Tropical Ecology **41**(2): 225-232, 2000 ISSN 0564-3295

Assessment of mineral content of tree leaf litter of Nokrek biosphere reserve and its impact on soil properties

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Abstract: In the present investigation the leaf litter of eighteen dominant tree species of Nokrek biosphere reserve, Meghalaya, were studied for their natural chemical reserves and physical characteristics. The litter of most of the tree species had carbon content between 34.2% and 49.5%. The ash content varied from 2.2% to 24.0%. Leaf litter of almost all the species showed the dominance of divalent cations (Ca^{++} and Mg^{++}) over monovalent (Na^+ and K^+). Nitrogen and phosphorus contents ranged 1.6 - 2.7% and 0.34 - 0.62%, respectively. Further, the impact leaf litter addition of selected species on soil physico-chemical properties was evaluated. The higher dose of leaf litter to soil was found to be more effective in improving soil properties than the lower dose.

Resemen: En la presente investigación el mantillo foliar de dieciocho especies arbóreas dominantes de la reserva de la biosfera Nokrek, Meghalaya, fue estudiado en terminos de sus reservas químicas naturales y sus características fisicas. El mantillo de las mayoría de las especies arbóreas tuvo contenidos de carbono de entre 34.2% y 49.5%. El contenido de cenizas varió de 2.2% a 24.0%. El mantillo de casi todas las especies mostró una dominancia de los cationes divalentes (Ca^{++} y Mg^{++}) sobre los monovalentes (Na^+ y K^+). Los contenidos de fósforo y nitrógeno variaron entre 1.6 – 2.7%, y 0.34 – 0.62%, respectivamente. Además se evaluó el impacto de la adición de mantillo foliar de algunas especies seleccionadas sobre las propiedades fisico-químicas del suelo. Se encontró que la dosis más alta de mantillo foliar en el suelo fue más efectiva en el mejoramiento de las propiedades del suelo que la dosis más baja.

Resumo: A folhadao de dezoito espécies arbóreas dominantes na reserva da biosfera de Nokrek em Maghalaya foi estudada na presente investigação quanto à sua reserva química e às suas características físicas. A folhada da maior parte das espécies arbóreas apresentavam um teor de carbono entre os 34,2% e os 49,5%. O teor em cinzas situou-se no intervalo 2,2% e os 24,0%. Quase toda a folhada das árvores mostrou uma dominância de catiões bivalentes (C^{++} e Mg^{++}) em relação aos monovalentes (Na^+ e K^+). Os teores em azoto e fósforo variaram entre os 1,6 – 2,7% e os 0,34 – 0,62%, respectivamente. O impacto da adição de folhada de espécies seleccionadas nas propriedades fisico-químicas do solo foram avaliadas. A adição de uma maior quantidade de folhada ao solo mostrou-se mais efectiva na melhoria das propriedades do mesmo do que uma menor quantidade.

Key words: Ash content, leaf litter, mineral content, Nokrek biosphere, organic carbon.

Introduction

The Nokrek Biosphere reserve is situated in the district of Garo-hills in the state of Meghalaya under sub-Himalayan region. The Garo-hills forms the western region of Meghalaya and lies between 25° 9' and 26° 1' N latitude and 89°, 49' and 91° 2' E longitude with altitude ranging from 300 m to 1400 m above the mean sea level. The total area of the biosphere is about 80 sq. km with 60 sq. km being the core area. The area may be characterised as a close cluster of hills ranging from 600 m to 1200 m height and supports a wide variety of moist tropical forest species.

Working on phyto-edaphic nature of the biosphere, it is noticed that a large chunk of the biosphere's soil system is mechanically composed of high portion of sands and silica. On the other hand, the integrating agents in the soil system like liming materials, energy materials etc. are relatively less. Under the condition, the status of the soil may be described as ecologically very fragile. The next vital aspect of the biosphere is its climatic conditions. Climatically, the region falls under typical tropical climate with high rainfall, high humidity and high temperature (temperature ranges from 12°C in winter to 30.4°C in summer months). It is usually stressed that under moist tropical environment a large quantity of valuable minerals are locked up in the leaves and other parts of the plant body, whereas, its soil remains poor in energy materials owing to quick oxidation by high temperature and simultaneous leaching of minerals due to heavy precipitation. In such natural conditions of Nokrek biosphere, the role of the mineral components is very pivotal not only in the maintenance of bio-physico-chemical matrices of its environment but also in their conservation.

