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LITTER CHEMISTRY AND DECOMPOSITION IN RUBBER PLANTATIONS

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The quality and decomposition pattern of litter from three different sources *viz.* rubber (*Hevea brasiliensis*), *Pueraria phaseoloides* and *Mucuna bracteata* and the nutrient release from that in a rubber plantation were studied *in situ* in the central part of the traditional rubber growing tract in India by litter bag technique. Among the three species, rubber litter had significantly higher content of lignin and polyphenol and lower content of nitrogen, phosphorus and potassium than *Pueraria* and *Mucuna*. *Pueraria* litter had significantly higher cellulose, phosphorus and magnesium and lower lignin and polyphenol than the litter from the other two species. Significantly higher carbon, nitrogen and calcium and lower cellulose were recorded in *Mucuna* litter. The rate of decomposition of litter decreased in the order *Pueraria* > *Mucuna* > rubber. The decomposition half life values were 2.7, 3.3 and 3.6 months for *Pueraria, Mucuna* and rubber respectively. For 95 per cent decay, *Pueraria* took less time (11.5 months) than *Mucuna* (14.3 months) and rubber (15.8 months) litter. The nutrients remaining in the residual rubber litter were significantly higher than that of *Pueraria* and *Mucuna*. After one year, nitrogen, phosphorus, potassium, calcium and magnesium remained in the residual rubber litter were 13.2, 19.6, 3.3, 7.9 and 7.5 per cent respectively. The corresponding values for *Pueraria* litter were 2.2, 3.1, 1.0, 2.1 and 1.7 per cent and for *Mucuna* litter were 8.8, 7.4, 2.7, 4.1 and 3.9 per cent.

Keywords: Decomposition, Litter chemistry, Litter quality, Nutrient release, Rubber plantation.

INTRODUCTION

Plant litter plays an important role in forest/plantation ecosystems being a substrate for biological processes that enhance the recycling of nutrients. The decomposition of plant litter is the primary mechanism by which organic matter and nutrients are returned to the soil. Decomposition and nutrient release patterns of organic materials are determined by the resource quality, decomposing organisms and environmental conditions (Berg *et al.*, 2000).

Rubber tree (*Hevea brasiliensis*) has a defoliation cycle by which large quantity of litter is added to the soil. The litter addition in a mature rubber plantation is estimated to be about 5 - 6 t/ha/year (Krishnakumar and Potty, 1992; Philip *et al.*, 2003). In immature rubber plantation, leguminous cover crops like *Pueraria phaseoloides* and *Mucuna bracteata* are the main sources of litter input. The litter turn-over from these cover crops is estimated to be about 5.5 -7.5 t/ha/year (Philip *et al.*, 2005).

Chemical composition of plant litter is species-specific. Information regarding the

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chemical composition, decomposition pattern and nutrient release of these three litter species is scanty. A field study was conducted to evaluate (1) the quality (2) decomposition rate and (3) nutrient release pattern of these litter species in a rubber plantation.

MATERIALS AND METHODS

The study was conducted at Travancore Rubber Estate, Erumely (Latitude 9° 27′ N and longitude 76° 52′ E). The experimental area experiences tropical humid climate with a mean annual rain fall of 338 cm. The soil was sandy clay with pH 4.70 - 4.85 and the soil type was Ustic Haplohumults.

Freshly fallen litter of rubber was collected from a 12-year-old rubber plantation and that of cover crops (*Pueraria* and *Mucuna*) from 3-year-old rubber plantations during February 2001. The samples were oven-dried at 70 °C for two days. The decomposition of litter was studied using litter bag technique (Bocock *et al.*, 1960). In each case, 120 nylon litter bags of size 30 x 30 cm with a mesh of 2 mm were used. Litter bags containing 40 g of rubber litter and 35 g each of *Pueraria* and *Mucuna* litter were placed randomly in contact with the surface soil in the respective fields in March 2001 and were anchored to small pegs. Ten litter bags from each system were retrieved at monthly intervals from April 2001 to March 2002 and brought to the laboratory. The bags were gently rinsed over a fine soil sieve to remove soil and other extraneous material (Anderson and Ingram, 1993) and the residual litter was removed from the bags, oven-dried at 70 °C to constant weight and weighed.

Oven-dried samples of the fresh litter of the three species and those retrieved at monthly intervals were finely ground and C, N, P, K, Ca and Mg contents were estimated following standard procedures (Piper, 1966). The biochemical constituents *viz.* cellulose, lignin and polyphenols of the fresh litter were also estimated (Anderson and Ingram, 1993).

