PHOSPHORUS STATUS OF SOME PUMICE SOILS

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When laying down new pasture on the pumice soils of the North Island, it is common practice to apply 9cwt. of superphosphate per acre and thenceforth to support the pasture with dressings of about 3cwt. of superphosphate per acre per year.

The grazing animal returns to the soil, in its dung, a large proportion of the phosphorus in the herbage that it eats, and the removal of applied phosphorus from the land in animal carcasses and products is relatively small. Consequently one would expect a rapid build-up of phosphorus in the soil, such that applications of superphosphate could be discontinued without a serious drop in pasture production. Experience indicates that, in general, applications of superphosphate must be continued if pasture production is to be maintained and one is forced to the conclusion that the accumulated phosphorus in the soil is largely unavailable to the pasture plants.

The present work is a preliminary study of the effect of grassland farming on the distribution of various forms of phosphorus in some pumice soils derived from the Taupo ash shower in the Rotorua district. The object was to determine reasons for the unavailability of accumulated fertiliser phosphorus.

METHODS

Composite samples, taken from virgin land and land farmed for up to 20 years in the Waikiti Valley and Ngakuru districts, were analysed for various forms of phosphorus, defined below, and in some cases for organic carbon,

Total Phosphorus: Is the total phosphorus in the soil.

Organic Phosphorus: Is that portion of the soil phosphorus that has been biologically synthesised into organic compounds, such as phytin, nucleic acids, nucleoproteins, and phospholipids.

Inorganic Phosphorus: Is that portion of the soil phosphorus not combined with organic compounds.

Available Phosphorus: Is that portion of the soil inorganic phosphorus extracted by the Truog reagent.

RESULTS

The results for three profiles of Taupo sandy. silt, deep subsoil phase,* are given in Figure I, and for the top 2in., in Table I. The, samples from the soils under 6 month- and 12-year-old pastures were taken within 20 yards of each other while the samples of virgin soil came from a topographically similar position about a mile away. The younger pasture had received 9cwt./acre of superphosphate, the older 32cwt.

In the virgin soil the total phosphorus decreased regularly with increasing depth, a decrease that was closely paralleled by that of the organic phosphorus. Inorganic phosphorus was relatively constant over the depth sampled. The distribution of the phosphorus fractions were very similar to those found in other profiles of this soil type growing stunted. manuka and bracken. Organic phosphorus was the larger fraction, averaging (over three virgin profiles) 78 per cent. (0 to 4in.), 72 per cent. (4 to 6in.), 66 per cent.' (6 to 9in.) and 51 per cent. (9 to 12in.). A further sample was taken from an area growing vigorous manuka and bracken. The total phosphorus was higher (0.083 per cent. P in the 0 to 2in. layer) which probably accounted for the better plant growth. The organic phosphorus, was disproportionately high in the 2 to 4in. layer and was close to or greater than 80 per cent. of the total phosphorus a.t'all depths down to 9in.

The increase in organic phosphorus down to the 4 to 6in. layer in the soil under the 6-month pasture was due to the recent ploughing having inverted the organically rich top soil. The ploughing affected the distribution in the top layers of both total and organic phosphorus, but not appreciably the inorganic phosphorus, since this fraction 'was relatively constant at all 'depths within any one profile of virgin Taupo sandy silt. Thus, in the plough layer, the inorganic phosphorus in all three soils can be compared, but total and organic phosphorus can be compared only between the two soils under pasture, both of which had been ploughed at comparable stages of pasture development.

*All soils were typed by Mr I. Baumgart, Soil Bureau; Dept. of Scientific and Industrial Research. All type names are tentative.

