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International Fertilizer Industry Association - Secretariat: 28 rue Marbeuf - 75008 Paris - France
Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

THE INTERNATIONAL SUPERPHOSPHATE MANUFACTURERS' ASSOCIATION (I. S. M. A.)

AGRICULTURAL COMMITTEE

JOINT TECHNICAL AND AGRICULTURAL MEETING

LAUSANNE (Switzerland) - Monday 24th - Thursday 27th September, 1 9 5 6 .

PA/151

Subject : 1 c

QUANTITATIVE DETERMINATION BY MEANS OF P^{32} OF THE ABSORPTION OF P_2O_5 BY LIVING PLANTS,

by K.C. SCHEEL (Guano-Werke A.G., Lubeck-Dänischburg, Germany)

Immediately after it had become possible to produce radioactive phosphorus P^{32} in the uranium pile, agricultural chemistry made use of this new means to solve some of the problems which it has before it. The advantage of using radioactive isotopes as tracer elements in order to follow the movement of chemical substances during the most diverse processes, notably biological ones, is so obvious that there is no point in stressing it. Radioactive phosphorus is in routine use for determining, in the analysis of harvested products, whether P contained in them derives from the soil or from the fertiliser. While in this case radioactive phosphorus is used only as a tracer element, as a radiating element it is of use principally only in the botanical and plant physiological sphere, for making autoradiograms of the objects examined. In spite of the interest of these photographs and the clear indication which they give concerning the presence of P in plant tissues, or even within the various cells, they have no great significance from the quantitative point of view, a significance which would be of particular importance for our fertiliser manufacturing industry.

What now follows refers to experiments carried out in 1953/54 at the Central laboratory of Kali-Chemie A.G. at Hanover, the aim of which was to determine quantitatively, by means of radioactive phosphorus, the absorption of P_2O_5 by living plants. In this new method of measurement the radioactive phosphorus does not serve solely as a tracer element, for example to make possible a distinction between the fertiliser phosphorus and the phosphoric acid of the soil, but its beta radiation is made use of at the same time for the measurement.

Marking fertilisers

In experiments, the usual phosphate fertilisers are almost always used: superphosphate, Rhenania phosphate and basic slag. In order to mark them, various amounts of radioactive phosphorus have been used, depending on the intended duration of the experiment, normally c.6 mC/g P_2O_5, and 2 mC/g P_2O_5 for long experiments. In no case has any damage to the plants been observed.

Marking is done as follows:

1) The superphosphate is mixed with the given amount of the P^{32} solution, and enough water to form a mass resembling a pulp. After oven drying, this mass is finely ground. (We have found this method just as efficient as that cited in the technical literature, which consists of mixing the radioactive phosphorus with sulphuric acid, and using this to decompose rock phosphate in the laboratory).

2) After a similar mixing with the active solution, Rhenania phosphate is dried and ignited for 1 hour at 1000-1100ºC in an atmosphere passing from neutrality to a slight reductivity.

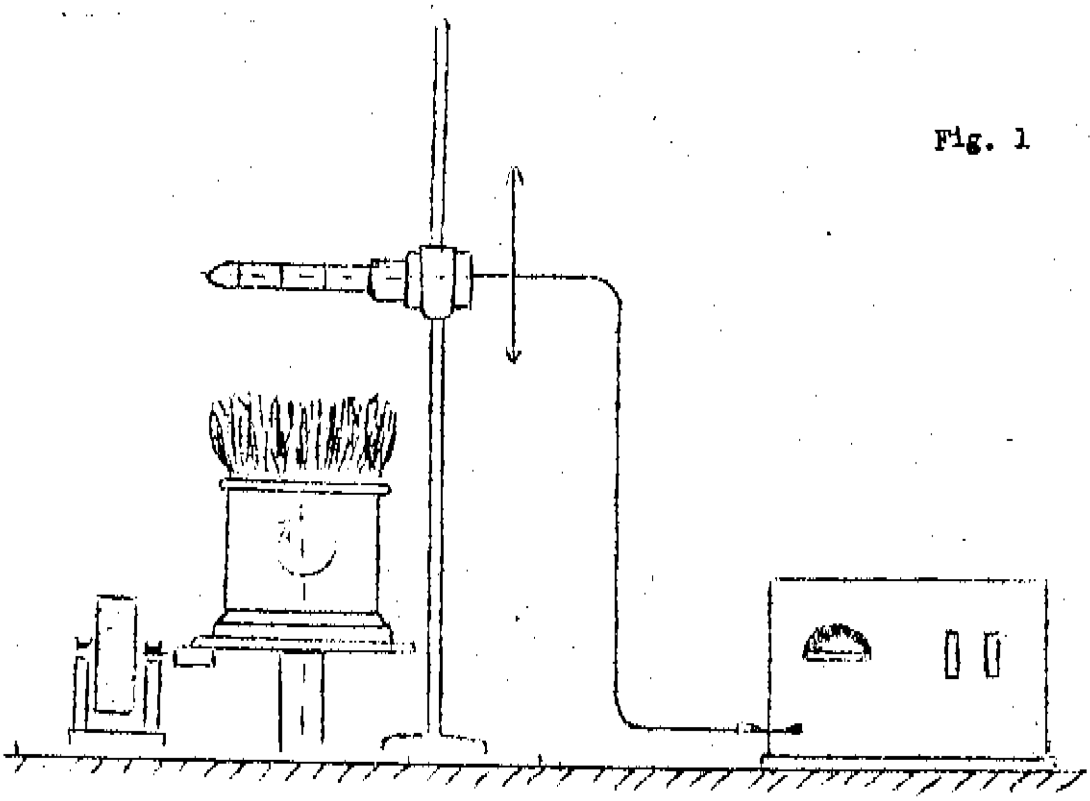
3) With basic slag the same procedure is followed, but the ignition must be to 1500ºC, since it is only when the phosphate softens that a uniform penetration occurs into the crystalline network.

