OUR PRESENT KNOWLEDGE OF THE VALUE OF ROCK PHOSPHATES.

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INTRODUCTION:

Before discussing such information as is available regarding the effectiveness and use of rock phosphates in New Zealand, a few remarks relative to the world's consumption of phosphate in different forms and the factors influencing the availability of rock phosphate, etc., will not be out of place.

This brief paper does not pretend to review all the information available. As many publications bearing on the matter as time would permit were consulted. One of the difficulties in interpreting published articles is that much of the information available is derived from laboratory and glasshouse studies which entail standardisation of conditions and consequently do not take into account the variable effects of soil and climate.

World Production:

Gray (1) estimates a production of approximately 10½ million metric tons of phosphate rock in 1929. About 80 years prior to this, in 1847, only 500 tons were mined. At least 95% finds its way into agriculture for use, directly or indirectly, as fertilizer. Of the total phosphates in terms of phosphoric acid (P_2O_5), about 69% is used as superphosphate, 22% as basic slag, 3.0% as ground rock phosphate, and the balance of 6% as various concentrated and bone fertilizers, Guano, etc.

Availability of Rock Phosphates:

Experience in the use of rock phosphates from various sources indicates considerable variation in availability and while it is recognised that fineness of grinding has an important bearing on availability, other factors also influence it. Discussing the influence of fineness of grinding Robertson (2) considered that the total citric solubility decreased by 10% for each of the gradients:- passes 100 mesh sieve, refuses 100, refuses 60, refuses 30 mesh sieve.

Robertson (3) states that the composition of the phosphate in various important materials to be as follows:

Makatea Is. Phosphate	$2Ca_3P_2O_8 . CaO$
Florida pebble Phosphate, Tunisian Phosphate	$4Ca_3P_2O_8 . 3 CaO$
Algerian Phosphate, Gafsa ", Belgian "	$Ca_3P_2O_8 . CaO$
Apatite	$3Ca_3P_2O_8 . CaO.$

The substitution of Fluorine or Chlorine for the oxygen in the CaO may occur in varying degrees with the result that the greater the amount of Fluorine the less the solubility in citric acid. Further, the higher the amount of lime actually entering into the phosphate compound the higher is its citric solubility (2). In a further publication (4) Robertson states it is his opinion that the citric acid solubility test is worthless as a means of judging the relative value to plants of phosphatic manures. In explanation, he points out that Belgian and Tunisian phosphates, with which he worked, were completely soluble in citric acid if enough acid is used and enough time is spent in the extraction; and if the fact that the process of solution in the soil is a continuous one is considered, then the reasons why so-called "citric insoluble" phosphates give as good results under some conditions as high citric soluble slags are readily understood. He produces evidence from field results at Cockle Park indicating that Belgian phosphate, having only a trace of citric soluble phosphate, as measured by the standard method, gave as good results as high citric soluble basic slag.

The Influence of Fluorine Content:

To return to the influence of the Fluorine content of rock phosphate on its availability, Bartholomew (5) found from pot experiments that "the availability of the phosphorus in phosphate rocks is very closely associated with their fluorine content," there being a general trend for the availability to decrease as the percentage of fluorine in the rock increases. From his results, Bartholomew concluded that "it appears evident that only those phosphate rocks low in fluorine content should be used as direct phosphatic fertilizers."

The phosphates with which this worker experimented and their fluorine contents were:- Curacao .41 and .70% F.; Christmas Is., 1.32%; Nauru Is., 2.1%; Ocean Is., 2/97%, and Tennessee brown rock, 3.79% of fluorine. To what extent the fluorine content of any deposit varies and just how such variation may influence the availability of the phosphate to plants would appear to be a matter for conjecture, Gray (1) quotes an analysis of Christmas Is. phosphate as showing 0.54% of fluorine compared with the 1.32% found by Bartholomew. Also, Gafsa phosphate quoted by Gray (1) as containing 2.46% fluorine is regarded in New Zealand as being more readily available to plants than Nauru, although admittedly the evidence is based on general experience rather than on critical trials and may be influenced by differences in fineness of grinding.