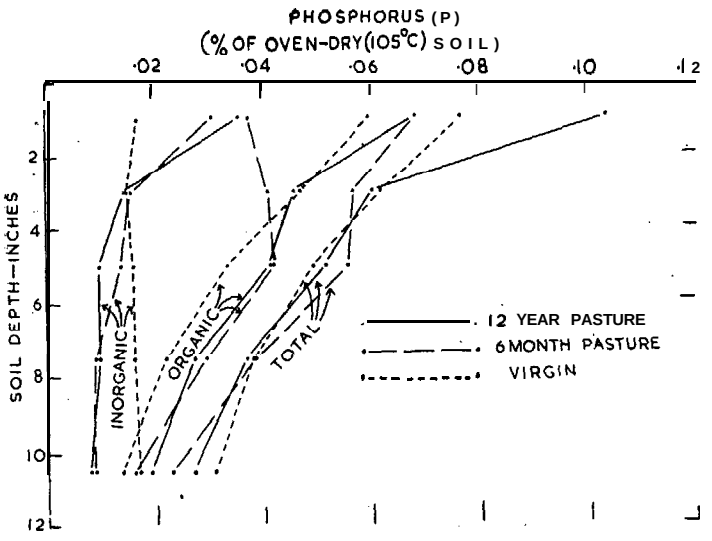

FIG. 1. TOTAL, ORGANIC AND INORGANIC PHOSPHORUS IN TAUPO SANDY SILT, DEEP SUBSOIL PHASE, VIRGIN AND UNDER PASTURE FOR 6 MONTHS AND 12 YEARS

Figure I shows that the phosphorus content of the two soils under pasture differed only at depths less than 4in. and mainly in the 0 to 2in. layer. There was no indication of deep penetration of applied phosphate. In the 0 to 2in. layer total phosphorus in the 12-year pasture soil, as compared to the soil under the 6-month pasture, had increased by an amount equivalent to 1240 pounds per acre of superphosphate (20 per cent. P_2O_5) of which 1070 pounds, or 86 per cent., was in organic form. Thus of the 23cwt. of superphosphate applied over 11 years, nearly half had accumulated in the top 2in. and of this 80 to 90 per cent. had been changed into organic form.

Both soils under pasture showed similar small increases in inorganic phosphorus in the top 2in. when compared with the virgin soil. The increase in the soil under the 6-month pasture 'was equivalent to about 500 pounds of 20 per cent. superphosphate—approximately 50 per cent. of the 9cwt. of super-phosphate applied. Since this pasture had been very lightly grazed there could. have been little removal of phosphorus and it is difficult to account 'for the low recovery of applied phosphorus. It is quite possible that

the rate of application was less than the stated 9cwt., and further that some of the fertiliser phosphorus had been changed into organic forms, even in the short period of 6 to 9 months.

To gain preliminary information on the rate of build-up of soil organic phosphorus a pot experiment was run using a virgin Taupo sandy silt. Superphosphate was mixed in the top 3in. at the rate of 6cwt. per acre. One series of three pots was kept fallow while another three pots were planted to white clover and perennial ryegrass. After 5 months (October to March), during which time all herbage clippings were removed, the top soil was analysed for organic phosphorus. There was no significant change in the organic phosphorus content in the fallowed soil, but under the ryegrass-clover sward the organic phosphorus had increased by an amount corresponding to about 17 per cent. of the fertiliser phosphorus added.

This result shows that the poor recovery of the applied phosphorus in the inorganic fraction in the soil under the 6-month pasture may have been partly due to the change of fertiliser phosphorus into organic form. Of greater general interest is the indication that in this soil type, under pasture, the change of applied phosphorus into organic form may be rapid, especially when the organic phosphorus returned to the soil in dung is taken into account. In the pot experiment the organic phosphorus increase, can only have come from plant remains and microbial synthesis.

A further comparison was made between two virgin soils and three under 20-year-old pastures, all from Ngakuru district. Again the main increases in soil phosphorus were in the top 2in. In Table I are given the phosphorus contents of the, 0 to 2in. layers of the soils under 20 year pasture, the average of the two virgin soils and the phosphorus increase in the soils under pasture based on average phosphorus contents of the two virgin soils. These increases are biased because the lack of ploughing of the virgin soils tends to reduce the increases in organic and total phosphorus but not in inorganic phosphorus.

All three soils under pasture showed increases in total, organic and inorganic phosphorus considerably greater than was found in the soil under the 12-year-pasture previously described. In soils A and B the percentages of the, total phosphorus increases in organic form were about the same as for the 12-year

pasture when compared with the virgin soil. Soil C showed a much greater increase in organic phosphorus, both absolutely and relatively. The two former soils both came from fields. carrying pastures beginning to run out, though still quite good, whereas soil C was from a paddock used, but not regularly so, as a night paddock and carrying a very high-producing pasture—the best on the farm. It was under this pasture that the greatest accumulation of organic phosphorus had occurred ; this correlation between high organic-phosphorus content of the soil and good plant growth agrees with the results for the virgin soil growing vigorous manuka and bracken. The main difference between the pattern of the phosphorus increases of the soils under 12- and 20-year. pastures was the greater increases in inorganic phosphorus under the older pastures.

