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FACTORS CONTROLLING THE EFFICIENCY OF ROCK PHOSPHATES FOR POTATOES AND RYE ON HUMIC SANDY SOILS

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INTRODUCTION

The results obtained in experiments and in farming with rock phosphate applied to any given crop on acid humic sandy soils are very variable. These variations are mainly due to relatively small differences between the soils. For practical reasons it is important to distinguish between soils suitable and unsuitable for the efficient use of rock phosphates.

It has generally been accepted that rock phosphates are converted into 'soil phosphate' by a direct 'decomposing' action of the soil. However, Butkevich [1] had claimed that the availability of rock phosphates to crops is not primarily due to the action of soil acidity in breaking them down. For several reasons he considers the soil a medium which determines the interaction of the plants with the rock phosphate rather than a factor operating directly in its decomposition. Thus, soil properties are important only in so far as they determine the capacity of plants to disintegrate the rock phosphate. According to this author the idea that the availability of rock phosphate depends on the entry of this phosphorus into the soil solution must be considered as an oversimplification of the problem.

This may hold for the conditions under which the problem has been studied in Russia. But it still is possible that the degree to which the content of easily soluble phosphorus in the soil is increased by the application of phosphate is a dominant factor regarding its efficiency to the main crops grown on the acid humic sandy soils in temperate humid climate. Potatoes, rye, and oats are known to have a low mobilizing activity in regard to rock phosphates. Nevertheless an effective use of these fertilizers can sometimes be made. It is known from our own experience that the phosphorus uptake of these plants is mainly determined by the content of watersoluble phosphorus of the soil[3].

The present investigation was made in order to elucidate the role of soil factors. It was continued for two years as it is often claimed that the efficiency of rock phosphate increases in course of time.

EXPERIMENTAL

Experiments in Mitscherlich pots were conducted in 1959–1960. Direct and residual effects of fertilizers were studied. The pots stood outdoors also during the winter.

1. *Fertilizers*

A soft North-African rock phosphate (Gafsa phosphate, trade mark Hyperphosphate Reno) having a microcristalline structure and a hard Florida rock phosphate were used for comparison with pure monocalcium phosphate.

The rock phosphates were obtained from the International Association for Research on Phosphates (A.I.E.P.) in Paris. The analysis of these phosphates (products A and C) of A.I.E.P.) is given in Table 1.

TABLE 1

Extract	Gafsa phosphate	Florida phosphate
P_2O_5 in mineral acid	26.4%	34.0%
P_2O_5 in formic acid *.	21.1	6.8

* 2,5 g phosphate + 250 cc formic acid 2 %.
½ hour rotation at 18°.

The phosphates were used in triplicate, in amounts corresponding to 0, 0.31, 0.93 (monocalcium phosphate only), 1.86, and 3.72 g P_2O_5 per pot (being equal to 0, 100, (300), 600, and 1200 kg/ha P_2O_5), applied at the start of the experiment only, thoroughly mixed with the soil.

The basic treatment was:

with potatoes in first year	1.5 g NH_4NO_3 1.0 g K_2SO_4 1.23 g $MgSO_4.7aq$	with rye:	0.7 g NH_4NO_3 0.5 g K_2SO_4

in second year	1.43 g NH_4NO_3	0.86 g NH_4NO_3
	1.11 g K_2SO_4	0.56 g K_2SO_4
	1.85 g $MgSO_4.7aq$	1.85 g $MgSO_4.7aq$

Each pot contained about 6 kg of soil.

2. *Soils*

Six soils were taken from experimental fields on humic sandy soils originating from heath reclamations in the province of Drente.

Considerable differences in phosphorus fixing capacity appear from the very different ratios between the contents of water-soluble phosphorus * and that soluble in AL-extract ** (Table 2).

These differences are attributable to the different methods of reclamation. 'Black soils' with a low phosphorus fixing capacity usually originate from older reclamations when the soil was tilled superficially. They contain the old heath turf (A_0), the dark A_1 soil and the bleached sand (A_2). 'Brown soils' are generally younger and were turned more deeply. The upper part of the B-layer was ploughed up and mixed with the A-material to different extents.

TABLE 2

Analysis of soils

Soil	Humus %	P-water 0.001%	P-AL 0.001%	Ratio P-w./P-AL × 100	pH-KCl ***
1	11.1	3.7	12.9	28.7	3.77
2	5.2	1.7	7.6	22.4	4.13
3	7.6	5.3	42.4	12.5	4.36
4	6.8	0.5	13.1	3.8	3.99
5	6.7	1.0	34.3	2.9	4.98
6	6.3	0.9	31.8	2.8	4.49

In the three soils with a low fixing capacity the pH–KCl varied between 3.77 and 4.36. In the other with strong fixation, it was 3.99, 4.49, and 4.98 respectively.