The decay rate coefficient was calculated using the negative exponential model of Olsen (1963) as represented by the equation $X/X_0 = e^{-kt}$ where X is the dry weight remaining at time t, X_0 is the original dry weight of the litter and k is the decay rate coefficient. The time required for 50 per cent (half life) and 95 per cent weight loss was estimated from the k values using the equations $t_{0.50} = 0.693/k$ and $t_{0.95} = 3/k$. The percentage of nutrients remaining in residual litter was estimated (Bockhelm *et al.*, 1991) by the equation

$$\text{Nutrient (\%) remaining} = (C/C_0) \times (DM/DM_0) \times 100$$

where C is the concentration of the nutrient at time t, C_0 is the initial concentration of the nutrient, DM is the dry weight of litter after time t, DM_0 is the initial dry weight of litter.

RESULTS AND DISCUSSION

The Table 1 shows the chemical composition of fresh fallen litter of the three species. Among them, rubber litter had significantly higher contents of lignin and polyphenol and lower nitrogen, phosphorus and potassium than *Pueraria* and *Mucuna*. *Pueraria* litter had significantly higher cellulose, phosphorus and magnesium than the other two species and lower lignin and polyphenol contents than rubber. Significantly higher carbon, nitrogen and calcium contents and lower cellulose were

Table 1. **Chemical composition of fresh litter (% dry wt. basis)**

Species	N	P	K	Ca	Mg	C	Cellulose	Lignin	Poly-phenols	C/N
Rubber	1.14[c]	0.05[c]	0.46[b]	1.56[b]	0.33[b]	36.58[b]	26[b]	37[a]	1.04[a]	32.09[a]
Pueraria	2.44[b]	0.12[a]	0.56[a]	1.21[c]	0.39[a]	34.10[c]	32[a]	21[b]	0.42[b]	13.98[b]
Mucuna	2.71[a]	0.08[b]	0.54[a]	1.74[a]	0.31[b]	38.44[a]	23[c]	22[b]	0.53[b]	14.18[b]

Different letters (a,b,c) indicate significant differences ($P < 0.01$) among species

recorded in *Mucuna* litter. The C/N value of the three species of litter was in the order *Pueraria* < *Mucuna* < rubber.

The pattern of litter weight loss in the three fitted an exponential model (Fig. 1). There was a rapid weight loss initially for

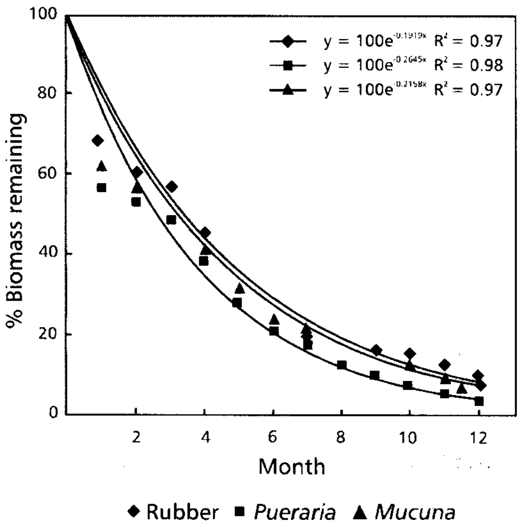

Fig.1. Litter decomposition pattern

all the three species and then followed a slow rate in the subsequent periods. In the first month 42, 38 and 32 per cent weight losses were recorded for *Pueraria, Mucuna* and rubber litter, respectively. The initial rapid disintegration may be due to the leaching of inorganic as well as soluble organic compounds from the litter (Swift *et al.*, 1979).

The slow rate of decomposition in the later phase may be due to the accumulation of resistant compounds like lignin and cellulose. The litter decomposition rates of the three species studied were not significantly different. After one year, 3.36 per cent *Pueraria,* 7.87 per cent *Mucuna* and 8.95 per cent rubber litter remained in the bag.