After marking, the activity added to the fertiliser is quantitatively measured. For this purpose, solutions are prepared in the way customary in the phosphate industry, by acid attack or by water extraction, or extraction by citric acid or a citrate solution; the P_2O_5 content of this solution is determined chemically and its activity is measured in the counter. All the activities measured must of course be converted in accordance with the duration of life of the isotopes, which is generally indicated on delivery of the radioactive isotope. This activity measured at the preparation of the fertiliser is of great importance, for it gives the measurement when the experiment is being interpreted. If necessary, the measurement is repeated after the conclusion of the experiment.

The arrangements for measuring

Fertiliser experiments were carried out first in Mitscherlich pots in the usual way and then by Neubauer's seedling method, which will later be given particular attention. The experimental soil was fertilised quite normally. There must be mentioned at this point a considerable advantage in marking fertiliser with radioactive phosphorus. While in most cases it is necessary to lighten the experimental soil by adding a large amount of sand in order to achieve a larger measurable "growth" from the application of phosphate fertiliser, there is no need to "denature" the soil when radioactive phosphorus is used since, on harvesting, the phosphoric acid absorbed from the fertiliser can be clearly distinguished from that derived from the soil. A small variation on the usual procedure is that, after setting the pots in place, the soil is covered with a layer of sand 5-10 mm thick, in order to protect the counter installed above the pot from the radiation coming from the soil. For the rest, the measuring apparatus used with Mitscherlich pots is shown in Fig. 1 below:

Fig. 1



The Mitscherlich pot is on a rotating disc turned slowly by a small synchronous motor without collector. This rotating movement is intended to improve the symmetry of the apparatus, which is not uniform since growth is not entirely uniform throughout the pot. On this latter is an aluminium counter, in this case a beta counter 20 cm long and prepared for the determination of potassium by the Central Workshop at Göttingen. The distance above the pot can be modified by adjusting the support. While the plants are very small it is of course necessary to bring the apparatus close to them in order to intercept the still very small amount of radiation. Later the distance must be increased in accordance with the growth of the plants and the perceptibly greater intensity of the radiation. If possible, the experimental apparatus is set up in such a way as to enable the counting of 3000 to 10000 particles per minute. With lesser activity it takes too long to attain a sufficiently exact measurement, and also time is in general short in experiments of this sort. An activity much exceeding 1000 IpM is unfavourable because it causes inaccuracies resulting from the insufficient dissolution capacity of the measuring apparatus.

At every measurement the length of the plants, the distance between the counter and the soil and also the activity measured are recorded. These measurements must be carefully carried out, as the accuracy of the result is affected, especially by the distance.

Utilization of the results

On the basis of the radiation measurements carried out in the way described, the amount of P_2O_5 absorbed by the plant must now be calculated. Before explaining the difficulty of this task, we must stress somewhat the various problems which occur. It is obvious that the intensity of radiation decreases with the distance between the radiating body, that is, the plant mass, and the counter. The law of radiation, which holds in optics, that this decrease is proportional to the square of the distance, is well known. However, this law holds only for a point source of radiation, whereas in the case before us not only the source of the radiation but also the measuring device, the counter, are of a certain size. The fact that the beta radiation is strongly absorbed by certain materials constitutes a further difficulty. Thus, absorption occurs not only in the interior of a plant, for example in a leaf, but the shading effect of neighbouring plants needs also to be considered. Finally, if the distance is large, absorption in the air cannot be neglected. While in the early stages these factors are of only secondary importance, while the plants are still small, they intervene to the extent of about 50% in the later stage, for example just before harvesting.

While early on we were content with approximate calculations for interpreting the results of the measurements, as the method of measurement was improved we felt the need of more exact interpretation. To this end H. Weichart developed a sufficiently accurate method of calculation that would require too long to discuss here in detail. We shall give only the main outlines of the principle:

The radioactivity of the different pots is measured during the course of growth. On the day of harvesting, this activity is measured again, the harvest is collected, weighed both green and dry, and is ashed. The P_2O_5 content of the ash is determined chemically in the usual way. At the same time, the activity of the solution of the ash is measured with the counter and is converted in accordance with the length of life. Using the comparative count obtained at the time of preparation of the active fertiliser, the amount of marked fertiliser that has been absorbed is calculated. It is thus possible to distinguish, in the amount of P_2O_5 found in the harvested product, between (marked) P_2O_5 derived from the fertiliser, and ordinary P_2O_5 from the soil.