Mineral studies on leaf litter were reviewed by McClaugherty *et al.* (1985); Berg (1980); Blair *et al.* (1990); Hall *et al.* (1992); Tiessen (1994); Veldkamp *et al.* (1994); Keenan *et al.* (1995); Byard *et al.* (1996); Bashkin *et al.* (1998) and Gonzales & Xzou (1999). In India, the works of Kaul *et al.* (1979); Ghosh *et al.* (1980); Rai & Proctor (1986); Sharma & Ambasht (1987); George & Varghese (1990); Raizada & Srivastava (1991); Tandon *et al.* (1991); Singh *et al.* (1993); Toky & Singh (1993); Mishra *et al.* (1994); Tripathi & Singh (1995); Varshney & Garg (1996); Rawat & Singh (1998); Roy (1999); Jha *et al.* and Sharma *et al.* (2000) deal with the subject.

Plant as such is a great intermediary through which animals and man derive their essential minerals in complex form. Thus, the minerals not only maintain the normal physiological activities of the biota but their role in the soil system is also noteworthy. In the present investigation an attempt has been made to assess the mineral reservoir of a few litters of dominant tree species growing in Nokrek biosphere reserve along with their efficacious impact on in-situ-soil system. The study may be of practical value in biosphere management/conservation.

The study sites within the biosphere reserve area are mainly characterised by a dense cluster of hills of highly undulating topography and support a wide variety of tropical forest species. These hills are commonly called `Giri' prefix with local names and possess innumerable streams and springs, which form the perennial drainage system for the area. The major hill slopes face north to south and finally end up in Brahmputra. The leaf litter under the study had been collected from the dominant tree species are distributed on these hills. *Lithocarpus elegans* (Bl.) Soepadmo and *Quercus semiserrata* Roxb. on Khakizagiri, *Q. leucotrichophora* A. Camus; *Macaranga denticulata* (Bl.) Muell.-Arg. and *Schima wallichii* (DC.) Korth. on Rongma-faromgiri, *Sterculia villosa* Roxb. ex DC. and *Polyalthia simiarum* Buch. Ham. ex Hook. on Rekmangiri, *Persea duthiei* (Hook. f.) Kosterm. on Darengiri, *Terminalia bellirica* (Gaertn.) Roxb.; *Ficus laevis* Blume and *Persea glaucescens* (Nees) Long on Rongasigiri, *Duabanga grandiflora* (Roxb. ex DC.) Walp. on Dona-adugiri, *Engelhardia spicata* Lesch. ex Blume on Anchhigiri, *Shorea robusta* Gaertn. f. on Nodongiri, *Stereospermum chelonoides* (Lf.) DC. and *Dellenia pentagyana* Roxb. on Warimagiri, *Artocarpus lacucha* Roxb. ex Buch. Ham. on Chokelagiri and *Derris marginata* (Roxb.) Benth. on Dagibadimagiri.

Materials and methods

One composite litter sample of each tree species was collected from the site for the determination of their physical characteristics and mineral status. The samples were air dried, powdered and sieved with 60-mesh sieve. The estimation of ash contents was done by the ignition method. The wet - digestion procedure was applied for individual mineral analysis. For determination of sodium and potassium, flame photometer was used. The remaining components were analysed by standard methods as described by Piper (1966).

For determination of impact of leaf litter on the physico-chemical characteristics of soil system of the biosphere, litter samples of *Quercus leucotrichophora, Q. semiserrata, Macaranga denticulata, Polyalthia simiarum* and *Persea duthiei* were chosen. The criteria behind selection of these species were not only their dominance in their respective area but their high energy content was also taken into consideration. The soil, which has been experimented with these leaf litters, was collected from the Jhooming field - a traditional practice of agriculture in the localities. The soil sample is the true representative of the majority soil types of the biosphere and demonstrates no significant difference with others in their physico-chemical nature. For the purpose of experiment, the powdered leaf litter of the aforesaid tree species were added to the soil sample in two different doses, viz. @ 5 g/250 g of soil and 12.5 g/250 g of soil respectively, which amount to @ 50 tonnes and 125 tonnes/ha. approximately. Three replicates in each category were kept for experiment. Simultaneously, a control was also set up and adequate distilled water was added to the mixture to ensure proper decomposition. Five months later, each set was once again analysed for change in physico-chemical characteristics. The standard methods were adopted for soil analysis as described by Jackson (1958).