The decay rate coefficient (k) and time required for 50 per cent and 95 per cent decay are presented in Table 2. *Pueraria* litter

Table 2. **Decay constant and time required for decay**

Species	Decay constant (k)	t_{50} (month)	t_{95} (month)
Rubber	0.19	3.6	15.8
Pueraria	0.26	2.7	11.5
Mucuna	0.21	3.3	14.3

recorded the highest decay rate constant (0.26) followed by *Mucuna* (0.21) and rubber litter recorded the lowest decay rate constant (0.19). Among the three litter species studied, the half-life for decomposition was the lowest in *Pueraria* (2.7 months), highest in rubber (3.6 months) and intermediate in *Mucuna* (3.3 months). For 95 per cent decay also *Pueraria* took less time (11.5 months) than *Mucuna* (14.3 months) and rubber (15.8 months). Similar results were reported for rubber litter by Deka *et al.* (1998).

Table 3. **Correlation between litter quality parameters and cumulative weight loss of litter**

Initial chemical composition of litter	Cumulative weight loss of litter
N	0.4311*
P	0.8389**
K	0.6670**
Ca	-0.7705**
Mg	0.8074**
Cellulose	0.7734**
Lignin	-0.5852**
Polyphenols	-0.6537**

* Significant at $P < 0.05$ ** Significant at $P < 0.01$

The correlation of initial chemical composition of the three species of litter with their cumulative weight loss is presented in Table 3. Phosphorus, cellulose, magnesium, potassium and nitrogen contents showed significant positive correlation with cumulative weight loss. Significant negative correlation was observed between cumulative weight loss and lignin, polyphenol and calcium contents. Similar observations were reported by Meentemeyer (1978) and Taylor *et al.* (1991).

High initial N and P contents can accelerate decomposition as these nutrients enhance microbial activities (Taylor *et al.*, 1989). Relative contents of organic substances are also important in determining rate of decomposition. Cellulose serves as an immediate source of energy for microorganisms and promotes breakdown of litter whereas phenols inhibit growth and activity of soil decomposers. Lignin, itself resistant to decay, also slows down the decay of other cell constituents (Chesson, 1997; Issac and Nair, 2005). The relatively faster decomposition of litter of *Pueraria* than *Mucuna* may be due to its higher cellulose and lower polyphenol contents. The slowest decomposition rate of rubber litter may be due to its higher lignin and polyphenol and lower N and P contents. These results are in agreement with the study of Abraham and Chudek (2008).

Nutrient contents in the residual litter of the three species at different time intervals are given in Table 4, 5 and 6. There was significant variation in N, P, K, Ca and Mg contents at different time intervals. All the three species showed an increase in N content in the initial phase of decomposition and a decline in the later phase. Accumulation of N in residual litter during decomposition has been reported by Melillo *et al.* (1982) and Schlesinger (1985). Phosphorus content in residual litter showed variable trends in the three species. In the residual rubber litter, it increased as decomposition proceeded. In the case of *Pueraria* litter, no definite trend was

Table 4. **Nutrient content in the remaining rubber litter in different months (% dry wt. basis)**

Month	N	P	K	Ca	Mg
March(initial)	1.14	0.05	0.46	1.56	0.33
April	1.47	0.07	0.33	2.13	0.31
May	1.61	0.08	0.26	2.13	0.29
June	2.07	0.08	0.21	1.92	0.29
July	1.77	0.09	0.19	2.86	0.24
August	1.96	0.10	0.19	1.75	0.24
September	1.98	0.10	0.21	2.00	0.23
October	2.15	0.10	0.20	1.78	0.24
November	2.07	0.10	0.21	1.05	0.24
December	2.09	0.11	0.21	1.16	0.27
January	1.88	0.11	0.20	1.00	0.24
February	1.71	0.11	0.20	1.27	0.24
March	1.69	0.11	0.18	1.34	0.24
SE	0.04	0.003	0.008	0.09	0.01
CD (P = 0.05)	0.12	0.01	0.02	0.25	0.03

Table 5. **Nutrient content in the remaining *Pueraria* litter in different months (% dry wt. basis)**

Month	N	P	K	Ca	Mg
March (initial)	2.44	0.12	0.56	1.21	0.39
April	2.49	0.10	0.20	1.78	0.29
May	2.46	0.10	0.20	1.73	0.28
June	2.78	0.12	0.19	1.87	0.26
July	2.52	0.12	0.19	1.72	0.23
August	2.64	0.11	0.18	1.29	0.23
September	2.76	0.11	0.18	1.16	0.20
October	2.83	0.12	0.19	0.77	0.24
November	2.68	0.12	0.19	1.01	0.25
December	2.62	0.12	0.18	1.04	0.26
January	2.44	0.13	0.17	1.13	0.21
February	2.16	0.12	0.16	0.85	0.22
March	1.75	0.11	0.16	0.86	0.22
SE	0.10	0.003	0.01	0.07	0.01
CD (P = 0.05)	0.28	0.01	0.03	0.20	0.03