Taking into consideration the distance between the counter and the soil, the height of the plants, the absorption of beta radiation in the air and in the plant mass, the Weichart method is used to calculate the "counter constant" from the last value of the activity measured with the aluminium counter on the living plants. This constant indicates the number of counts emitted by 1 mg of radioactive P_2O_5 with a given activity in the counter, at a distance reduced to 1 cm. Finally, it also enables the calculation – from the measured values obtained during the whole growth period – of the amount of phosphoric acid that has been absorbed from the fertiliser.

Experimental results

1) **Fertiliser experiment with** 4 different fertilisers on oats in Mitscherlich pots

In this experiment, as in all that follow, two different soils were used, namely:

a) a sandy organic soil from Sohnelsen

b) a loess from Rosdorf

characterized as follows:

	pH	mg K_2O	mg P_2O_5	(according to Egner)
Sohnelsen soil	7.o	4.o	2.4	
Rosdorf "	7.4	7.o	o	

Harvesting was carried out after a growing period of 52 days. Measurement of the radiations on the day of the harvest, together with analysis of the harvested product, gave the following counter constant:

$$C = 1.47 \cdot 10^7 \text{ counts/min mg } P_2O_5$$

with a mean error of the mean .... $m = \pm$ o.o278 = 1.88%

and " " " " " unit value .... $f = \pm$ o.171 = 12.2%

Using this constant, the values obtained during the growing period of the living plants is converted into mg of P_2O_5. These results are reproduced in figures 2 and 3 below:

Fig. 2 Fig. 3

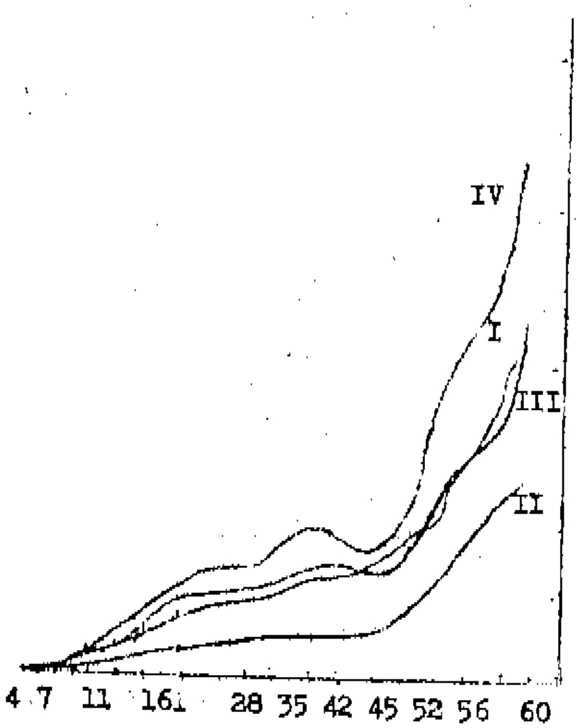
Absorption by oats of P_2O_5 from different fertilisers :

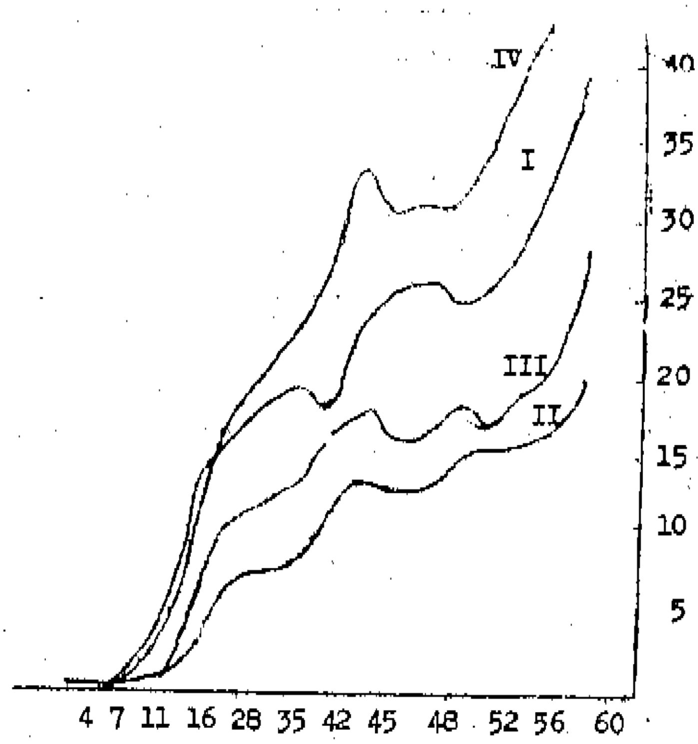
I Superphosphate

II Tricalcium phosphate

III Basic slag

IV Rhenania phosphate





The behaviour of each fertiliser in this experiment is shown extremely clearly. In particular should be mentioned that the tricalcium phosphate used was present in its beta form. The unfavourable effect of this form, that has been expressed in the literature reporting on it, is easily observed in both cases. Mention should also be made of the clear inflexion in the curves after the 35th day of growth, when even a falling-off in the P_2O_5 content of the plant mass was observed. As we discovered later, this falling-off was due to the fact that at this time (early October) there were some nights of frost which stopped the growth of the plants. Growth and absorption of P_2O_5 did not start up again until the pots had been put into the greenhouse.