Results and discussions

The physical and chemical composition of leaf litter are recorded in Table 1. Data on physical properties demonstrates that the water holding capacity varies from a minimum of 329% in the leaf litter of *Artocarpus lacucha* to a maximum of 579% in the leaf litter of *Ficus laevis*. A total of 11 species out of 18 recorded water holding capacity above 400%, whereas, the remaining species between 329% and 395%. It is clear from the observations that when these leaf litters are assimilated in the soil system, they may enhance the water holding capacity of the soil and may enable the soil system to maintain the supply of water requirement to the tree species. The data on density explicitly demonstrate their close range of variations within 10 species (0.508 g cc^{-1} - 0.578 g cc^{-1}), whereas, in remaining species the range of variations is quite wide, which varies from a minimum of 0.39 g cc^{-1} in case of *Persia duthiei* to a maximum of 0.614 g cc^{-1} in the species of *Macaranga denticulata*. The value of standard error (S.E. ± 0.014) clearly suggests that even closely arranged leaf litter for density values differ significantly among the species, however, the density of leaf litter of tree species viz., *Steriospermum chelonoides, Deillenia pentagyna* and *Derris marginata* on one hand and *Schima wallichii, Polyalthia simiarum, Terminalia bellirica* and *Duabanga grandiflora* on the other have no significant variations within their leaf litter body density.

Among all chemical constituent of the leaf litter, ash contents and organic carbon are very vital. The value of ash content indicates the salt tolerance or susceptibility of the species, whereas, by organic carbon, their potentialities for trapping solar energy and converting it into organic compounds may be judged. Data on ash values indicate wide variations (2.2% in *Engelhardia spicata* to 24.0% in *Sterculia villosa*). The high salt potential in the leaf litter of *Sterculia villosa, Stereospeumum chelonoides, Dellenia pentagyna, Artocarpus lacucha, Derris marginata* etc., are very relevant to the condition of high precipitation with a view to mineral conservation of the soils. Equally important is the value of organic carbon content, which is high in the leaf litter of the tree species of the biosphere area. The organic carbon content is more than 45% in 9 species and its value has touched its summit at 49.5% in *Quercus leucotrichophora*. In the remaining species its value ranged between 34.2% and 44.1%. High carbon content in the leaf litter is extremely useful particularly in the forest soil system of the biosphere, which is either low or moderate in its carbon status.

The soil system depends largely on organic materials for the nitrogen content because it is not the constituent of rocks. The observation on nitrogen value expresses vividly its high status in the leaf litter of the tree species. Almost 11 tree species out of 18 have nitrogen content more than 2%. In the litter of remaining 7 species the value of nitrogen ranged from 1.62% (*Schima wallichii*) to 1.96% (*Ficus laevis*). The C: N ratio varies between 14.4:1 (*Stereospermum chelonoides*) and 28.3:1 (*Schima wallichii*). The high C:N ratio in the tree leaf litter has the potentiality to enrich the soil by liberating the nutrients for the growing vegetation.

The phosphorus content in the leaf litter of these species is usually high. It is significant to note that the biosphere soil system, with high quantum of total phosphorus maintains comparatively lower value of its availability due to high presence of sesquioxides. The greater phosphorus in leaf litter, not only compensates the low availability of the soil system but it also enhances formation of highly stable nitrogenous compounds such as Phosphoproteins and ameliorates the system from the point of view of carbon and nitrogen status. The work of Dhar & Singh (1974a and 1974b) is in total agreement with the above statement. The data on phosphorus content indicate close range of variations i.e. from 0.40% (*Shorea robusta*) to 0.621% (*Artocarpus lacucha*) except *Schima wallichii* and *Engelhardia spicata* showing lowest phosphorus values of 0.342% and 0.362% respectively.

The divalent cations such as calcium and magnesium are significantly dominant over monovalent viz., potassium and sodium. The status of calcium, in general, is quite high among the four cations followed by magnesium, potassium and sodium. A perusal of calcium content demonstrates its wide range of variations i.e. 1.4% (*Polyalthia simiarum*) to 4.48% (*Terminalia bellirica*). Content of magnesium ranges between 0.84% (*Polyalthia simiarum*) and 2.54% (*Terminalia bellirica*). Among monovalent cations, potassium content is significantly higher than sodium. It has been noted that the exchangeable sodium is dominating over exchangeable potassium in the soil system. However, the potassium content is higher over sodium in the body of the phytomass of either grasses or leaf litter.

Table 2. Analyses of soil from Nokrek Biosphere.