DISCUSSION

The above results indicate that in virgin Taupo sandy silt, the phosphorus supply is relatively low owing to a low phosphorus content enhanced by a low soil volume weight of about 300,000lb. per 2in. acre. Organic phosphorus is the greater fraction at all depths down to about 9 inches. When this land is laid down to grass and farmed to stock there is a build-up of phosphorus, mainly in the top 2 inches; the accumulated phosphorus is largely organic in younger pastures but with increasing time inorganic phosphorus may also increase. Further, the more abundant the vegetation the relatively more important is the organic phosphorus fraction.

A possible explanation of the differing increases of organic phosphorus may be found in the nature of soil organic phosphorus itself. In the presence of hydrolysing enzymes (phosphatases) known to be present in the soil, the organically bound phosphorus can be rapidly split off. Organic phosphorus is stabilised in the soil by being either absorbed by the soil colloids or precipitated as insoluble salts and so protected from enzymatic attack. That is, the soil "fixes" organic phosphorus. It appears reasonable to postulate an organic phosphorus "fixing capacity" in the soil 'and also, as organic phosphorus accumulates, that the stability of added: increments will decrease as the capacity is approached. Consequently the rate of accumulation will progressively decrease until equlibrium is reached when the rate of supply is equalled by the rate of enzyme-catalysed hydrolysis.

The soils under the 20-year-old pastures all contained greater amounts or organic phosphorus than did the 12-year pasture soil. It is possible that under the older pastures, the organic phosphorus had more nearly approached equilibrium and that the rate of accumulation of organic phosphorus had so decreased that it was less than' the rate of addition of inorganic phosphorus, in fertiliser and dung. The above hypothesis accounts for the small accumulation of inorganic phos-

phorus in the soils under the younger pasture and the greater accumulation under the older pastures.

Organic nhosahorus 'in the soil comes from microbial synthesis, plant 'remains, and animal excrement, principally the dung. Microbial synthesis is dependent mainly on the amount of energy material-supplied to the soil micro organisms in plant remains. Thus the rate of supply from all three sources, and the rate of accumulation, can be expected to be greater under good pastures as compared to poor. The higher rate of 'supply of organic phosphorus, due to the better pasture growth, probably accounts for the greater accumulation of organic phosphorus in soil C and in the virgin soil growing more vigorous manuka and bracken.

Conversely, anv factor which limits plant growth will tend to limit organic phosphorus accumulation. 'in alluvial soil derived from Taupo ash, Whenuaroa sandy silt, which was carrying a very poor pasture was found to be low in potash. The total. inorganic. and available nhosahorus were very high but the organ& phosphorus was relatively much lower than was found in the Taupo sandy silt under good pasture. It is probable that lack of potash was the cause of the poor pasture which in turn was limiting the supply of organic phosphorus. The difference in soil type weakens this conclusion. However, it is supported by two further observations. Firstly, the correlation between low potash and high available phosphorus in varying soil types has been noted by other workers. Secondly, the organic carbon/organic phosphorus ratio (C/P) in this soil was found to be 97 (0 to 4in.) as compared 'to 114 to 137 in the soils under good pasture. American work indicates that as organic matter decomposes, the organic phosphorus is decomposed less rapidly than is the organic carbon and consequently the C/P ratio decreases. The lower C/P ratio indicates either a declining organic matter content or a slower build up than in the higher producing soils.

Organic phosphorus is generally considered to be relatively unavailable to plants, However, availability studies have commonly 'been carried out with arable soils. in which, owing to regular cultivation the soil organic matter and organic phosphorus are decreasing, the residues becoming progressively more inert. It is not known whether organic phosphorus in pasture soils is unavailable to the same extent. If the equilibrium concept is sound it can be expected to be essentially unavailable during the early stages of accumulation under pasture. That part at least of the organic phosphorus is very stable is indicated by the shape of the curve for organic phosphorus in the soil under the 12-year pasture (Fig. I). The organic phosphorus was disproportionately high in the 4 to 6in. layer indicating that some of the original surface organic phosphorus ploughed down to this level had remained unchanged for about 11, years. This evidence together with the fact that organic phosphorus does accumulate in these pumice soils under pasture, suggests that biological fixation does account in great degree for the low availability of accumulated fertiliser phosphorus.