2) Is the fertilising effect of very finely ground rock phosphate improved by the presence of soluble phosphate fertiliser ?

This experiment served mainly to try out the new method of measurement. Also it was investigated at the same time whether the absorption of very finely ground rock phosphate is favoured by the presence of soluble phosphate fertilisers. Some earlier experiments had led us to this problem, as it had been observed that absorption of the phosphoric acid of the soil was clearly much stimulated by a phosphate fertilising. This phenomenon may be empirically explained by the fact that suitably fertilised plants develop an extensive root system and are thus able to win a much larger quantity of phosphoric acid from the soil. From this it may be concluded that plants fortified by phosphate fertilising are also better able to use the rock phosphate. Unlike in the preceding experiments, Italian ryegrass (Lolium italicum) was chosen as the experimental plant, as it provides several cuts close together. Because of this, there is no loss of time before the pots are resown, which is advantageous in view of the short life of the radioactive phosphorus. As regards the problem under study, there is a further advantage in the fact that the ryegrass does not come to flower and ripen like the oat. Thus there is no P enrichment of the grain causing an unequal distribution of activity in the plant mass and making the estimation very difficult. The first cut was also made but it was impossible to make a quantitative evaluation, as the activity was reduced to o.22% of the original, made 126 days before.

As a mean value for all the pots:

$C = 2.68 \cdot 10^7$ counts/min mg P_2O_5 at 1 cm

mean error of the mean .... $m = \pm$ o.o34 = 1.24%

" " " " unit value .... $f = \pm$ o.489 = 18.3%

In calculating the amount of P_2O_5 absorbed from the intensity of radiation of the living plants, the following difficulty was met. In order to calculate the absorption of beta radiation by the plants it is necessary to know their green weight, which cannot be accurately determined in any simple way, i.e. without harvesting the plants. Moreover, the absorption becomes so considerable as they grow that it cannot be neglected.

As the green weight of plants during the different stages of growth can be determined only by intermediate harvests, and as it is in general obtained only at the time of the main harvest, a study was made with one of the pots of the magnitude of the differences between the amounts of P_2O_5 determined when, to over-simplify grossly, the green weight is allowed to increase in proportion with time to the main harvest (column 1) or when the green-weight curve is traced to the definite points of the intermediate harvests (column 2).

Schnelsen soil : 1st cut (pot № 755)

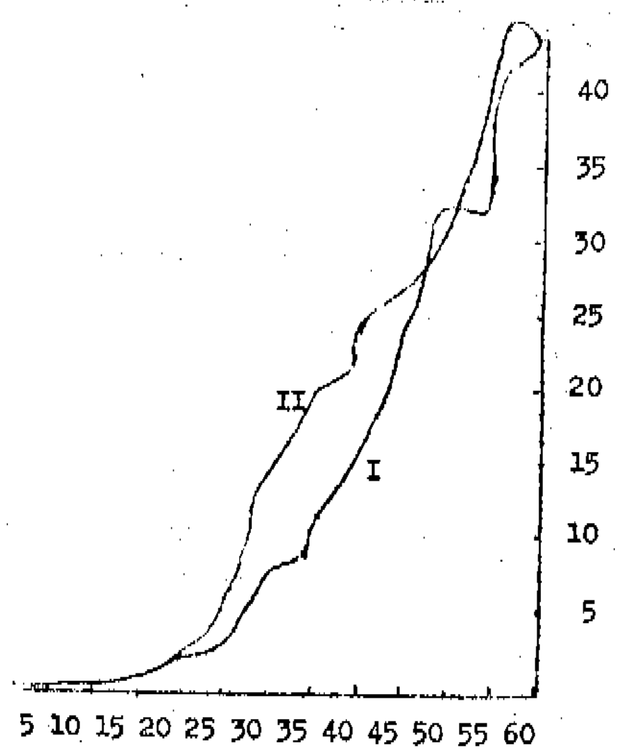
Days of growth	Column 1	Column 2
1	0.036	0.036
4	0.067	0.068
11	0.19	0.17
14	0.50	0.49
18	0.94	0.90
20	1.42	1.56
23	2.04	2.00
27	4.4	4.3
30	7.7	7.3
33	9.5	9.4
36	12.8	11.7
40	17.0	15.5
43	21.7	19.7
48	32.8	27.8
50	35.4	32.6
54	34.4	30.5
57	39.1	37.7
61	48.4	50.0

It can be seen from this comparison that the error involved in the inexact determination of the green weight falls within the limits of the fluctuations present when the arithmetic mean of the different counter constants is established. It thus appears justifiable, in the quantitative interpretation of radioactivity measurements with living plants, in general to proceed as though the green weight of the plants from their germination to their harvest increased in proportion with the time.

As an example or results determined with the counter constants, fig. 4 indicates the development of the absorption of the P_2O_5 of Rhenania phosphate in two soils up to the last cut.