The soils are tabulated in the sequence of increasing P-fixing capacity (1–6). The variation in the ratio, P-water/P-AL, between 28.7 and 12.5 in the slightly fixing soils is possibly also due to the differences in pH, as may also be the variation between 3.8 and 2.8 in the strongly fixing group.

The relatively high P–AL values of the Soils 3, 5, and 6 suggest the presence of fairly large residues of phosphorus. The other soils are poor in phosphorus. A rather high P-water value was found in Soil 3 which accounts for the

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* Extraction of 1 part of soil with 10 parts of water at 50°C in 24 hours.

** Ammonia-lactate-acetic acid, according to Egnér, Riehm, and Domingo [2].

*** Averages of determinations in soils not dressed with phosphate.

relatively weak response of the crops on this soil. The stock (P–AL) was small in Soil 1, the P-water was relatively high; the deficiency was less pronounced than in the other soils (except 3).

3. *Crops*

Potatoes (Bevelander) followed by rye (Petkuser) were grown in succession in both years. After a few weeks the shoots were cut in a green state.

Young potato sprouts, separated from the seed potato, were planted in the pots (7 in 1959, 9 in 1960). 22 and 21 rye plants were grown respectively.

4. *Yields and analyses*

Yields of dry matter were determined for each pot separately, but the determination of N and P_2O_5 in the crop was performed after pooling the crops from the replicate pots. In both years soils were analysed at the start of the experiment and before rye was sown.

RESULTS

1. *Efficiency of phosphates in relation to fixation capacity and pH of soil*

a. Monocalcium phosphate. The rise of the P–AL value due to the application of monocalcium phosphate proved to be only slightly affected by the kind of soil in this experiment.

Much more pronounced differences between soils were found by water extraction. With a dressing of 600 kg P_2O_5 per ha the P-water value rose by 13, 14, and 10 units respectively on the weaker fixing soils and by 1.5, 1, and 1 units on the strongly fixing soils.

The importance of these difference is clearly demonstrated by the different response of crops to a fertilization with phosphorus. As might be expected the increase of yields and P_2O_5 content of the plants effected per unit of P fertilizer was considerably lower on the soils with a high fixation capacity (Fig. 1).

The effect of pH on the efficiency of monocalcium phosphate can be determined provided the fixing capacities of the soils are equal. This is approximately the case with the brown Soils 4 and 5, where pH–KCl amounts to 3.99 and 4.98 respectively.

The effect of monocalcium phosphate on the P-water value was equal in both cases. Dressings with 600 and 1200 kg P_2O_5 per ha in this form increased the P-water value with 1.0 and 3.9 units respectively (averages of determinations at 3 dates).

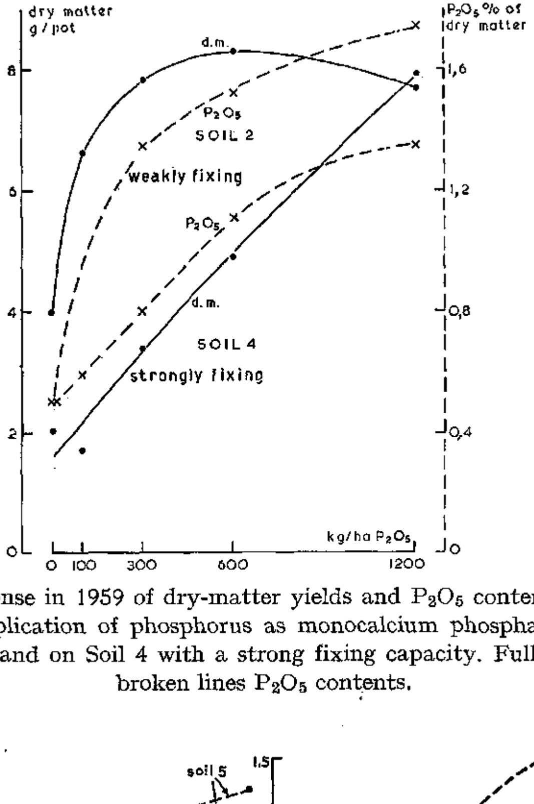

Fig. 1. Response in 1959 of dry-matter yields and P_2O_5 contents of potato shoots to application of phosphorus as monocalcium phosphate on Soil 2 with a weak and on Soil 4 with a strong fixing capacity. Full lines yields, broken lines P_2O_5 contents.