Overseas work has shown that microbial synthesis- of inorganic phosphorus into organic form takes place rapidly if the supply of energy material is adequate. It appears possible that topdressing of soluble phosphates on pasture may be an

ideal method of ensuring that applied phosphorus is biologically fixed by the soil micro-organisms since by this method the phosphorus is finely distributed in that zone of the soil which contains the greatest proportion of energy material.

No investigations have been made concerning methods of reducing biological fixation. It is probable that liming, which by raising the soil pH reduces the fixation of organic phosphous by the soil colloids, periodic cultivation to hasten the decomposition of organic matter, and the placement of non-water soluble phosphates below the organically rich top soil offer the best avenues of approach.

Table I-Total, organic and inorganic phosphorus in the top 2in. of Taupo sandy silt, deep subsoil phase, virgin, and under pasture for increasing periods of time.

PHOSPHORUS

(Percentage of oven-dry (105 degree C.) soil

Soil history	Total		Inorganic		Organic		Increase as percentag of total increase
	Amount	Increase	Amount	Increase	Amount	Increase	
		YOUNGER PASTURES (WAIKITI VALLEY)					
Virgin	.076 (2660)	—	.017 (580)	—	.059 (2080)	—	
6-month pasture	.068 (2370)	-.008 (-290)	.031 (1070)	.014 (490)	.037 (1300)	-.022 (-780)	—
12-year pasture	.104 (3610)	.027 (950)	.036 (1240)	.019 (660)	.068 (2370)	.008 (290)	30
		OLDER PASTURES (NGAKURU)					
Virgin (Average)	.074 (2580)	—	.014 (490)		.060 (2090)		
20-year pastures							
A.	.124 (4330)	.050 (1750)	.050 (1750)	.036 (1260)	.074 (2580)	.014 (490)	27
B.	.157 (5460)	.083 (2880)	.071 (2470)	.057 (1980)	.086 (2990)	.026 (900)	31
C.	.182 (6330)	.108 (37511)	.063 (2190)	.049 (1700)	.119 (4140)	.059 (2050)	55

*Pounds per acre of superphosphate containing 20 per cent. P_2O_5.

DISCUSSION

Q. To what extent does organic phosphorus build-up, as observed in pumice soils, occur in other soil types?

A. It was at first thought that the build-up would occur in all soil types where pasture was topdressed: with superphosphate. However, the figures quoted by Dr. Davies for organic phosphorus in a Taranaki soil indicated that differing soil types might behave differently.

Q. What work has been done on the releasing of the tied-up organic phosphorus ?

A. Very little work has been done and as far as is known no field work or Laboratory work had shown that raising the soil pH by liming tended to reduce the fixation of some forms of organic phosphorus. There is also evidence that raising the soil temperature accelerates the release of organic phosphorus. Surface cultivation is likely to be a good practice as this hastens the decomposition of organic matter and organic phosphorus. However, this should not be carried too far, as the organic phosphorus residues become progressively more stable.

Q. What are the. possibilities of releasing organic phosphorus by spraying with organic acids ?

A. 'Not too good. Such acids might temporarily release the phosphorus, but are themselves carbonaceous and would soon be destroyed by the soil micro-organisms.

Dr. Melville commented that in every paper presented phosphorus had been mentioned. Mr Burgess and Dr. Davies had mentioned 500.000 acres of land containing the eauivalent of 13 tons of sup&phosphate per acre,, much of which- was in the organic form. Mr Jepson had quoted 7cwt. of superphosphate per acre per year as being needed to maintain production. Of this probably 5cwt. remained in the soil. It was a majdr national problem to unlock the phosphorus already in the soil in which there was ample total phosphorus. If this could be done more phosphates would be available for those areas markedly deficient in phosphorus.

Mr Iversen commented that this 'ieleasing of the soil phosphorus might be dangerous-the whole reserve might be exhausted.

Dr. Hamilton commented that there was a great lack of 'factual evidence as to the residual value of superphosphate and the requirements of superphosphate in maintaining production. In the case of a group of farms in the Whangarei district the reduction of superphosphate during the war years had not resulted in a fall in production. Further, there might be new and profitable methods of applying phosphate to pastures, such as spraying. This method might increase the phosphate availability as much as five times.- The East Malling Research Station, England, in response to an inquiry, had replied that sprayed phosphate would be absorbed very quickly by the plants.