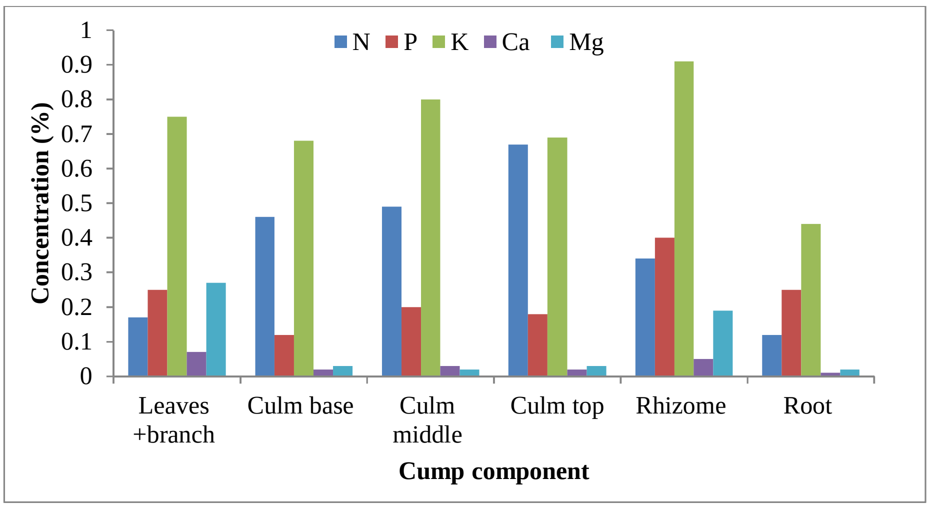

FIGURE 2. Nutrient concentrations in the clump components of *Ochlandra setigera*

Nutrient storage in standing stock biomass of *O. setigera* also varied significantly (p=0.01) among the clump components (Table 2). Total nutrients locked in the biomass components was 306.5±116.2 (N), 2085.9±698.0 (P), 658.8±228.7 (K), 52.1±16.1 (Ca) and 38.4±6.8 (Mg) kg ha^{-1}. With regard to components, nutrient storage in the standing biomass was in the order Stem> Rhizome> Leaves+ Branches> Root and that of nutrients was K>N>P>Ca>Mg.

TABLE 2. Nutrient storage in the standing biomass stock of *Ochlandra setigera*

Nutrient	Biomass components (kg ha^{-1})				
	Stem	Leaves+branches	Rhizome	Root	Total
N	137.2±35.9^{b}	39.9±16.9^{c}	118.8±69.6^{b}	10.7±5.4^{c}	306.5±116.2^{a}
P	123.3±32.3^{b}	33.3±±14.1^{c}	49.1±28.8^{c}	2.8±1.4^{d}	208.6±69.8^{a}
K	366.0±95.8^{b}	87.9±37.2^{c}	193.9±113.7^{b}	10.9±5.5^{d}	658.8±228.7^{a}
Ca	35.7±9.4^{a}	3.4±1.4^{c}	12.8±7.5^{b}	0.2±0.1^{c}	52.1±16.1^{a}
Mg	23.8±11.2^{a}	6.5±2.7^{b}	7.3±4.3^{b}	0.8±0.4^{c}	38.4±6.8^{a}

Values with same superscript with in a column are homogenous
The values given are mean and standard deviation

Soil nutrient concentration and storage

The quantification of concentration and stock of nutrients in the soil under bamboo stands also showed marked differences with depth. Table 3 depicts the N, P, K, Ca and Mg concentrations and nutrient storage at different soil depths of *M. ritchiei*. Except for P and K, the nutrient concentration decreased with depth of the soil. The concentration of P and K declined in the order 0-20 cm > 40-60 > 20-40 and 20-40 cm> 40-60 cm> 0-20 cm, respectively. Results also indicated that P was the nutrient in the highest concentration in the soil followed by N and the least concentration was recorded for Mg. Statistical analysis revealed the significant differences in concentrations of N, P and K at 5% level and Ca and Mg at 1% level among soil depths.The total N, P and K stock in the soil was 30.3±1.30, 81.03±4.01 and 22.97±1.30 kg ha^{-1} respectively and that of Ca and Mg was 2.78±0.63 and 1.92±0.34 t ha^{-1} respectively which reveals that the decline in the magnitude of nutrient stock was in the order P >N> K> Ca >Mg. Analysis of variance revealed significant differences in concentrations of N, P and Mg at different soil depths at 5% and K and Ca at 1% level.