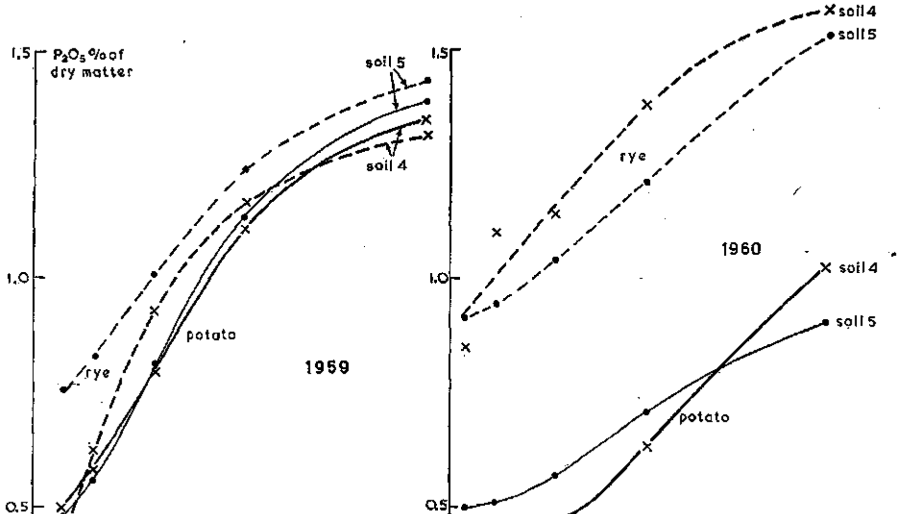

Fig. 2. Responses of P_2O_5 content of crops in 1959 and 1960 to supply of monocalcium phosphate on Soil 4 (pH 4.0) and soil 5 (pH 5.0).

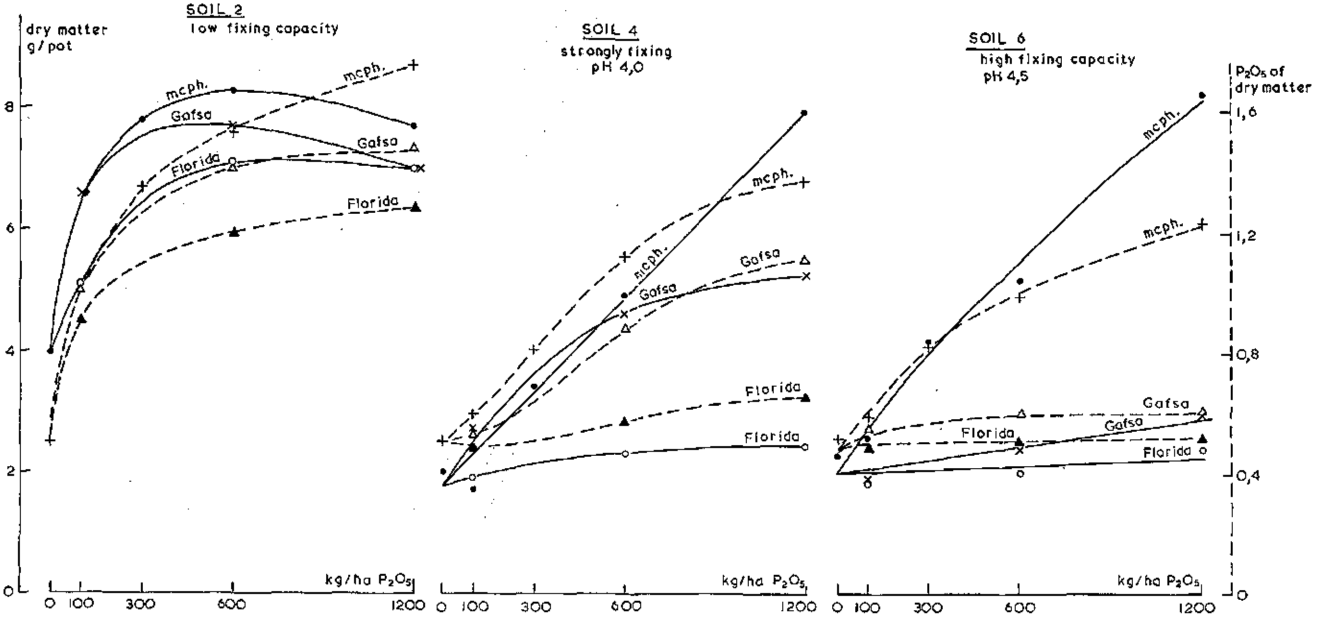

Fig. 3. Response of yields and P_2O_5 contents of potato shoots in 1959 to dressings with phosphorus as monocalcium phosphate and Gafsa and Florida rock phosphates on soil 2 with a low fixing capacity, and on the strongly fixing Soils 4 (very acid) and 6 (less acid).