Effect of Soil Acidity on Availability:

In reviewing the effects of rainfall and soil acidity on the results from English experiments on grassland, Robertson (6) says "It would seem that on "sour" soils well supplied with organic matter and situated in districts with a moderately high rainfall, rock phosphates may give even superior results to those secured from basic slag.! Slags of high citric solubility are referred to. Bartholomew (5), however, is more reserved in his conclusions, pointing out that, although he found no close relationship between increased soil acidity and availibility of phosphorus in phosphate rocks, there is some tendency for the availability of the phosphorus to increase with an increase in soil acidity, although not in all cases. His studies indicated that it is only in extremely acid soils that the acidity of the soil may increase the relative availability. It should be noted that Bartholomew's studies were conducted under standard conditions of moisture and temperature and consequently the influence of differential moisture supply is eliminated.

Continental investigators claim that the use of mineral phosphate in combination with physiologically acid manures such as sulphate of ammonia is an advantage (7).

Effect of Moisture Supply on Availability:

There aypears to be very little definite data on the effect of moisture supply on the availability of rock phosphate to plants. Experience in New, Zealand points definitely to a well distributed rainfall of about a minimum of 35 inches per annum being necessary for the successful use of such fertilizers. Rainfall in itself is apparently not sufficient, a necessary accompaniment being a soil of a fairly high moisture-retaining capacity and aoid in reaction,

The Influence of Organic Matter:,

To the extent that the carbon dioxide produced has a slight solvent action 'on soil minerals, the presence of a good supply of organic matter would appear to influence the availability of rock phosphate. Jenkins (8) points out that availability tests on insoluble phosphates as influenced by organic manures seem to lead to conflicting conclusions according to whether the measure. of availability is the amount of soluble phosphate produced under standardised conditions on the one hand, or the recovery of phosphorus in the crop on the other. He quotes interesting results obtained by Lyon and Buckman on the comparison of superphosphate with rock phosphates in the presence and absence of farm-yard manure. These workers found that the availability of superphosphate was independent of the presence of farm-lard manure but the effect of insoluble phosphate on yield was greatly increased by the presence of organic manure,

The Effect of Liming on the Availability of Rock Phosphate:

In investigating the results of extensive experiments with phosphates, Roberts, as quoted by Ames & Kitsuta (9), found that on some soils rock phosphate appears to be as effective as superphosphate on limed soil. In other cases lime has reduoed the efficacy of rock phosphate, He suggests that the addition of lime far enough in 'advance of the use of rook phosphate to permit of the disappearance of calcium carbonate as such might be a solution of the difficulty when lime interferes with the availability of rock phosphate.

Roberts also states that where lime alone produces a significant effect compared with super alone, rock phosphate seems to function well in the presence of lime. Where lime alone produces small effects compared with super alone,, lime seems to depress the effect of rock phosphate,

Ames & Kitsuta further suggest that if rock phosphate is rendered available according to the reaction:

$$Ca_3(PO_4)_2 + H_2CO_3 \quad Ca_2H_2(PO_4)_2 + Ca(HCO_3)_2$$

then the effectiveness of insoluble'phosphates will depend on soil conditions affecting solubility, among which is supply or absence of calcium carbonate. If calcium carbonate is present in sufficient quantity, no appreciable amount' of di-calcium phosphate will be produced and the availability of the phosphate will be depressed. They then state that "Some of the numerous field tests with phosphate under different conditions have indicated that rock phosphate is more effective on acid soil, while other tests show that better, returns were obtained on limed soil." They present data in illustration of this. Cases have been observed in New Zealand, notably at Dargaville, Te Kumi, and near Paraparaumu, where liming has definitely reduced the effect from rock phosphate compared with phosphate alone.