(a) Mechanical composition	
Coarse sand %	53.40
Fine sand %	18.45
Silt %	10.50
Clays %	18.06
Mechanical Class	Sandy loam
(b) Physico-chemical properties	
Moisture %	2.95
Sesquioxides %	5.40
Fe_2O_3 %	1.96
CaO %	0.195
MgO %	0.204
K_2O %	0.216
Total P_2O_5 %	0.289
Available P_2O_5 %	0.003
Silica %	87.2
Total Carbon %	0.548
Available Nitrogen %	0.042
Water Holding Capacity %	38.30
Porosity %	40.5
Cation exchange capacity (m.e./100g)	14.6
Electrical conductivity (m.mhos/cm at 25^{o}C)	0.3
pH	5.2

It is apparent from Table 2, which presents the textural composition of the soil, that its two third portion is composed of sands (coarse and fine) and rest one third by clays and silts where clays are dominating over silts. Data on physico-chemical properties of the same soil (Table 2b) show that it is acidic in reaction (pH 5.2) and heavily loaded with silica content (87.2%). In comparison to silica the presence of sesquioxides, iron oxides and liming material of the soil is fairly low. Observations on other physico-chemical properties viz., water holding capacity, electrical conductivity value etc., show their lower status except the porosity which is highly conducive. Data further demonstrate the high presence of total phosphorus (0.289%) but its availability in the soil is remarkably low (0.003%) and it is due to large scale fixation of phosphorus on account of high presence of sesquioxides and iron oxides. The available nitrogen content of the soil is also noticeably low (0.042%).

The results on impact of leaf litter on in-situ-soil system have been shwon in Table 3. It indicates the comparative influence of leaf litters of five trees on the physico-chemical characteristics of the experimental soil after the compounding period of 5 months of their incorporation. Results show a significant improvement in all the physico-chemical parameters observed for the experimental soil on both doses. However, the higher dose leaf liter chemistry appears to be superior and stable over lower dose. The similar results have been recorded earlier by Singh & Ghosh (1983). It is further evident from the observation that the leaf litter of *Quercus leucotrichophora* demonstrates its vital role in obtaining the highest value of energy content (2.014%), available nitrogen (0.138%) and cation exchange capacity (24.4 m.e.%) over the value of respective control of the experimental soil. Similarly, the leaf litter of *Quercus semiserrata* enhanced the value of porosity (49.4%), and available phosphorus (0.006%) and *Macaranga denticulata* particularly raised the limit of water holding capacity (61.2%), available phosphorus (0.006%), exchangeable calcium (9.2 m.e.%), pH (7.2) and electrical conductivity (1.1. milli-mhos cm^{-1}) of the experimental soil to its zenith over its respective control. These observations are only confined with higher dose. It is further observed that leaf litter may be categorised into two; on the basis of their organic and inorganic compound possession. Firstly, with high energy content (organic) and less ash (inorganic), and secondly, its vice versa. Either of the categories differs significantly in their efficacious impact on the soil system. The impact of *Quercus leucotrichophora* and *Q. semiserrata* which come under former category are found to impact on organic carbon and available nitrogen; whereas, the influence of *Macaranga denticulata, Polyalthia simiarum* and *Persia duthiei* of the latter group is very apparent on soil's exchangeable calcium, cation exchange capacity and electrical conductive values.

The condition in which Nokrek biosphere reserve is situated the leaf litter of the second category are highly relevant, whereas, the litter of first category may prove to be a cheapest source of reclaiming agent for the sick soils like saline or alkali or degraded alkali type (Singh 1974). Data further prove the positive impact of the leaf litter on two key defects of the soil system viz., its low pH and low electrical conductive values under wet conditions. It is observed in this respect that higher dose of leaf litter is comparatively better suited to bring the pH to normalcy (from pH 5.0 - 7.0) and may raise the electrical conductivity values (from 0.29 m. mhos cm^{-1} to 1.1 m. mhos cm^{-1}) faster than the lesser dose.

It is claimed elsewhere that the humid tropic soil can not sustain extensive development owing to the factors that lead the soils towards base deficiency and quick loss of energy materials (Anon 1973). But the present study amply demonstrates that such problem with respect to Indian humid tropic conditions may be vehemently averted to a sufficient degree by judicious application of forest tree leaf litter, which aid in bringing the effective conditions of the soil to the normal level. Such a treasure of lost minerals can safely be harvested for revamping the nutrient deficient terrestrial media by the application of such biological tool as forest leaf litter phytomass, possessing an extraordinary salt bearing potential.

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