The responses of yields and P_2O_5 contents of the crops to fertilization were rather similar in both soils (Fig. 2, the responses of the P_2O_5 contents only are shown). The P_2O_5 content of potatoes varied considerably between the two years.

It is concluded that the efficiency of monocalcium phosphate strongly depended on the fixing power of the soil but that it was little affected by pH in the range used in this experiment.

b. Rock phosphates. As is shown by a comparison between the responses in yield and P_2O_5 content of potatoes grown on different soils in 1959 the efficiency of rock phosphates depended on both the fixing capacity and the pH of the soil (Fig. 3).

On soil 2 with its weak fixation the effect of Gafsa phosphate almost equalled that of monocalcium phosphate (Fig. 3), and the effect of Florida phosphate was also rather satisfactory.

In the strongly fixing Soil 4 with pH slightly lower than Soil 2 the efficiency of monocalcium phosphate was much lower. However, Gafsa phosphate was not very much less effective than monocalcium phosphate though the P_2O_5 contents of the shoots were lower. The effect of Florida phosphate was weak (Fig. 3).

On the other strongly fixing Soil 6 with higher pH, monocalcium phosphate is as efficient as in Soil 4 but hardly any effects of the rock phosphates were found (Fig. 3).

These results justify the conclusions that the availability of rock phosphates for the crops apart of being more affected by the fixing capacity of the soil than that of monocalcium phosphate, also is much depressed by higher pH-values.

2. *Response of crops to rock phosphates in relation to the increase of the water-soluble phosphorus fraction of the soil*

It is known from our experiments that yields and P_2O_5 uptake of potatoes and rye are correlated closely with the content of water soluble phosphorus of the soil. This might suggest that the effect of rock phosphate on the phosphorus absorption of these crops may be controlled by the degree to which these phosphates are present in a water soluble form.

This has been investigated by correlating crop yields and contents and uptake of P_2O_5 with the P-water values of the fertilized soils.

For the sake of brevity only the relation with P_2O_5 contents

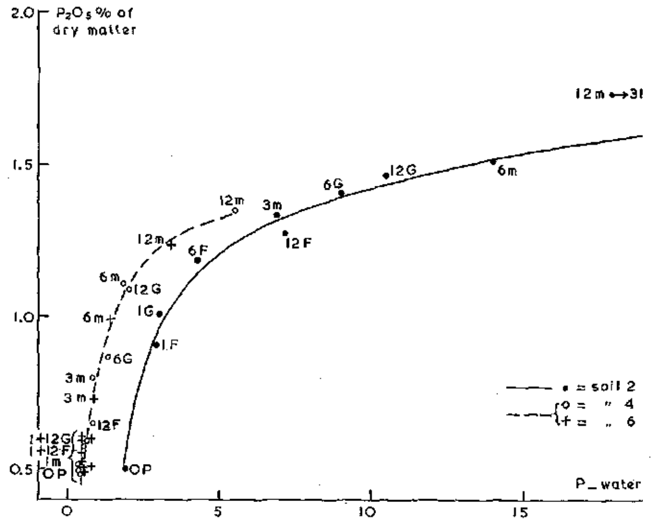

Fig. 4. Relation between P-water contents of soils dressed with different phosphates in varied quantities and P_2O_5 contents of potato shoots in 1959 on the strongly fixing Soils 4 and 5 and the less fixing Soil 2.

in the Soils 2, 4, and 6 will be described. The other results were very similar.

It is evident from Fig. 4, 5, 6, and 7 that the P-water values of Soil 2 (weak fixation and low pH) were increased appreciably by all fertilizers. In the strongly fixing soils 4 and 6 the increases of the content of water-soluble phosphorus were smaller. Relatively the increase effected by Gafsa phosphate was still considerable in Soil 4 but only small with Florida phosphate. On the less acid fixing soil 6 there was hardly any effect of the rock phosphates.

With rye in 1959 similar results were obtained (Fig. 5).

As slight analytical errors may account for the small deviations from the average curve of the separate dots it may be concluded that the degree to which the water-soluble fraction of phosphate in the soil was affected by the fertilizer, largely explains its effect on the plant.

The P-water values determined in the second year did not differ very much from the values found in 1959. Generally the figures were somewhat lower.

The relations between P-water values and P_2O_5 contents of dry matter in 1960 also agreed well with those of the first year.

