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SEASONAL VARIATION IN ELEMENTAL COMPOSITION OF COCOA LITTER UNDER SHADED AND OPEN CONDITIONS

Nutrient recycling through litter fall is primarily decided by its elemental composition, nutrient ratios and the quantity of litter produced. The maximum leaf fall takes place along with intensive flushing or just before or after it. Changes in the nutrient concentration of leaves might be a function of nutrient transfer from older parts of the plant to the actively growing regions. The elemental composition of leaves is also decided by the stage of growth and conditions under which it is grown like shade, nutrient and water availability and climate. The concentration of N, P and K was found to decrease during or just prior to senescence, these elements being translocated away from the dying leaves (Small, 1972). The litter fall has a vital role in recycling of nutrients since the nutrient addition through litter inputs frequently exceeds inputs from inorganic fertilizers in crops like cocoa which has lot of foliage, synchronized flushing, abundant litter fall either due to natural senescence or pruning. It has been reported that an average yield of 1000 kg ha^{-1} yr^{-1} of dry cocoa beans removed 38, 6 and 77 kg of N, P and K respectively (Omotoso, 1975) whereas the litter fall (6-7 t ha^{-1}) contributed around 88, 6 and 82 kg of N, P and K ha^{-1} yr^{-1} (Sreekala, 1997).

A field experiment was conducted in well-managed 10 year-old cocoa plantations of Cadbury-KAU Co-operative Cocoa Research Project, Vellanikkara, Trichur during 1995-96 to study the seasonal variations in the elemental composition of litter fall under shaded and open conditions. The experimental area enjoyed a wet humid tropical climate. The soil texture of the field was sandy clay loam. The shaded field with rubber which was selectively thinned to give adequate shade for cocoa plants had a pH of 4.25, organic C 1.43 per cent, available N, P, and K as 452, 14.5 and 443 kg ha^{-1} respectively and exchangeable Ca and Mg as 688 and 304 kg ha^{-1}. The field without shade tree was having a pH of 5.25, organic C 1.36 per cent, available N, P and K as 426, 11 and 430 kg ha^{-1} respectively and exchangeable Ca and Mg as 1147 and 648 kg ha" . The plants were spaced at 3 m x 3 m in both cases. Litter traps of 1 m x 1 m size were placed for one year in the central point formed by four cocoa trees. The litter was collected from the trap at fortnightly intervals, and under shaded condition the leaves falling from rubber were removed carefully. The N, P, K, Ca and Mg contents were analyzed using standard procedures.

There was significant seasonal variation in N content and it varied from 0.92 to 1.61 per cent in shaded condition and 0.87 to 1.64 in open condition (Table 1). During the same month the N content varied according to the situation and the mean N content in open condition was slightly higher than the shaded condition. There are reports that under light-limited environments, leaf N content and pod yield were generally low (Field and Mooney, 1983; Hirose, 1988; Nair *et al.*, 1996). Under shaded condition, mobilization of N from older leaves to new meristematic regions was reported to be greater than plants in open condition and consequently a lower N content was expected. In the open condition due to water stress and temperature effects leaves are retained for a lesser period and there is destruction of chlorophyll compared to chlorophyll decomposition due to ageing in the shaded plants. It was also observed that during rainy months of June, July and August (Table 2) the N content was significantly lower than the non-rainy months. Leaching of nutrients from leaves through canopy washing under heavy rainfall is also reported (Raizada and Srivastava, 1991). There is active growth in cocoa during the rainy months and that may be one of the reasons for low N content in the falling leaves during that period. Profuse flowering starts in cocoa 2-3 weeks after pre-monsoon showers and the N might have been re-translocated and utilized for the flower and pod production in June. The quantity and quality of beans produced in October is much higher than the other periods. Normally it takes 5-6 months for the pods to be harvested.

The P content varied from 0.04 to 0.14 per cent in both situations; but unlike N, low P content in the litter was observed during the non-rainy periods from January to May. More P is available from the soil under moist situations by diffusion and it is reflected in its

Table 1. Variation in elemental composition of litter under shaded and open situation

Year/month	Percentage nutrient content									
	N		P		K		Ca		Mg	
	Shaded	Open	Shaded	Open	Shaded	Open	Shaded	Open	Shaded	Open
1995 July	1.00	1.02	0.14	0.14	0.76	0.82	1.85	1.51	0.61	0.61
Aug	1.14	1.15	0.14	0.14	0.50	0.66	1.61	1.11	0.72	0.67
Sept	1.38	1.51	0.13	0.14	0.72	0.99	1.33	1.49	0.67	0.59
Oct	1.20	1.30	0.09	0.12	1.12	1.64	1.77	1.40	0.60	0.62
Nov	1.27	1.29	0.13	0.12	1.03	1.15	1.79	1.24	0.87	0.71
Dec	1.22	1.28	0.12	0.08	1.11	1.22	1.52	1.50	0.75	0.73
1996 Jan	1.53	1.64	0.07	0.08	1.40	1.53	1.48	1.09	0.80	0.83
Feb	1.23	1.30	0.05	0.05	1.20	1.67	1.46	1.14	0.75	0.74
Mar	1.17	1.24	0.04	0.05	1.21	1.59	1.47	1.18	0.76	0.69
Apr	1.61	1.23	0.08	0.07	1.11	1.16	1.61	1.27	0.71	0.69
May	1.10	1.64	0.05	0.04	0.90	0.90	1.55	1.32	0.73	0.68
June	0.92	0.87	0.10	0.07	0.98	0.98	1.56	1.49	0.67	0.70
Mean	1.19	1.25	0.09	0.09	1.02	1.19	1.58	1.31	0.72	0.69
CD (0.05)										
Month	0.113		0.097		0.174		0.210		0.117	
Condition	0.032		NS		0.050		0.060		0.034	
Interaction	NS		0.028		0.246		0.297		NS	