Absorption by Italian ryegrass (Lolium italicum) of P_2O_5 from Rhenania phosphate

mg P_2O_5



Days of growth jours de végétation

I Schnelsen soil
II Rosdorf "

Fig. 4

Let us deal now with the question of the utilization of rock phosphate in the presence of soluble phosphates. The following table shows the overall result of the four cuts:

Schmelsen soil		Rhenania	Gafsa	Rhenania Gafsa	Triple super Gafsa
Total P_2O_5 mg		181.o	83.6	126.7	131.7
Active phosphoric acid of the fertiliser	mg	87.9	o.o	38.5	39.7
	% of total P_2O_5	48.7	-	3o.4	3o.1
	% of application	29.3	-	25.7	26.5
Difference total P_2O_5/active P_2O_5 (mg)		93.1	83.6	88.2	92.o

Rosdorf soil					
Total P_2O_5 mg		157.6	62.6	133.1	113.4
Active phosphoric acid of the fertiliser	mg	93.4	o.o	44.o	43.2
	% of total P_2O_5	59.3	-	38.8	38.1
	% of application	31.1	-	29.4	28.8
Difference total P_2O_5/active P_2O_5 (mg)		64.2	62.6	69.1	7o.2

This table shows that in both cases no considerable amount of phosphate was absorbed from the very finely ground Gafsa phosphate (wet grinding to impalpable fineness).

3) Application of the Neubauer seedling method

This method, worked out by H. Neubauer and W. Schneider to determine the root-soluble nutrients of the soil, is based on the fact, apparently ignored formerly, that seedlings do not go on living as long as possible on the endosperm reserves alone, but absorb nutrients from the soil by means of roots formed during germination. In this method 1oo grains of rye are used in only 1oo g of soil, involving a great excess of seedling roots, so that even in a soil rich in nutrients, those nutrients which are root-soluble are rapidly utilized.

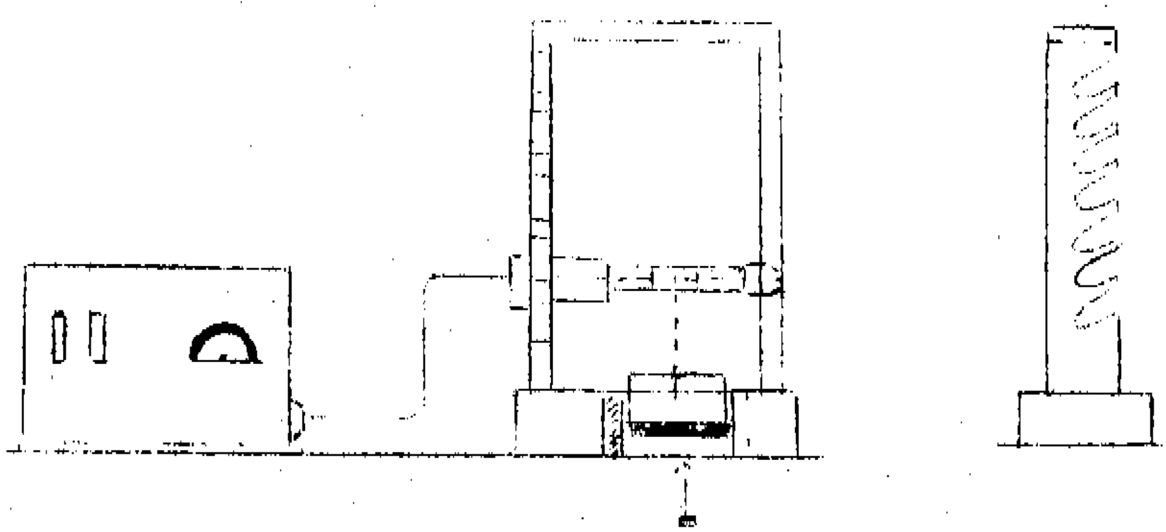
Only 17 days after sowing, the plants are ready for harvesting, for at this time the absorption of nutrients, especially phosphorus, is finished. With a longer growing period than this, the nutrient content of the plants falls again. The seedling method is also recommended for rapidly determining the fertilising effect of phosphate fertilisers. It appeared likely that this method could be improved by using P^{32} to mark the phosphoric acid of the fertiliser, for it is then possible to distinguish this acid from that derived from the soil and the endosperm.

Six Neubauer pots were filled with Schmelsen soil, 7.5 mg of P_2O_5 being added in triple repetition in the form of marked superphosphate and Rhenania phosphate. Also, in order to establish the best possible balance between the different elements, a base fertilising of 15 mg of N as NH_4NO_3 and 3o mg of K_2O as K_2SO_4 was given.

The pots were prepared on 13th August 1954 and on the 16th the counted and weighed rye grains were sown in the sand layer. By the use of 25o g of sand as the germination bed, the radiation from the soil is completely neutralized, as is proved by measurements made with unplanted pots, so that, in measuring the activity of the planted pots, only the intensity of radiation of the plants themselves needs to be considered.

To facilitate the measurement on the plants and especially the fixing of the counter distance, a support is constructed of wood (because of its low dispersing power), whose two side walls have at intervals of 5 cm devices for suspending an aluminium beta counter. Exactly at the centre below the counter the base of the support has an opening 14 cm wide, so that a Neubauer pot of diameter 12 cm can easily be introduced. The bottom of this opening is formed by a disc which can be raised or lowered by 7.5 cm by means of a toothed rack. The opening in the base of the support is set so that the upper edge of the sand layer of the Neubauer pot is at about the same height as the base. By means of the moveable disc the distance between the counter and the surface of the sand layer can be adjusted as required.