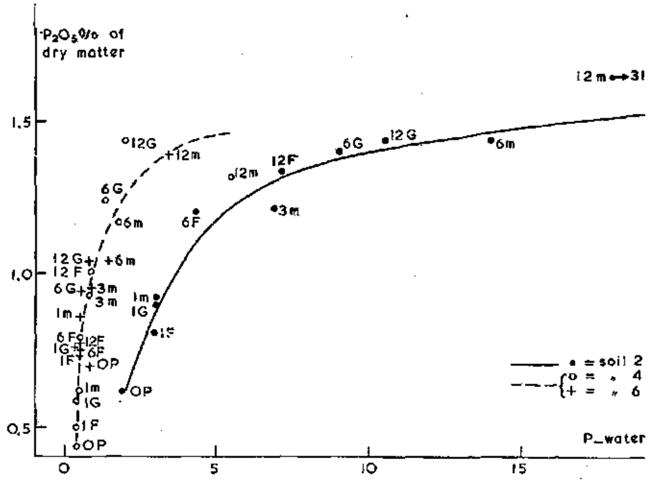

Fig. 5. Same as Fig. 4 for rye in 1959.

The curves now obtained with potato (Fig. 6) on the slightly fixing Soil 2 and on the strongly fixing Soils 4 and 6 are almost similar. There was a slight improvement in the availability of rock phosphates relative to that of monocalcium phosphate in Soil 4 (in 1960 12 G > 6 m, 6 G almost equals 6 m, the difference between 6 G and 3 m has increased). The effect of Florida phosphate was still very low in the fixing soils.

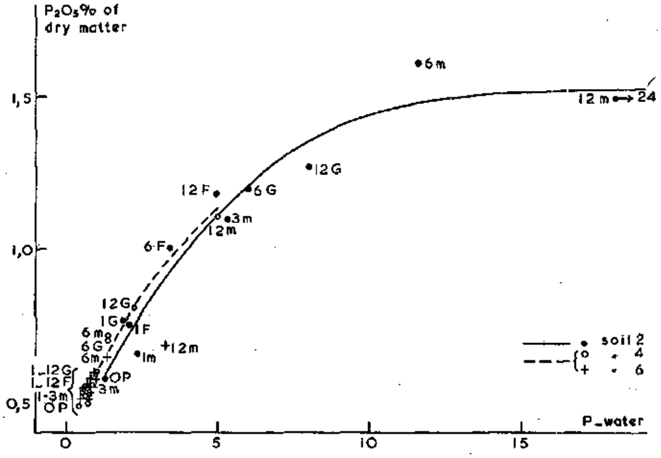

Fig. 6. Same as Fig. 4 for potato shoots in 1960.

The resulst with rye also confirm the preceeding ones (Fig. 7). The effect of Florida phosphate was slightly better than might have been expected from the P-water values.

A rather sudden jump of the P-value was found at the last soil test in Soil 4 treated with Gafsa phosphate. The P-water value with 1200 kg P_2O_5 per ha (12 G, open dot) improved from 2.3 (Fig. 6) tot 4.2 (Fig. 7) and equalled that obtained with aequivalent amounts of monocalcium phosphate (12 m). In agreement with this the P_2O_5 contents of the crop dressed with Gafsa phosphate were as high as those obtained with monocalcium phosphate. The reason why the solubility of the Gafsa phosphate should have improved so suddenly in this case is not understood.

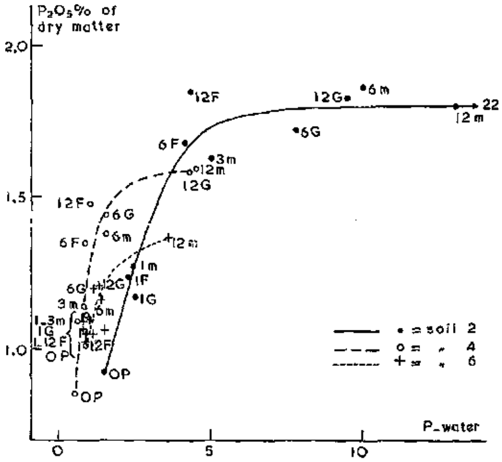

Fig. 7. Same as Fig. 4 for rye in 1960.

It is clear, however, that slight improvements of the availability of rock phosphates noticed in the second year have proceeded rather slowly. Besides, the improvement with rock phosphates in relation to monocalcium phosphate was partly due to a somewhat greater decrease in the content of water soluble phosphorus in the case of monocalcium phosphate (compare Figs. 7 and 5).

The degree to which rock phosphates were available in water-soluble form, must have been determined during the early contact of these phosphates with the soil. After the period of growth of the first crop, cultivated after the application of the phosphates, the solubility of the residues of the rock phosphates changed insignificantly.

For crops which can scarcely decompose rock phosphates, like potato and rye, the degree to which the rock phosphate is present in a water-soluble form determines the availability of these phosphates and their residues for these crops.

It seems not unlikely that the conversion into a more soluble form which takes place in course of time is due to the activity of micro-organisms.