Table 2. Meteorological data during the experimental period

Month	Rainfall, mm	Temperature		RH (%)		Sunshine hours	Wind speed, km h^{-1}	Evaporation, mm day^{-1}
		Max °C	Min °C	FN	AN			
1995 July	719.7	29.9	23.2	96	81	2.2	2.1	2.9
Aug	626.6	30.5	23.7	95	78	3.5	2.3	3.0
Sep	345.1	31.4	23.5	94	70	6.6	1.8	3.2
Oct	38.6	33.1	23.2	91	64	8.3	1.8	3.7
Nov	160.2	31.7	22.5	91	67	6.9	1.0	3.1
Dec	-	32.4	21.4	71	44	10.3	6.7	6.4
1996 Jan	-	33.1	22.4	71	36	9.3	6.9	6.6
Feb	-	34.4	23.2	71	34	9.9	6.4	7.2
March	-	36.4	24.4	81	37	8.9	3.8	6.9
Apr	152.0	34.6	24.9	87	59	8.4	2.9	5.3
May	95.6	32.9	25.3	90	63	7.8	2.6	4.4
Jun	400.3	30.7	23.9	93	73	4.9	2.9	3.5

content in the litter during rainy months. Wessel (1970) had observed that P is mobilized from older cocoa leaves to developing adjacent leaves. In general, the concentration of P in the litter was found to be lower than N, K, Ca and Mg. Even though P is required for pod formation, its requirement is very less compared to N and there was a high content of P in the falling leaves even during the active growing stage of cocoa. In the shaded condition, less P content was observed from January and May; but in the open condition this phenomenon started early in December and ended late in June indicating favourable microclimate under shaded condition for cocoa which reduces the energy wastage and better

Table 3. Month-wise litter fall in cocoa

Month	Dry weight of litter, kg ha^{-1}		Mean
	Shaded condition	Open condition	
1995 July	291	277	284
Aug	162	562	362
Sept	358	744	551
Oct	368	590	479
Nov	374	502	438
Dec	722	1304	1013
1996 Jan	1047	1564	1306
Feb	748	864	806
Mar	610	866	738
Apr	159	238	199
May	318	510	414
Jun	166	209	188
Total	5323	8230	6777
Mean	444	686	565
CD (0.05)	Month 203.2	Condition 58.4	Interaction 287.4

availability of P under moist situations and retention of the foliage.

The absorption of K was depressed by shade and as a result, foliar K levels were less in shaded condition compared to open conditions. The K content varied from 0.50 to 1.40 per cent in shaded and 0.66 to 1.67 per cent in the open condition. The low K content was in the rainy months irrespective of the situation but the highest content was in January in the shaded condition while it was increasing up to February in open condition. In general, K content in the litter was at a higher range from October to April. Litter fall is usually high in cocoa from December to March with the peak in January-February under the site conditions (Table 3). The K content showed similar pattern of N indicating their significant role in pod formation and development. The effect of canopy washing and leaching of K from leaves is also evident (Tukey, 1969). During the wetter months, the atmospheric temperature was low which also decreased the rate of K uptake of plants.

The concentration of Ca was higher than all other nutrients analyzed in the litter. The Ca content varied from 1.33 to 1.85 per cent in shaded condition and 1.09 to 1.51 per cent in open condition. Ca being a structural element has no possibility of back translocation. Wessel (1970) reported that in cocoa tree, the Ca concentration was 1.03, 1.69 and 2.33 per cent in the young, medium old and senescing leaves respectively. The movement of cations into dying leaves would facilitate their removal during leaf abscission (Waughman and Bellamy, 1981).

The higher Ca content was observed in the shaded field than the open field, which might be due to the inactivation of Ca in the soil as well as in the plant. The litter fallen during the hot and non-rainy period of January to March showed the lowest Ca content and it was the period of maximum litter fall. During the wetter periods, the Ca absorption is more and this has a role in chlorophyll stability and leaf retention. The low Ca content hastens the leaf senescence and it is also related with uptake and metabolism of N.

Magnesium, which is another primary constituent of chlorophyll, varied from 0.60 to 0.87% in the shaded condition and from 0.59 to 0.83% in the open condition. A higher range of Mg was maintained from November to May in the shaded condition and up to June in the open condition with the lowest content in July and October in the shaded condition and July and September in open condition. It may be because of the difference in flushing under shaded and open situations. Wessel (1970) reported that in cocoa Mg content of leaves increased from 0.43 to 0.61 per cent within one month of leaf growth. However, in senescing leaves it was only 0.59 per cent. In the present study, K-Mg antagonism is also seen. The K level in litter was higher in the open condition which tended to depress the Mg content. During January, the month of peak litter fall, content of N, K and Mg increased and P and Ca decreased.

The nutrient dynamics in cocoa appears to have a direct bearing on its production characteristics. The conspicuous decline in P content in the litter produced during the dry months is indicative of low phosphorus content in the plant either due to low availability of P from the soil or due to P inactivation within the plant. The low yield of beans during the season can only be related to this apparent inadequacy of P in the plant system because no other nutrient under study has shown any profound variations. These results further suggest that enhanced availability of P can increase quality and yield of cocoa either by supplemental P application and or by irrigation.

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