Table 6. **Nutrient content in the remaining *Mucuna* litter in different months (% dry wt. basis)**

Month	N	P	K	Ca	Mg
March (initial)	2.71	0.08	0.54	1.74	0.31
April	3.16	0.10	0.20	1.71	0.24
May	3.00	0.10	0.20	1.69	0.25
June	3.59	0.11	0.19	1.80	0.22
July	3.49	0.12	0.19	1.34	0.21
August	3.17	0.11	0.18	1.12	0.21
September	3.40	0.10	0.19	1.10	0.20
October	3.51	0.11	0.19	1.16	0.19
November	3.38	0.11	0.19	1.12	0.18
December	3.32	0.11	0.20	0.81	0.17
January	3.33	0.11	0.19	1.08	0.16
February	3.45	0.10	0.18	0.94	0.16
March	3.08	0.08	0.18	0.92	0.16
SE	0.08	0.003	0.008	0.07	0.009
CD (P = 0.05)	0.22	0.01	0.02	0.19	0.03

observed. In *Mucuna*, initially there was an increase in P content and in the later phase a decrease was noticed. The increase in N and P contents may be due to the immobilization of these nutrients by microorganisms. The declining trend in later stage may be due to the mineralization. Unlike N and P, the K and Mg contents in litter decreased continuously as decomposition progressed. For K, the decrease was rapid in the early stages and gradual in later stages of decomposition. In general, Ca in the three species showed an increase in the initial phase of decomposition and then a declining trend. This may be due to the relatively immobile nature of calcium in the cell wall. Calcium is firmly bound as calcium pectate in the cell walls and protected by lignin till the last stages of decomposition. Studies on forest litter decomposition have consistently shown that in the early stages of decay, concentration of N and P tend to accumulate while K declined (Berg *et al.*, 1992). Nutrient dynamics is influenced by the litter quality, especially the palatability of the compounds by

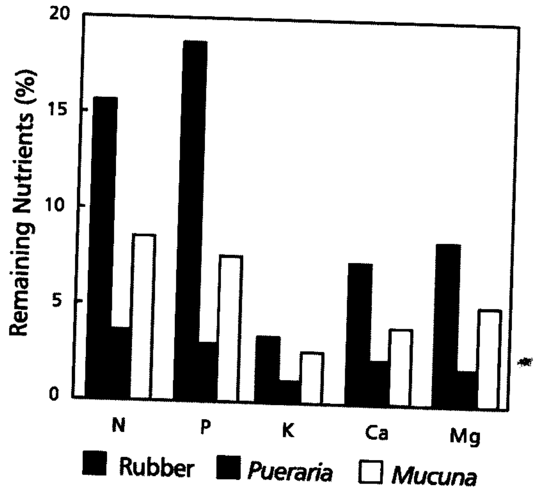

Fig. 2. Nutrients remaining in the residual litter after one year

microorganisms and to their solubility. Also it is influenced by the nature of chemical bonds which attach the element to the organic matter. Since K is not a structural component of litter, its rapid decline can be due to leaching. As Mg is partly occurring as a constituent of complex molecules like chlorophyll and pectin, its decline is relatively slower than K.

The nutrients remaining in the residual litter after one year are depicted in Figure 2. The three species differed significantly in this aspect. *Pueraria* retained only 2.17, 3.11, 1.00, 2.13 and 1.69 per cent N, P, K, Ca and Mg, respectively after one year whereas for *Mucuna*, the corresponding values were 8.75, 7.44, 2.69, 4.08 and 3.90. After one year, the nutrients in the residual rubber litter were 13.22 per cent N, 19.56 per cent P, 3.29 per cent K, 7.94 per cent Ca and 7.51 per cent Mg. In the case of *Pueraria*, 97-99 per cent of the nutrients were released within a year.

The study revealed that the three species of litter *viz.* rubber, *Pueraria* and *Mucuna* in a rubber plantation vary in quality, decomposition process and nutrient release. Among the three species studied, *Pueraria* litter having more cellulose and less lignin and polyphenols decomposed faster whereas rubber litter having more lignin and polyphenols was the slowest to decay.

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