Attention may be drawn to the difference between soils with strong and weak fixing capacities in respect to the relation between P-water values and crop responses. With the same P-water value more phosphorus is absorbed from the fixing soils (Figs. 4 to 7). Apparently a relative larger part is hereby taken up from the non-soluble fraction*. This is especially the case with rye, which perhaps may have a greater ability to absorb phosphorus from a fixed form than potatoes.

3. *Effect of pH and fixing capacity on the increase of the water soluble phosphorus fraction brought about by fertilization with rock phosphates*

Owing to the fact that the response of the crops to the application of phosphates depends on the effect of the latter on the magnitude of the water-soluble phosphorus fraction in the soil, the effect of pH and fixing capacity of the soil can be derived from the degree to which the P-water values are increased by these fertilizers.

The effect of these factors on the increase of the water-soluble phosphorus fraction by application of rock phosphates was studied in comparison with monocalcium phosphate. Therefore, the increase of the P-water values caused by Gafsa and Florida phosphates are expressed as percentages of those obtained with monocalcium phosphate. As has been mentioned the effect of the latter depended very much on the fixing capacity but very little on pH. As the accuracy of differences between soil testing data was rather low, the results obtained with applications of 600 and 1200 kg P_2O_5 per ha were averaged and the original pH-values of the soils are used. For present purposes it is unimportant whether initial or final (determined after the addition of fertilizers) values of pH

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* This difference is narrowed when a wider extraction ratio (1 : 40) is used.

are used, the correlation was essentially unaffected. This is due to the aproximately equal rise of pH found in the different soils after dressing with Gafsa phosphate. Analogous results were obtained with Florida phosphate though the average increase was smaller.

The relative increase of the water-soluble phosphorus fraction brought about by the rock phosphates clearly proved to depend on pH (Fig. 8). With an initial pH of 4.5 or higher, a very small increase was observed.

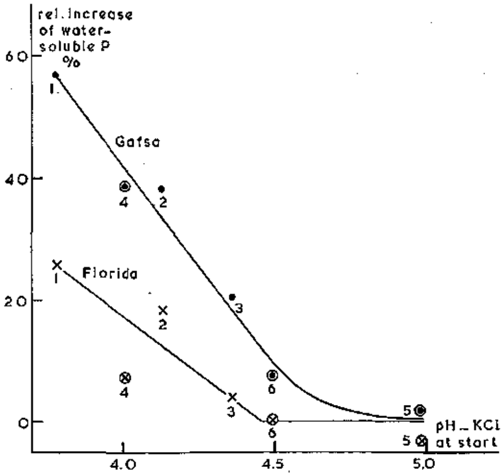

Fig. 8. Relative increase of P-water contents of soil brought about by dressing with 600 and 1200 kg P_2O_5 per ha (average) as Gafsa or Florida rock phosphates (as percentage of the increases obtained with monocalcium phosphate). pH determined before fertilization; encircled dots and crosses represent strongly fixing soils.

In Fig. 8 illustration of the relative effect of the fixing capacity is achieved by the encircling symbols corresponding to highly fixing soils. In these soils the increase of the water-soluble phosphorus fraction is apparently smaller than in the less fixing soils with corresponding pH. This is especially the case with Florida phosphate. This confirms the observation that a high fixing capacity of a soil depresses the availability of rock phosphates more than of monocalcium phosphate. In the case of the Soils 5 and 6, it cannot be decided to which degree the low efficiency is due to pH and to fixation.

The effect of Gafsa phosphate on the most acid soil is considerable. The picture, however, is unfavourably affected by the alkalinity of the fertilizers when applied in large quantities. Comparing the (less accurate) results obtained with applications of 600 and 1200 kg P_2O_5 per ha (not printed) it appeared that the latter did not increase the P-water values much more than the former. Though according to Fig. 8 Gafsa and Florida phosphates - using the average figures for the application of 600 and 1200 kg – increased the water-soluble phosphorus fraction at pH 4.0 by 43 and 17% respectively, the corresponding percentages for the application of 600 kg were 64 and 20 per cent. A still better result was obtained with dressings of 100 kg P_2O_5 per ha.

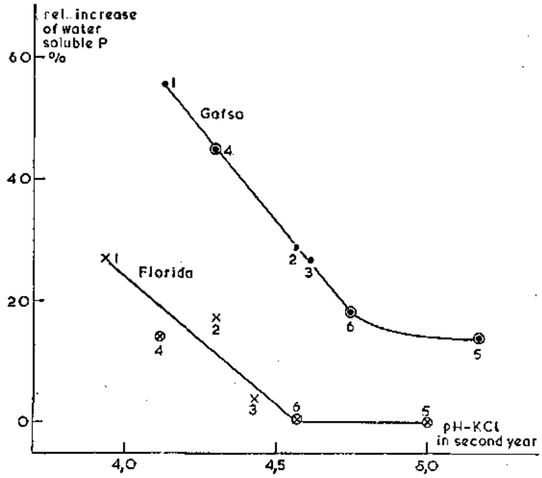

Fig. 9. Same as Fig. 8 in second year; pH determined in second year.

