SHORTER CONTRIBUTION

Ammonium and nitrate nitrogen in the rainwater at Samaru, Nigeria

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Throughout the 1969 wet season rain samples were collected at Samaru (11°10′ N; 7°38′ E., Alt. 686 m) and analysed for NH_4–N and NO_3–N by steam distillation methods. Samples were of individual showers or storms, except where two showers fell in close succession, when it was not always possible to make separate collections. The main purpose of the study was to measure the total addition of mineral-N to the soil from rainwater, and summarized results have been published elsewhere (Jones & Bromfield, 1970). Few rainfall analysis data for the non-maritime areas of the tropics have been published, and the purpose of this communication is to put on record the trends observed in the rain mineral-N concentrations of the samples collected. However, since the samples were from one site and for one season only, any inferences drawn are necessarily of a tentative nature. A summary of data (Table 1) provides a general picture of the season's rainfall and rainfall-N distribution. Presentation of the data is on a monthly basis, a month being a convenient, if somewhat arbitrary, unit of time. Examination of the detailed data has revealed two main features of interest.

A. Rain mineral-N concentrations

It has been noted elsewhere (Ångström & Högberg, 1952*a*; Meyer & Pampfer, 1959) that small showers tend to have a much higher mineral-N concentration than do larger falls and that concentration decreases with shower size in an approximately exponential manner. Rain mineral-N concentration was therefore plotted against the natural logarithm of the shower size. For each month the plotted points fell about a straight line, but a different line for each month. The calculated regression constants of these lines are given in Table 2.

The consistent decrease in mineral-N concentration with shower size throughout the season strongly implies that in any one shower

Table 1. *Summary of rainfall data, Samaru, 1969*
No rain fell in January, March, November or December

Month	Rainfall occasions	Total rainfall (mm)	Mean mineral-N conc. (ppm.)	Mean ratio NH_4–N:NO_3–N[a]	Mineral-N deposited kg ha^{-1}
February	1	0.3	3.11	0.86	0.008
April + May[b]	15	160.0	0.65	1.37	1.042
June	18	184.7	0.39	1.02	0.723
July	18	445.5	0.33	1.25	1.483
August	27	233.7	0.28	1.41	0.650
September	15	89.9	0.30	0.98	0.272
October	13	104.4	0.37	1.46	0.387

[a] Method for NO_3–N includes NO_2–N, if present.
[b] Months of April and May taken together so that the 4 showers in April could be included in the statistical analysis.

Table 2. *Regression constants and correlation coefficients between rainfall total mineral-N concentration and the natural logarithm of shower size*

Month	Regression constants[a] 'a'	'b'	Correlation coefficients
April + May	2.339	−0.426	−0.868**
June	1.837	−0.370	−0.912***
July	1.001	−0.130	−0.645**
August	1.020	−0.191	−0.903***
September	0.983	−0.199	−0.768***
October	0.931	−0.140	−0.688*

[a] For the equation: $y = a + b \log R$, where y = ppm mineral-N in rainwater, and R = shower size (mm × 254).

Levels of significance: * 0.05; ** 0.01; *** 0.001.

the rain mineral-N concentration is greatest at the beginning of the shower and thereafter falls off. In one shower of 15.5 mm at Samaru a concentration of 0.5 ppm in the first 0.3 mm declined to 0.05 ppm in the rain falling at the end of the shower. Such a result is consistent with the view that the greater part of the rain mineral-N derives from "washout" of mineral-N compounds from the air through which the rain is falling.

However, the monthly regression constants (Table 2) changed as the season progressed; values of the intercept, 'a', decreased, and the magnitude of the slope, 'b', of the regression line declined from −0.426 in (April + May) to −0.130 in July. This means, firstly, that small showers tended to have a very high mineral-N concentration in the early part of the season, but only a moderately high concentration later on. This may be explained in terms of a decrease in the air mineral-N concentration as the season progressed, and there are some air analysis data to support this explanation (Bromfield, 1970). Secondly, the rate of decrease in concentration with increasing shower size was rapid in the early rains, but much less rapid in the heavy rains of July. This suggests that, whereas in the early rains much of the mineral-N that fell in a shower did so at the beginning of the shower, in the heavy mid-season rains the mineral-N concentration was maintained at an appreciable level throughout the shower. This is most clearly seen in the data for the last week of July (Table 3). During this period there were six falls of rain. In the two smallest, mineral-N levels were not outstandingly high and gave no hint of any abnormally high levels of atmospheric mineral-N. In the four largest falls mineral-N levels were lower, but showed no dependence on shower size at all. A concentration of 0.260 ppm in a fall of 152.7 mm (representing nearly 0.4 kg ha^{-1} of N) argues either an enormous washout of atmospheric mineral-N at the beginning of the storm (and therefore a correspondingly enormous atmospheric concentration before the storm) or else a relatively constant fall of mineral-N throughout most of the storm. If the latter, then simple atmospheric washout is not the sole source of mineral-N during the heavy mid-season rains.

Table 3. *Rainfall and rainfall-N in the last week of July*

Date	Rainfall (mm)	Mineral-N in rain (ppm)	Mineral-N deposited (kg ha^{-1})
24/7	43.2	0.375	0.161
26/7	51.8	0.255	0.132
27/7	12.4	0.245	0.030
28/7	0.3	0.510	0.001
30/7	7.1	0.755	0.054
31/7	152.7	0.260	0.397

Other investigators (Meyer & Pampfer, 1959; Wetselaar & Hutton, 1963) also working in non-maritime areas, have suggested that rainfall mineral-N derived from atmospheric washout is no more than part of the terrestrial nitrogen cycle. The present data, suggesting as they do a second, possibly more distant, source of rainfall-N associated with the heavy monsoonal rains, may be evidence that part of the rainfall mineral-N at Samaru is a real, if small, addition to the soil.

B. Rainwater NH_4–N: NO_3–N ratios

Earlier workers (Ångström & Högberg, 1952*b*; Stevenson, 1965; Wetselaar & Hutton, 1963) have observed that rainwater NH_4–N: NO_3–N ratios are relatively constant and have pointed out correlations between the NH_4–N and NO_3–N concentrations. In the present samples the NH_4–N:NO_3–N ratios varied from 0.38 to 2.55, but most were in the range, 0.80–

Table 4. *Statistical association between rainfall NH_4–N and NO_3–N concentrations*

Month	Correlations between NH_4–N and NO_3–N		Degree of association (%)
	Straight	Partial[a]	
April + May	0.770	0.450 N.S.	20.3
June	0.954	0.768 ***	59.0
July	0.913	0.852 ***	72.6
August	0.914	0.601 **	36.1
September	0.828	0.645 *	41.6
October	0.811	0.812 **	65.9

[a] Shower-size effect eliminated.

Levels of significance: * 0.05; ** 0.01; *** 0.001. N.S. = not significant.

1.60. No effect of season or shower size could be detected. The mean of all samples, 1.26, is comparable with the value, 1.45, calculated from the mean of seven tropical, but non-savanna, rain areas, quoted by Allison (1965).

NH_4–N and NO_3–N concentrations were highly correlated in all months, partly as the result of shower size, which affected the concentrations of both forms of N similarly. However, the partial correlation coefficients (Table 4), calculated to eliminate the effect of shower size, were still significant in all months except (April + May). This result implies a real association between the NH_4–N and NO_3–N concentrations and suggests that part of both forms, particularly during the period of heavy rains, arise from a common source. There is no evidence to show what this source might be.

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