The Effect of Rock Phosphate on Soil React-

Smith (10) used up to 1,000 lb. of rook phosphate in the field and found that under a 5-year rotation and over a period of 5 years both superphosphate and rook phdsphate tended to decrease the acidity but to an insignificant degree. In another experiment of shorter duration there was no apparent influence of either on the reaction of the soil. Doak (11) found a slight reduction in acidity of the top few inches of the soil at Marton following the application, over a period of 4½ years, of about 12 cwt. -of North African rock phosphate. This work is still proceeding,

EVIDENCE FROM FIELD EXPERIMENTS WITH VARIOUS ROCK PHOSPHATES IN NEW ZEALAND.

Nauru Rock Phosphate:

With the development of the phosphate deposits on Nauru and Ocean Islands by the Empire countries subsequent to the War, a certain amount of experimental work was conducted with Nauru raw rock-phosphate. In view of the very high phosphate content of this material it was naturally concluded that good results would be obtained, especially after Scott-Robertson, working on North African rock phosphates, had indicated the value of the latter when finely ground,

Observational trials with Nauru on pasture, except in one or two instances, failed to give any indication that phosphate from this source was as good. as superphosphate or slag even when applied at the same weight per acre, and hence at about twice the amount of phosphate as the latter two.

Patterson at Te Kumi, in the Auckland Province, (12) commenced haying trials in 1920 in which Nauru phosphate was compared with other phosphates applied at 3 cwt. annually on limed and unlimed ground respectively. The plates were cut and weighed for four years, the yields from Nauru phosphate always being lower than those from superphosphate, although about equal to basic slag. The production from Nauru plus Lime was much below that from Nauru alone. The botanical composition of super and slag, however, was always superior to Nauru, or Nauru plus Lime, and this, as judged by observation, was in evidence right through the history of the trial, which terminated in 1935.

Nauru rock phosphate was included in several subsequent pasture topdressing observational trials. Out of five reported on by Smallfield (13) Nauru was distinctly infe-rior to super or slag in four, and, while in the remaining one it was judged to be equal to super, it was not up to the standard of basic slag.

Nauru was not as effective as other phosphates in three trials conducted in the Wellington Province, one of which was measured by means of hay weights. In one trial in Westland, however, Nauru consistently gave results at least equal to super alone, but it is of interest to record that at this centre a very high lime response was recorded and Nauru with lime was about equal to super and lime and much superior to Nauru alone.

Seychelles "Guano:"

Although this phosphate does not come under the heading of rock phosphates in the accepted sense, its effects arc sufficiently similar to warrant inclusion here.

This material retains a certain amount of popularity, particularly in the higher rainfall areas of the South. It was included in two haying trials in Southland carried out in 1927-28, and while giving yields equal to super in one experiment at Brydone, it was inferior to super at Thornbury.

Since then, thirty-one observational experiments have been conducted but in only five (including three in Otago-Southland) has it given results judged to be equal to superphosphate. In the remainder (six of which were in Otago-Southland) indications were that the quicker-acting phosphate was the more efficient in promoting more growth of a better type of pasture.

Egyptian Phosphate:

Ephos: This k pho-sphate was one of the first to be put on to the New Zealand market and was commonly used for several years on arable crops in Canterbury but has since been replaced largely by superphosphate. Following a series of top-dressing trials in Wellington and Southern Hawke's Bay districts, including some experiments in which hay weights were measured, McCulloch (14) indicated that Ephos was less effective than slag or superphosphate.

North African Phosphate:

Gafsa Phosphate: Considerable quantities of Gafsa phosphate were imported during the years 1928-1931, but these imports fell off during the general reduction in topdressing in the next few years. Gafsa is sold undervarious trade names, and thus in some cases is confused with Moroccan phosphate, which is also imported to a certain extent.

In the report on the topdressing trials in Auckland province referred to previously (13) Gafsa (referred to as North African) was included in eighteen experiments. It was stated that the results from rock phosphates were generally inferior to superphosphate or slag and the records revealed that in only two trials was Gafsa considered equal to both the above.

In twelve other observational trials, including four in Wellington Province, five in Canterbury, and three in Southland, it has not been regarded as being as efficient as superphosphate, although there were two trials in which Gafsa was equal to super.