The increases found in the second year were plotted against the actual pH values found at the final soil test (Fig. 9). The relative availability of Gafsa phosphate was again closely related to pH; the dots representing the Soils 1–4 and 6 were situated on a straight line. Compared with the preceding year the solubility has somewhat increased in the soils with the highest pH in case of Gafsa phosphate. In contrast to the first year the residual effect of Gafsa phosphate in the strongly fixing Soil 4 was not different from that in the less fixing soils. This may indicate that the increased depression due to the high fixing capacity was of short duration.

With Florida phosphate the correlation with pH was somewhat less pronounced. Again it was evident that the relative effect of this phosphate was smaller on the fixing Soil 4. There was no indication of an effect of this phosphate with pH 4.5 or higher.

4. *Effect of a moderate dressing with rock phosphates*

It has been mentioned in the preceding paragraph that the effeciency of rock phosphate was unfavourably influenced by the application of large amounts. A more normal picture is obtained when the results of the treatment with 100 kg P_2O_5 per ha are considered.

With the acid Soils 1 and 2 with Gafsa phosphate relative increases of the P-water values of 89 and 100 per cent were found. In the other soils with low supplies the rise of the P-values were too small to allow for an accurate determination.

The effect of the changes observed on crop yields was often small and the accuracy of differences may be poor. Information by crop analysis proved to be more reliable.

P_2O_5 contents of shoots found without a supply of phosphorus and after addition of 100 kg P_2O_5 per ha in different forms are given in Table 3. By means of the symbols = and > it is indicated whether the results are believed to be equal or different. For this evaluation the whole shape of the curve was taken into consideration. Hence it may be that slightly differing figures sometimes are estimated as equal. When the responses were very small, no estimation was made.

It appears that Gafsa phosphate equalled monocalcium phosphate in all cases in the slightly fixing very acid Soils 1 and 2 (pH–KCl 3.77 and 4.13).

The same was found on the strongly fixing acid Soil 4 (pH 3.99) except with the first crop. On the insignificantly fixing Soil 3 (pH 4.36) the results with potatoes in 1960 were equal but in two other cases monocalcium phosphate was better; the result in 1959 with rye was not clear. On both strongly fixing soils with higher pH (4.49 and 4.98) the effect of Gafsa was always decidedly less than that of monocalcium phosphate. Effects of Gafsa phosphate with rye were slightly better than with potatoes.

The effect of Florida phosphate was fairly satisfactory only on the acid Soils 1 and 2. It approximately equalled monocalcium

TABLE 3

P_2O_5-contents of dry matter found with lowest application (0.31 mg/pot P_2O_5)							
		P-source					
Soil	pH-KCl	No phosphate	Monocalcium phosphate		Gafsa phosphate		Florida phosphate
1959 Potato							
1	3.7	1.03	ab. 1.35 †	=	1.31	=	1.39
2	4.0	0.50	ab. 1.00 †	=	1.01	>	0.91
4	4.0	0.50	0.59	>	0.52	>	0.48
3	4.4	1.23	1.41	>	1.33	=	1.31
6	4.6	0.51	0.59	>	0.51	=	0.49 *
5	5.1	0.48	0.56	>	0.48	=	0.48 *
1959 Rye							
1	3.7	1.07	1.14	=	1.23	>	1.12
2	4.0	0.62	0.93	=	0.90	>	0.81
4	4.0	0.43	0.62	=	0.59	>	0.50
3	4.4	1.25	1.27		1.25		1.23
6	4.6	0.70	0.86	>	0.76	>	0.74
5	5.1	0.76	0.83	>	0.76	>	0.75 *
1960 Potato							
1	3.7	0.83	0.98	=	0.99	=	1.00
2	4.0	0.57	0.66	=	0.76	=	0.75
4	4.0	0.46	0.51	=	0.49		0.52
3	4.4	0.94	1.02	=	1.07	>	0.95
6	4.6	0.57	0.53		0,54		0.51 *
5	5.1	0.56	0.57	>	0.57 *	=	0.53 *
1960 Rye							
1	3.7	1.22	1.37	=	1.38	=	1.37
2	4.0	0.92	1.27	>	1.17	<	1.24 **
4	4.0	0.85	1.10	=	1.03	=	1.09
3	4.4	1.57	1.63	>	1.50 *	=	1.43 *
6	4.6	1.05	1.10		1.02		1.07 *
5	5.1	0.91	1.04	>	0.99	>	0.97 *

* No effect at all.