Fig. 5



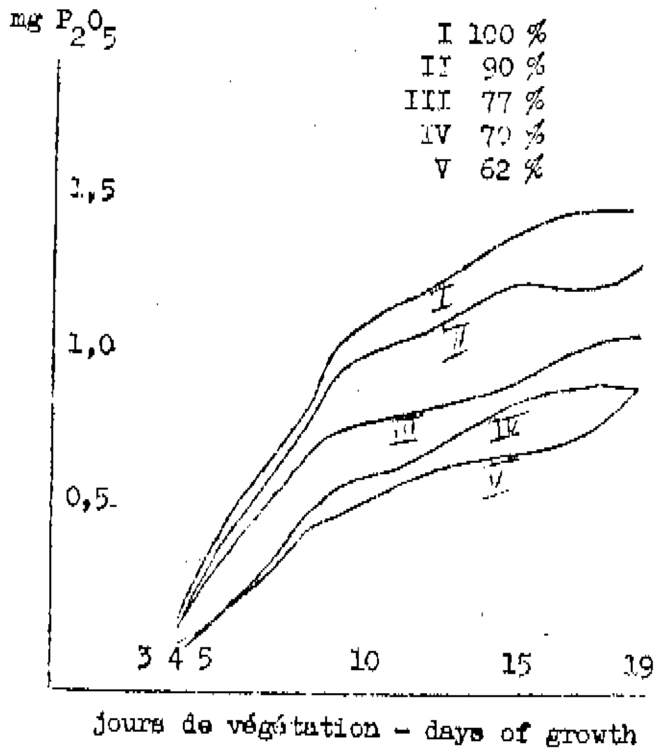
On the 3rd September 1954, the 18th day of growth, the pots were harvested in accordance with Neubauer's method. The harvested product - roots and shoots - were separated as usual and were chemically and radiometrically analysed.

The results are shown in a table on the following page (9).

Interpretation of the measurements done on 2o pots in the way described gave results as in fig. 6 below:

Absorption by rye seedlings of P_2O_5
from Rhenania phosphates of different solubilities

Fig. 6



The trend of the curve clearly shows that the absorption of P_2O_5 from Rhenania phosphate varies from the start approximately in accordance with its solubility. This experimental result is of great importance. It shows clearly that recent criticisms of our efforts to obtain a good decomposition of rock phosphate are completely unjustified.

5) Effect of simultaneous application of different fertilisers

The marking of phosphate fertilisers with radioactive phosphorus enables study of an important problem, study which otherwise could not be envisaged, at least objectively: the action of different phosphate fertilisers when applied together. By marking one fertiliser and not another it is possible, on applying them together, to determine which of the two is preferentially absorbed by the plant. It is of interest to observe the results obtained by such a fertilising in experiments carried out in this case with all other factors equal. These experiments were done with Rhenania phosphate, superphosphate and basic slag, using Neubauer's method and giving to each pot an application of 7.5 mg of each fertiliser, marked or ordinary. The experimental results are given in figures 7 and 8, for the Rosdorf and Schnelsen soils (see page 12).

Fig. 7 Rosdorf soil

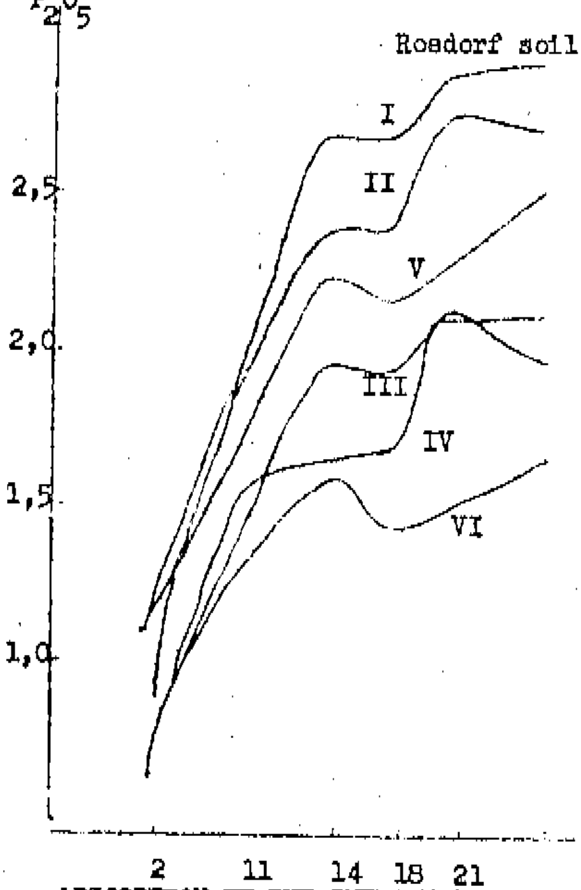
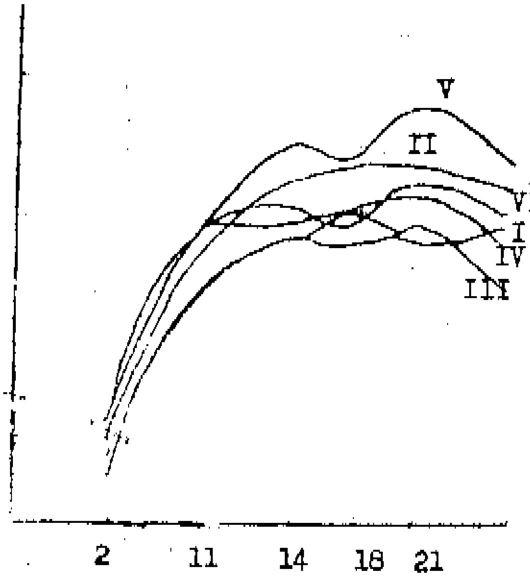