TABLE 3. The soil nutrient concentration and stock of *Munrochloa ritchiei* stand

Soil depth	0-20 cm		20-40 cm		40-60 cm		Total nutrient storage (t ha^{-1}
Nutrient	%	Storage t ha^{-1}	%	Storage t ha^{-1}	%	Storage t ha^{-1}	
N	0.430±0.026^{a}	10.67±0.65^{a}	0.422±0.023^{b}	10.48±0.56^{a}	0.369±0.020^{b}	9.16±0.49^{b}	30.3±1.30
P	1.186±0.085^{a}	29.41±2.10^{a}	1.033±0.054^{b}	25.62±1.35^{b}	1.048±0.041^{b}	25.99±1.02^{b}	81.03±4.01
K	0.267±0.021^{b}	6.63±0.52^{b}	0.371±0.020^{a}	9.21±0.51^{a}	0.287±0.034^{b}	7.13±0.85^{b}	22.97±1.30
Ca	0.064±0.018^{a}	1.58±0.45^{a}	0.032±0.003^{b}	0.79±0.09^{b}	0.016±0.018^{b}	0.40±0.20^{c}	2.78±0.63
Mg	0.039±0.005^{a}	0.96±0.12^{a}	0.024±0.010^{b}	0.59±0.24^{b}	0.015±0.009^{b}	0.37±0.22^{b}	1.92 ±0.34

Values with same superscript with in a column are homogenous
The values given are mean and standard deviation

The soil nutrient concentrations and stock of *O. setigera* stand also decreased with soil depth (Table 4). The concentration of N was in the order 20-40 cm > 0-20 cm> 40-60 cm at different soil depths. The concentration of P was in the order 40-60 cm> 20-40 cm > 0-20 cm; that of K was 20-40 cm >0-20 cm>20-40 cm and that of Ca and Mg was 0-20 cm > 40-60 cm > 20-40 cm. Analysis of variance revealed significant differences in N, K (p=0.01) Ca and Mg concentration (p=0,05). The perusal of nutrient stocks under the bamboo stand indicated that the total N, P, K, Ca and Mg stock was 21.67±2.24, 83.31±5.11, 7.90±0.15, 1.60±0.70 and 1.13±0.27 t ha^{-1} respectively. The nutrient storage in the soil was in the order P > N> K >Ca > Mg. Analysis of variance revealed significant differences in stock of N and K at 1% and Ca and Mg at 5% level.

TABLE 4. The soil nutrient concentration and stock of *Ochlandra setigera* plantation

Soil depth	0-20 cm		20-40 cm		40-60 cm		Total nutrient storage (t ha^{-1}
Nutrient	%	Storage t ha^{-1}	%	Storage t ha^{-1}	%	Storage t ha^{-1}	
N	0.385±0.071^{a}	9.847±1.808^{a}	0.413±0.026^{a}	10.583±0.654^{a}	0.048±0.007^{b}	1.241±0.186^{b}	21.67±2.24
P	1.034±0.042	26.479±1.079^{a}	1.068±0.121^{c}	27.341±3.092^{a}	1.152±0.124	29.488±3.167^{a}	83.31±5.11
K	0.092±0.004^{b}	2.355±0.102^{b}	0.125±0.009^{a}	3.191±0.242^{a}	0.092±0.000^{b}	2.355±0.000^{b}	7.90±0.15
Ca	0.047±0.025^{a}	1.215±0.639^{a}	0.003±0.002^{b}	0.070±0.048^{b}	0.012±0.004^{a}	0.314±0.094^{a}	1.60±0.70
Mg	0.025±0.012^{a}	0.640±0.305^{a}	0.006±0.002^{b}	0.144±0.043^{b}	0.014±0.002^{b}	0.348±0.058^{a}	1.13±0.27

Values with same superscript with in a column are homogenous
The values given are mean and standard deviation

DISCUSSION

Bamboos with faster growth and biomass production play an important role in ecosystem dynamics. The beneficial role of bamboo planting includes recovery of soil physio-chemical properties (Embaye *et al*. 2005; Shiau *et al*. 2017), soil redevelopment (Singh and Singh 1999) and soil nutrients (Shiau *et al*. 2017; Borisade and Odiwe 2018). Yang *et al.* (2014) opined that the rapid growth and abundance of bamboo may contribute to nutrient pumping by which nutrients leached deep into the soil are deposited at the surface as bamboo litterfall (Christanty *et al.*1997). Shanmughavel *et al.* (2001) had stated that the bamboo is a heavy nutrient feeder among the grass family.