** No difference between monocalcium phosphate and Florida phosphate.

† Determined by interpolation.

phosphate in one case in the first year and in 5 cases in the second one. In most cases it was less effective.

Monocalcium phosphate never produced an effect significantly lower than any of the rock phosphates.

DISCUSSION

The above experiment showed that the availability of rock phosphate to crops with a low mobilizing activity in acid humic soils is determined by the degree to which its application increases the content of easily soluble phosphorus of the soil. This opinion has been opposed by Butkevich[1] who stated that the effect of rock phosphate is primarily due to the desintegration of the fertilizer particles by the action of the plant.

The question whether the solubility of rock phosphates is either promoted or reduced by the action of the soil on them is not however under discussion in the present paper. It is merely claimed that the equilibrium established by the contact between fertilizer particles and soil is a dominant factor in the effectiveness of the rock phosphate over a considerable period of time. How far phosphorus can be mobilized by plant or by soil, must be considered of secondary importance in our case.

The divergent views on rock phosphate of Russian agronomists may in fact be connected with a different attitude to the role of a phosphate fertilizer. Without any doubt their positive attitude is due to the appreciation of the high residual effects of rock phosphates, being decidedly better than those of superphosphate. The latter is converted into less available 'soil phosphate' in a few years, whereas the former are able to maintain in the character of a calcium phosphate for some decades. Thus, it is evident that the best use of rock phosphate is for the purpose of improving the phosphorus status permanently. The Dutch farmer, however, aims at a complete elimination of phosphorus limitation of crop growth. The direct effect of phosphate is therefore highly appreciated and residual effects are relegated to second place.

The results obtained in pots are not fully applicable to farming. In pots the soil is thoroughly mixed with the fertilizer. The establishment of an equilibrium in the field will probably require more time. Unequal distribution may favour local increases of pH and reduce the effect immediately after application. This might be a reason why an early application is often advised.

After some time, however, the situation found in the pot experiment may also be realized in the field. The fertilizer will be partly present in a water-soluble form depending on pH and fixing capacity of the soil. Later the phosphate is converted only slowly. This process might be accelerated in a microbiologically active soil or by growing crops (also weeds) if they are able to decompose rock phosphates.

In the pot experiment the effect was reduced by the alkaline reaction of the larger amounts applied. With moderate applications the results are better.

As the fixing capacity of the soil reduces the efficiency of rock phosphates still more than that of monocalcium phosphate, there is no reason to use the insoluble phosphates in stead of superphosphate on strongly phosphorus fixing soils. This holds especially for crops with a low phosphorus solving activity; for other crops the reverse may be true.

Gafsa phosphate may be applied fairly effectively to soils with pH–KCl values of 4.2 at most and Florida phosphate only to soils with pH 3.8 or lower. Unfortunately these values are considered below the optimum for humic sandy soils, where for the usual rotation a pH-value of at least 4.5 is wanted and for soils with a lower pH liming is advised. It is consequently evident that the possibilities of an effective use of rock phosphates are limited.

SUMMARY

The efficiency of Gafsa and Florida rock phosphates as compared with monocalcium phosphate was investigated in pot experiments with acid humic sandy soils. The soils varied considerably in fixing capacity and the pH–KCl ranged from 3.77 to 4.98. Crops (potato and rye) with a low capacity to mobilize rock phosphate were grown.

The efficiency of monocalcium phosphate was much affected by the fixing capacity but hardly or not by the pH of the soils.

The efficiency of rock phosphates varied between approximate equality with monocalcium phosphate and nil.

The different availability depended on the degree to which the water soluble phosphorus fraction of the soil was increased by the phosphates.

The equilibrium which determines the degree to which rock phosphates are present in water-soluble form is attained after a rather fairly short contact between soil and fertilizer. Thereafter the degree of solubility changes only slowly. Residual effects of the fertilizers in the second year were almost comparable with those of a fresh application.

The increase of the content of water-soluble phosphorus brought about by a dressing of rock phosphates was inversely proportional to the pH (Fig. 8 and 9). The water-soluble fraction is also more reduced by a high fixing capacity of the soil in the case of a dressing of rock phosphate than with one of monocalcium phosphate.

The efficiency of large amounts of rock phosphates is unfavourably affected by the alkalinity of these fertilizers. Applied in moderate amounts its effectse qualled in some cases those of monocalcium phosphate at least

on very acid soils. This is especially true for Gafsa phosphate, which is more effective than Florida phosphate.

The possibilities of applying these phosphates are restricted when the aim is a complete elimination of phosphorus deficiency. The pH values which allow a high efficiency of rock phosphates are too low for optimum growth.

ACKNOWLEDGEMENT

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