Fig. 8 - Schmelson soil



ABSORPTION BY RYE SEEDLINGS OF P_2O_5 FROM THE DIFFERENT FERTILISERS :
I = Rhenania$^+$/super II = Rhenania/super$^+$ III Rhenania$^+$/slag IV = Rhenania/slag$^+$
V = Super$^+$/slag VI = Super/slag$^+$ (+ = marked)

These diagrams show - insofar as the method is accurate - that super and Rhenania phosphate behave similarly. Slag however showed a perceptibly lower efficiency, which is easily understandable in view of the short growing period in the Neubauer test. The effect of the Rhenania phosphate was considerably weakened by the presence of slag, but superphosphate was not so affected.

S U M M A R Y

The method of measuring radiation which we have developed aims at following quantitatively, by means of radiation intensity measurements on plants, the development of P_2O_5 absorption up to the time of harvest. For this, the counter constant must be known for each set of experimental conditions, the marking of the fertiliser and the sensitivity of the counter to radiation emitted by P^{32}. This constant C is calculated from the amounts of phosphoric acid found in the harvested material and the dates of measurement on the corresponding living plants. Thus, quantitative use of radiation measurements would appear possible only at the end of the experiment, unless one is able to calculate in advance the counter constant for the experimental conditions in question.

The three last mentioned experimental series on one side, it is now necessary to examine whether, having once calculated the counter constant, it is possible to convert it, under the same set of experimental conditions, for another marking or another counter.

By set of experimental conditions is understood a given type of counter on pots of the same diameter and with the same experimental plant; for example an aluminium beta counter 20 cm long on rye crops in Neubauer pots or on oat crops in Mitscherlich pots.

During the experiments on rye seedlings we noticed the following differences:

Exp. series	Marking: mC/g P_2O_5	Marking: counts 250 ml / min μC	Counter: Nº	Counter: Sensitiveness towards P^{32} - radiation
3	0.6	6840	007	100.0%
4	2.0	7425	008	85.7%
5	0.6	6900	008	85.7%

In the following table the counter constants calculated earlier are indicated as C_1. C_2 means the same constant converted from "counts/min mg P_2O_5" to "counts/min . μC" considering the different marking. C_3 means that value finally corrected according to the sensitiveness of the counter in use.

Exp. series	C_1 counts/min mg P_2O_5 at 1 cm distance	C_2 counts/min . μC at 1 cm distance	C_3 counts/min . μC at 1 cm distance
3	$10.38 \cdot 10^6$	$1.73 \cdot 10^7$	$1.48 \cdot 10^7$
4	$3.61 \cdot 10^7$	$1.81 \cdot 10^7$	$1.68 \cdot 10^7$
5	$9.30 \cdot 10^6$	$1.55 \cdot 10^7$	$1.55 \cdot 10^7$

As a mean value of the constants of the three series we then obtain:

$$M = 1.57 \cdot 10^7 \text{ counts/min } . \mu C \text{ at 1 cm distance}$$

with a mean error of the mean $m = \pm 0.06 = 3.8\%$

The remarkably good agreement between the corrected values of the counter constant shows that, as soon as this constant is evaluated, it is possible to convert it for another marking of the fertilisers and a different sensitiveness of the counter, with the same experimental device.

We believe we were able to show by the facts emphasized by our two year experiments briefly explained here, that it is possible - by using the radiation method worked out - to follow quantitatively the P_2O_5 uptake already on the living plant. This method can be used for quite different purposes; some experiments have shown for instance that we can connect the radiation measuring apparatus to a device which enables to register even continuously the P_2O_5 uptake. Thus, we can well prove, among other things, the influence of various outside factors, as temperature, light, moisture, etc. We believe in particular to have found by applying this process to the Neubauer method a means to determine quickly and accurately the action of phosphatic fertilisers the most different. We should not forget to mention that the method is only suitable for the time being, when P is uniformly distributed in the plant matter. Then, it arises from the known radiographs, especially, that this is not quite the case. As already mentioned, a strong P translocation occurs in the plant which gives rise to the growth, i.e. at the formation of the seed. In this case, the method cannot be applied in its simple provisional form.

At the end of my paper, I want to thank very much my previous colleague, Dr. Behrens, for the help he gave me when carrying out these experiments. I also express thanks in particular to Fräulein Dr. Richter who contributed so much to the practical side of the experiments and their strenuous interpretation. I am also grateful to Physician H. Weichart who found the solutions of the mathematical problems of the method.

