

Fertility and plant nutrition

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FERTILIZATION IN STORAGE WITH PHOSPHORITE MEAL
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Poland has no rich phosphorite deposits. The low-percentage phosphorite of Cenomanian derivation, found on the middle Vistula in the vicinity of Annapol, is used in agriculture in the form of fine meal, called "Annofos" ($80\% < 0.06$ mm) containing 15% P_2O_5 . In pot experiments, these phosphorites were found to be a valuable phosphorus fertilizer, somewhat less effective than calcined phosphate, but tantamount to North African (Maroccan and Tunezian) phosphorite meals [2].

As the form of phosphorus compounds contained in phosphorite meal is not readily available to plants, it is a slowly acting fertilizer. The longer will the reaction of this fertilizer last, during which time the phosphates, difficult to dissolve, will begin to dissolve under the action of various soil factors and a more available form for the plants will be produced, the more effective the action of the fertilizer is expected to be. Hence the problem issues of not fertilizing with phosphorite meal under particular plants, but in cumulative doses, a single time for the entire crop succession ("in storage"). In this way, not only will the action of the phosphorus fertilizers, which dissolve with difficulty, be more effective but also a savings will be achieved in the cost of the work, which is lower when fertilizers are spread a single time in a joint dose provided for several years.

The problem of phosphorus fertilizers "in storage" was and is an object of investigations carried out in various countries [2—9]. From a scientific point of view, such fertilization arouses some reservations, especially as regards phosphorite meals and thermophosphates. A saving of time and work in farm management, insufficient quantity of stores for fertilizers etc. also speak in favour cases also to potassium [8].

However this measure still requires experimentation. Large differences may arise in the behaviour of various fertilizers, taking for instance in the extreme — calcined phosphate and phosphorite meal as depending on the variable soil and climatic factors and those connected with the manner of farming itself.

Field and meadow experiments, of which a synthesis of the results has been presented in this paper, have shown that fertilization "in storage" with phosphorite meal Annofos and calcined phosphate were equally effective and in certain cases even more advantageous than their application every year.

EXPERIMENTS OF FERTILIZATION "IN STORAGE" WITH PHOSPHORITE MEAL IN THE NORFOLK CROP ROTATION

The experiment in the crop rotation was carried out on acid ($\text{pH}_{\text{KCl}} = 5.33$), sandy and fine-sandy loam containing 2.3 mg P_2O_5 and 7.5 mg K_2O in 100 g of soil according to Egner. The mean annual total of precipitation amounted to 689 mm during 4 years. Within the experimental period more precipitation was recorded during two years (I and III) and during the other two years (II and IV) less than the long-term mean. The experimental field was at an altitude of 300 m above sea level.

The effectiveness of annual fertilization with calcined phosphate and phosphorite meal Annofos was compared in the experiments with that of fertilization with phosphorite meal a single time under all crop plants of the rotation (once every four years). The order of the plants in the crop rotation was as follows: potatoes, oats, field peas with oat for greens, wheat.

Farmyard manure in a quantity of 200 q/hectare (under potatoes) and a total of 120 kg N/ha (nitrochalk) and 200 kg K_2O /ha (40% potash salt) were used a single time as the basic fertilization. The total of yearly doses of phosphorus and the dose every 4 years ("in storage") amounted to 140 kg P_2O_5 /ha in each case. Both the doses of calcined phosphate and phosphorite meal were computed on the basis of the total phosphorus content (soluble in hot aqua regia).

The average annual plant yields from the entire rotation, expressed in cereal units, are given in Tab. 1, and in Fig. 1; the mean increases in each of the crops during the 4-year experiment are presented in relative values. The values of the yield increases obtained on phosphorite meal, which were compared in Fig. 1 with the yield increases obtained on calcined phosphate, the value of which was adopted as 100.

Table 1

Average crops and crop increases during the entire crop rotation in cereal units

Fertilization	Crops in cereal units	Crop increases	
		in cereal units	relative numbers
Without phosphorus	36.98	-	-
Calcined phosphate - every year	40.52	3.54	100.00
Rock phosphate meal - every year	39.78	2.80	83.83
Rock phosphate meal - fertilized "in storage" *	39.83	2.85	85.33
Confidence interval (P = 0.95)	-	1.22	

* Fertilized "in storage" - 4-year dose given once.

