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AVAILABLE NUTRIENTS IN PUMICE LAPILLI OF A KAINGAROA FOREST SOIL

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In preparation of soil for chemical analysis the > 2 mm fraction is frequently discarded. For most soils this is an acceptable procedure since mineral material > 2 mm has only a small surface area : volume ratio relative to finer soil components. However, in pumiceous parent material the > 2 mm fraction may contain appreciable exchangeable bases and cation exchange capacity (Wright & Metson 1959; Youngberg & Dyrness 1964).

In Typic Vitrandept profiles in Kaingaroa Forest, mapped within the Kaingaroa soil set, pumice lapilli > 8 mm can make up to 60% by weight of B horizon whole soils (McIntosh 1978). The lapilli appear fresh except for a dark yellowish-brown (10YR 4/6) external staining. Under *Pinus radiata* D. Don pores of some lapilli were observed to be penetrated by bifurcating roots of the type described by Harley (1969) as mycorrhizal and in some lapilli fungal mycelium lined pores. These observations indicated that lapilli might contain nutrients available to fungi and *P. radiata.* Lapilli (8–16 mm) and soil (< 8 mm) from a B horizon under *P. radiata* were therefore analysed so that the relative contribution of the two size fractions to soil nutrient status could be established.

Lapilli and soil were air-dried at 30°C and adhering soil was dislodged from lapilli by gentle hand-sieving. Soil chemical analyses were made by the methods described by Blakemore *et al.* (1977) except that P in acid extracts was determined by the method of Fogg & Wilkinson (1958) and exchangeable cations were extracted by allowing the soil or lapilli to stand in neutral N ammonium acetate for the time specified in Table 1 (with occasional shaking), the extracts subsequently being filtered. Total carbon was determined by the method of Kosaka *et al.* (1959).

Table 1 shows that lapilli contain appreciable exchangeable cations; as expected, longer extraction times result in a greater percentage increase of cations extracted from lapilli than from < 8 mm soil, the effect being most marked for Ca and Mg, and least for Na and K. After 114 hr extraction, values for exchangeable cations from lapilli are approximately 60% of the values obtained from < 8 mm soil. Values for phosphorus fractions in lapilli are also about 60% of values in < 8 mm soil, and much of the P is in the "available" form extracted by 0.5M H_2SO_4 from air-dry soil. As unweathered lapilli from the Taupo Pumic Formation have total P values of 200 $\mu g/g$

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TABLE 1—Exchangeable cations extracted from B horizon lapilli (8–16 mm) and < 8 mm soil

Material	Extraction time (hr)	Exchangeable cations (me %)*				
		Ca	Mg	Na	K	Total
< 8 mm soil	1	2.1	0.69	0.21	1.03	4.03
	114	2.4	0.82	0.22	1.15	4.59
% increase 114 hr v. 1 hr		14	19		12	14
Lapilli 8–16 mm	1	0.9	0.30	0.07	0.32	1.59
	114	1.6	0.48	0.10	0.40	2.58
% increase 114 hr v. 1 hr		78	60		25	62

* me % = milliequivalents per 100 g oven-dry soil
1 me = 1 m. mol/ion charge number

TABLE 2—Chemical analyses of lapilli and < 8 mm soil

Analysis	Lapilli	Soil
P_t (μg/g)	1290	1750
P_a (μg/g)	1000	1380
P_i (μg/g)	1070	1500
P_o (μg/g)	70	120
Total C (%)	1.0	1.6
Total N (%)	0.12	0.09
C/N	8	18
Oxalate Al (%)	0.58	0.84
Oxalate Fe (%)	0.18	0.31
Oxalate Si (%)	0.46	0.57

P_t = Total P; P_a = P soluble in 0.5 M H_2SO_4 (air-dry soil);
P_i = P soluble in 0.5 M H_2SO_4 (ignited soil); P_o (organic P) = $P_i - P_a$.

(Ewart 1966) illuviation of P into both lapilli and < 8 mm B horizon soil must be considered likely. Illuviation may also be responsible for the oxalate-extractable Al, Fe, and Si in lapilli (Table 2).

The lapilli examined contained more nitrogen, but less carbon, than < 8 mm soil, and have a C/N ratio of 8, one half that of the < 8 mm soil. Similar C/N ratios were found in lapilli and < 8 mm soil from 3 other sites. Bacteria and fungi frequently have lower C/N ratios than those commonly recorded in soils (Burges 1958) and it appears possible that both the carbon and nitrogen in lapilli pores are derived from fungal mycelium and micro-organisms.

The significant amounts of nutrients found in pumice lapilli, and the close relationship of roots and fungi with lapilli, emphasise that in soils derived from volcanic ash, lapilli are an integral part of the soil chemical and biological systems.

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