In the foregoing trials the merits of rock phosphates as compared with super were based chiefly on growth and pasture composition from observational plots visited about four times, during the year.

Mowing and Grazing Trial with North African Phosphate:

With the object of obtaining accurate data on the yield obtained from North African phosphate, superphosphate, and basic slag respectively, a trial under the alternate mowing and grazing technique (15) was established on pasture at Marton Experimental Area in 1932. The above fertilizers were applied at amounts which provided equivalent quantities of phosphate so that as superphosphate was put on annually at 4 cwt. per acre as control, North African was applied at 350 lbs. and basic slag at 612 lbs. per acre (each supplying 93.5 lbs. of P_2O_5 per acre per annum.) Half of each of the above quantities was applied in the autumn (April) and half in early summer (late December) except in the first year when applications were made in September instead of early summer.

On half of the plots applications of carbonate of lime were made ; 1 ton at the 'commencement of the trial and 3 cwt. annually.

A comparison of the yields of dry-matter in lbs. per acre from each treatment on lined and unlined ground respectively is given for each year in the following table:-

TABLE I: Yields of dry matter in lbs. per acre from North African Phosphate, Superphosphate and Basic Slag at Marton Experimental Area.

Rain-fall. Ins.	Period.	Unlimed Plots, Super	Unlimed Plots, N. African.	Unlimed Plots, Slag	Lined Plots, Super	Lined Plots, N. African	Lined Plots, Slag,
31.9	30/9/32 to 14/9/33	8185	7343	7841	8642	7560	8001
	(relative, yields) .	100	89.7	95.8	105.6	92.4	97.7
34.7	14/9/33 to 13/9/34	7955	7440	7504	8799	7842	8197
	(relative yields . .	100	93.5	94.3	110.6	98.6	103.0
38.9	13/9/34 to 20/9/35	9382	[illegible]	9343	[illegible]	9234	9228
	(relative yields)	100	95.0	99.6	103.4	98.4	98.4
43.7	20/9/35 to 25/9/36	12.384	12042	12745	13619	12608	12871
	(relative yields	100	97.2	102.9	110.0	101.8	103.9
	Part Year:						
28.2	25/9/36 to 13/5/37	9726	9302	9690	9893	9531	9579
	(relative yields)	100	95.6	99.6	101.7	98.0	98.5
	TOTAL	47631	45036	47123	50649	46775	47876
	(Relative Yields)	100	94.6	98.9	106.3	98.2	100.5

Comments on -Table I:

For ease of comparison the relative yields (superphosphate = 100) have been given in the table and. the annual rainfall figures as recorded at Bulls, a few miles away, have also been included. A feature of the relative yields of North African phosphate on unlined ground is the progressive improvement except. in the last uncompleted period. This may be due either to the residual effect of earlier dressings of the North African (although it should be borne in mind that an equivalent quantity of phosphate is applied in each treatment) or to the higher rainfall which has occurred during the later years of the trial. The same trend is to be noted in the case of slag and in view of the generally accepted ideas that both slag and rock phosphates are more effective in higher rainfall districts the latter alternative may be the main factor responsible for the improved performance of these fertilizers at Marton. A continuation of the trial for a few more years should throw further light on this aspect. There is a further possibility that. increased organic matter in the surface layer of the soil, which must result from the intensive system of management, may be influencing the availability of the insoluble phosphates.