Results of the harvest

Phosphate fertiliser		Pot Nº	Total P_2O_5 mg	Total P_2O_5 mg ∅	P_2O_5 of the fertiliser mg	P_2O_5 of the fertiliser mg ∅	% of application
RHENANIA PHOSPHATE	Shoots	1	14.9o	13.73	1.28	1.23	16.4
		2	12.8o		1.17		
		3	13.5o		1.25		
	Roots	1	1o.75	11.13	1.o2	1.1o	14.7
		2	1o.5o		1.12		
		3	12.15		1.15		
	T o t a l	1	25.65	24.86	2.3o	2.33	31.1
		2	23.3o		2.29		
		3	25.65		2.4o		
SUPERPHOSPHATE	Shoots	5	13.8o	13.65	1.27	1.25	16.6
		6	13.5o		1.22		
	Roots	5	12.75	11.83	1.17	1.13	15.1
		6	1o.9o		1.1o		
	T o t a l	5	26.55	25.48	2.44	2.38	31.7
		6	24.4o		2.32		

The utilization of the phosphoric acid of the fertiliser, both that of the Rhenania phosphate and the superphosphate, was on the whole very good, with a rate of absorption of 16% in the shoots, and of 31% of the total.

These results very clearly show the great advantage of using marked fertilisers. Of all the phosphoric acid contained in the harvested material, only about 1o% is due to the fertilisers, while far the greater part comes from the endosperm and the soil. With the differential method in use up till now, it was necessary, in order to calculate the phosphoric acid of the fertilisers, to deduce a theoretical value much larger than the true one. An inaccuracy in the theoretical value would lead to large errors. On the other hand, if the phosphoric acid of the fertiliser is marked, the fertiliser phosphoric-acid content in the harvest material can be immediately determined, independently of its ratio with the phosphoric acid derived from the endosperm and the soil.

Another purpose of this series of experiments was to check, by radiation measurement, the method of determination of P_2O_5 absorption by intact plants. If this determination can be carried out with sufficient accuracy and the counter constant is known, it is possible:

1) To follow continuously the absorption of phosphoric acid derived from the soil and thus to detect differences which may disappear again by harvest.
2) To neglect, in case of need, any anomalous harvest which may occur.

Following the system of evaluation developed by H. Weichart, the counter constant for each pot is calculated in the first place from the accounts of fertiliser phosphoric acid in the harvested material and the impulses measured on the day of the harvest. These calculations are summarized in the following table:

Date	Fertiliser	Pot Nº	Distance between counter and soil Zu (cm)	Height of plant h (cm)	Green matter of plant Mp (mg)	Counts per minute I	P_2O_5 harvested $M_{P_2O_5}$	Counter constant C
Sept. 3rd 1954	Rhenania	1	26.5	21.o	$14.o \cdot 1o^3$	$6.95 \cdot 1o^3$	1.28	$9.87 \cdot 1o^6$
		2	26.5	21.5	$14.o \cdot 1o^3$	$6.95 \cdot 1o^3$	1.17	$1o.23 \cdot 1o^6$
		3	26.5	21.o	$14.o \cdot 1o^3$	$7.o2 \cdot 1o^3$	1.25	$1o.23 \cdot 1o^6$
	Super	4	26.5	21.o	$14.o \cdot 1o^3$	$7.36 \cdot 1o^3$	1.27	$1o.58 \cdot 1o^6$
		5	26.5	2o.5	$14.o \cdot 1o^3$	$6.87 \cdot 1o^3$	1.22	$1o.98 \cdot 1o^6$

The mean value is:

$$M = 1o.38 \cdot 1o^6 \text{ counts/min mg } P_2O_5 \text{ at 1 cm distance}$$

with a mean error of the mean .... $m = \pm$ o.1876 = 1.8%
and " " " " " unit value .... $f = \pm$ o.42 = 4.1%

The differences, slight in spite of the small number of pots, demonstrate the usefulness of the method.

4) <u>Effect of the solubility of Rhenania phosphate on its fertilising action</u>

As the seedling method, modified by the use of radioactive phosphorus, has been shown to be useful, some experiments have been carried out on its further application. Thus, a series of experiments was carried out in order to study the effect of the solubility of Rhenania phosphate on its fertilising action.

For this purpose, rock phosphate was marked by ignition with radioactive phosphorus (2 mC/g P_2O_5) and then precipitated in the usual way (ignition with soda and silicic acid) to obtain Rhenania phosphate. The precipitation was controlled in such a way as to obtain products of different solubility. The following table gives the analysis results for the different precipitation products:

Solubility %	P_2O_5	%	Counts 25o ml / min. mg P_2O_5
1oo	Total	3o.o5	15 1oo
	Citrate sol.	29.9	15 o1o
9o	Total	29.75	14 31o
	Citrate sol.	26.85	13 91o
77	Total	29.o	13 96o
	Citrate sol.	22.42	13 87o
7o	Total	29.12	14 35o
	Citrate sol.	2o.35	14 25o
62	Total	3o.o5	14 35o
	Citrate sol.	18.65	13 3oo

The good agreement betwenn the chemically and the radiometrically determined solubility is sufficient proof that P^{32} is present in the prepared fertilisers in the same combination as the phosphoric acid of the fertiliser.