Nutrient availability is the most important soil chemical parameter that determines the growth and yield of bamboo species. Nutrients uptake is mainly for their growth and development and a portion of these nutrients is accumulated in the plant body. The studies on nutrient locking in biomass and soil are scanty in most of the bamboo species. Plant nutrient levels are commonly expressed as nutrient concentrations. In the present study with some exceptions, the concentration of nutrients declined in different biomass components of *M. ritchiei* and *O. setigera* in the order K>N>P>Mg>Ca. Rai *et al.* (2013) had reported that the order of decline in nutrient concentration was K>N>Mg>Ca>P in all the biomass components of *Meloccana baccifera* and similar order of decline was expressed in 6 year old *Bambusa bamboos* plantation (Shanmugavel and Francis 1997).Similar to our study, a high K concentration followed by N was observed in all these studies. Potassium is not the part of any structural component of plants and as a soluble ion in the plant sap, it is essential for the activity of plant enzymes. Itis a nutrient known for luxury consumption, those plants absorb in amounts above their requirements if readily available. Kumar *et al.* (2005) had reported that the average N, P and K removals through culm harvesting were 9.22, 1.22 and 14.4 kg per clump respectively for *Bambusa bambos.*

In the present study, the maximum amount of all nutrients per hectare in the biomass components of both bamboo species was in the order stem> Rhizome>leaves+culm> root. Stem weight being larger than other components of bamboo biomass it dominated. Whereas, in large clump forming *Bambusa bambos* the order was culms> branches > rhizome > leaves (Shanmugavel and Francis 2002). This might be due to the species-specific variation in morphology and soil characteristics and *B. bambos* branches contribute significantly to total biomass.

Studies on nutrient cycling of bamboo stands suggest an active nutrient cycling by quick and vigorous bamboo growth and litter production, decomposition and nutrient release improve the soil fertility (Christanty *et al.* 1997; Singh and Singh 1999, Jijeesh and Seethalakshmi 2016 & 2018). Chemical properties of soil play a major role in crop production. Litter production, decomposition in both bamboo species are already studied (Thomas *et al.* 2014 & 2016). Soils are not just to supply adequate nutrients alone but the nutrients to be in proper balance. Species- specific variation was obvious in the soil nutrient storage under bamboo stands. *In M. ritchiei* 70% N, 68% P, 69% K and 81% Mg was stored at a depth of 0-40 cm but 86% Ca was stored between the depth 0-20 cm. Whereas, in *O. setigera* 94% N, 65% of P, 70% K and 69% Mg was recorded in the 0-40 cm layer. Similar to *M. ritchiei* 76% of Ca was present in 0-20 layer. In *M. ritchie*, N, Ca and Mg storage decreased with the increasing soil depth whereas, such trend was absent *in O. setigera*. Compared to *M. ritchiei*, the highest nutrient storage was observed in *O. setigera*. However, the K storage was slightly higher in *M. ritchiei* which was nearly 1.5 times more in comparison to *O. setigera*. About the nutrient locking in soil, Naugraiya (2015) had reported C, N, P and K accumulation was 272.28 q ha^{-1}-1,321.96 kg ha^{-1}, 8.89 kg ha^{-1} and 234.95 kg ha^{-1} respectively in 11 year old *Dendrocalamus strictus* which was lower compared to the present study. However, their study was confined to a depth of 30 cm only. Hariprasanth *et al.* (2014) reported a considerable improvement in available nitrogen, available phosphorus, available potassium and organic carbon status in *Bambusa vulgaris* plantation. *Tang et al.* (2016) had reported that N stock in Moso bamboo forests were comparable with Chinese forests. In the present study also most of the nutrients were concentrated within the upper layer, where almost all bamboo roots are found (Rui *et al.* 1999).

CONCLUSION

In the present study we investigated the nutrient storage in biomass and soil of two endemic bamboo species of Western Ghats Overall, it can be concluded that both the bamboo species accumulate considerable quantity of nutrients in their biomass and soil. The nutrient accumulation was the highest in the shoots in both the species. Species-specific variations were obvious in nutrient storage.

RECOMMENDATION

From the study it was obvious that both bamboo species can accumulate considerable nutrients in the biomass and soil contributing to the carbon sequestration and they can play a major role in global climate change mitigation. Since O. setigera and M. ritchiei are facing serious threats to their existence in their natural habitat. Measures are to be initiated for the conservation and cultivation of these species.

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