A consideration of the total yields during the 4½ years of trial indicates that on unlimed ground super is at least as effective' as slag and is 5.4% more effective than N. African phosphate. On limed ground the superiority of super over the other phosphates is more marked,

The Need for more Critical Research:

It is a matter for regret that, in view of the importance of phosphatic fertilizers to New Zealand, no serious attempt has yet been made to carry out a thorough and critical study of the long range effects of phosphatio soil. An average soil contains. about 3,000 lb. of phosphoric acid in the top 8 or 9 inches. In the course of 50 years annual applications of about 160 lbs. of Nauru phosphate or 300 lbs. of superphosphate will add a further 3,000 lbs. In districts where such quantities are being regularly applied only a fraction is being removed in crops or by stock. What of the balance? For how *long* will such applications be necessary and remunerative? What, in the long run, is the best form in which to apply our phosphate? These are some of the questions with whioh we are already faced, and it is certain that the answers to these, which at present cannot be given, will be much more pressing in another 50 years. The only means whereby such question8 can be answered lies in the establishment of absolutely permanent experiments under different conditions of soil and climate. *Such* data as is at present available in this country is provided by experiments of short duration only. The weight of such evidence favours the use of readily available phosphates. Long-term investigations may emphasise their value still further, but one.. must not lose sight of the possibility that other forms of phosphate may prove more desirable over a long period of years. The point is that we do not know and it is necessary that we should obtain the information.

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DISCUSSION ON TWO PRECEDING PAPERS.

R. CAMERON, DUNEDIN.

The Otago district varies so greatly in climatic conditions and soil types that it is very difficult in the short space to give detailed descriptions of the various manurial practice8 adopted by farmers) and the response to fertilizer treatment.

Dr.' Hilgendorf's vegetation map show8 that there is very little first class land in Otago, the great bulk of the *sown* grasslands being second and third class country, carrying dominant brown top swards, the largest proportion of which are found *in* South Otago..

In general, this class of country is very lime deficient, and **sown** out pastures usually deteriorate in three or four years, reverting eventually to dominant brown top.

The treatment of this class **of** country before **the** days of motor transport presented great diffioulty, as lime was absolutely essential for its improvement. Metalled roads, coupled with motor transport, have, however, brought lime within the reach of the great majority of farmers in South Otago. I think I can safely say , without fear of contradiction, that much money and time was wasted in the topdressing of pastures before adequate liming was possible,. and this led to the belief whioh is still prevalent in many districts that fertiliser treatment is not profitable. My experience shows that the great bulk of the brown top country can be built up to carry excellent swards of cocksfoot, rye, white clover pastures,when adequate liming and consistent top-dressing are undertaken.

On some of the better class tussock country in South Otago, outstandingly good results are being obtained where lime, plus super, has been applied along with a surface sowing of English grasses. The palatability and growth of both native and English grasses has been increased, enabling the carrying capacity of the tussock lands to be considerably improved.

We now turn to Central Otago. The rainfall in certain districts is fairly adequate, but the great bulk of the area is arid and to obtain results water is necessary.

Even under irrigation one gets conflicting results; for instance, in one or two districts no result can be seen by topdressing with any type of fcrtiliser. But in general, splendid results are being obtained from the use of superphosphate. With the exception of limited areas the use of lime does not appear necessary.

MR.. C. C. LEITCH, TIMARU.

Messrs. Woodcock and Hudson appear to have covered the ground **very** fully indeed in regard to insoluble phosphates.

In dealing with the position in regard to insoluble phosphates as far as Otago is concerned, some of the first topdressing done by farmers was with mineral phosphates, and there is evidence to support my statement that, in the main, the response obtained was very disappointing.

In fact, in areas enjoying a fair annual rainfall only the no&response had' the effect of putting the topdressing of grassland in ill repute, and it took years of constant effort to persuade users that the wrong type of phosphatic fertiliser had been used in the first instance.

However, when eventually the water soluble phosphate was used, the response was, in general, excellent.

In thinking of insoluble phosphates; one would associate their use on lime deficient soils enjoying a high annual rainfall, and 'in Otago the only district falling in this category is South Otago.

Here liming is proving of such immense benefit that adequate quantities of lime are being applied as quickly as possible.

Although mineral phosphates and phosphatic guanos have been tried out in conjunction with lining, when topdressing grassland, results have 'not by any means been satisfactory. After the first experience users generally prefer to use super, or super plus the insoluble phosphate previously used, which goes to show that the water soluble phosphate gives by far the best all-round response when applied as a surface dressing to grassland.