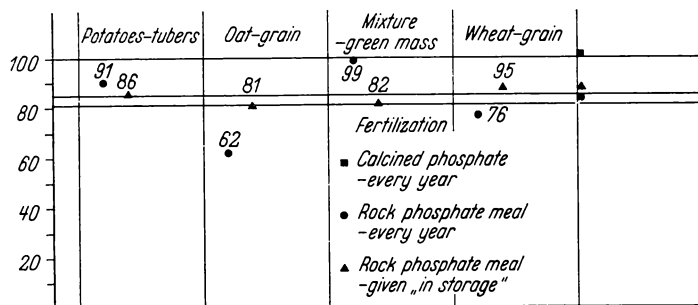


Fig. 1. Average crop increases of the separate plants (relative values) in four-years experiments

As indicated in Fig. 1, the phosphorus from phosphorite meal was well utilized by potatoes, field peas and winter wheat, oats reacting the most weakly to this fertilizer. The effects of fertilizing "in storage" as compared with annual fertilization appear to be better for the cultivation of cereals.

INVESTIGATIONS ON THE DYNAMICS OF THE UPTAKE OF PHOSPHORUS FROM CALCINED PHOSPHATE AND PHOSPHORITE MEAL ANNOFOS BY PLANTS

Investigations were carried out in 1960 during which the occurrence and magnitude of the differences in uptaking phosphorus from calcined phosphate and phosphorite meal by plants in the various phases of

their development [4] was studied. The evaluation of these differences was based on a comparison of the value of the ratio of the total nitrogen content to the total phosphorus content in the plants investigated [1]. The objects of the investigation were potatoes (tubers and leaves), oat, mixture of field peas and oats and winter wheat, harvested 3 times during the vegetation period and conducted during the 3rd year of the experiments in the Norfolk crop rotation [5]. Samples of the plants were gathered and analyzed from each of the particular fertilizer combinations. The dates of the harvests is given in Tab. 2.

Table 2

The dates of the harvests

Harvests	Potatoes	Oat	Field peas with oats	Wheat
I harvest	July 20 beginning of blooming	June 1 tillering	June 1 tillering of oats	May 5 tillering
II harvest	August 24 lower leaves die	July 6 heading	July 6 heading	June 16 blooming
III harvest	November 24 fully ripe	August 4 fully ripe	July 16 field peas bloom	August 9 full ripeness

A similar basic fertilization (nitrogen-potash) was used in the experiments on all fields, and the phosphorus fertilization was diverse. Apart from the control series, without phosphorus, the experiments included a series with annual doses of calcined phosphate and phosphorite meal Annofos and a series in which phosphorite meal was used "in storage" under all the crops in crop rotation once every 4 years. The plant samples were gathered for investigation in the 3rd year of the application of this fertilizer.

It was expected that the differences in fertilization as regards the solubility of phosphorus compounds will have a marked influence on the chemical composition of the plants, especially in the younger phases of their development. It was also judged that the plants from the series without phosphorus and those fertilized with not readily available forms of phosphate compounds in the form of phosphorite meal will have a larger ratio $N : P_2O_5$ than the plants from the series fertilized with calcined phosphate.

The phosphorus fertilizer dose under potatoes amounted to 50 kg, under the remaining plants — 30 kg P_2O_5 per hectare. The doses of both fertilizers were computed according to the total phosphorus content.

Basic fertilization consisted of nitrochalk in a dose of 30 kg N per hectare under each of the plants and 40 percent potash salt in a dose of 89 kg K_2O per hectare under potatoes and 40 kg per hectare under the remaining crops. Farmyard manure (200 q/ha) was also used for the potatoes.

The results of the analyses confirmed the supposition that the phosphorus supplied to plants was less in the series fertilized by phosphorite meal compared to those fertilized by calcined phosphate. The plants from the series without phosphorus had the largest ratio $N:P_2O_5$ and the smallest — those fertilized with calcined phosphate. The values of the ratio $N:P_2O_5$ in crops from the series fertilized with phosphorite meal were more advantageous (lower) when using this fertilizer "in storage"

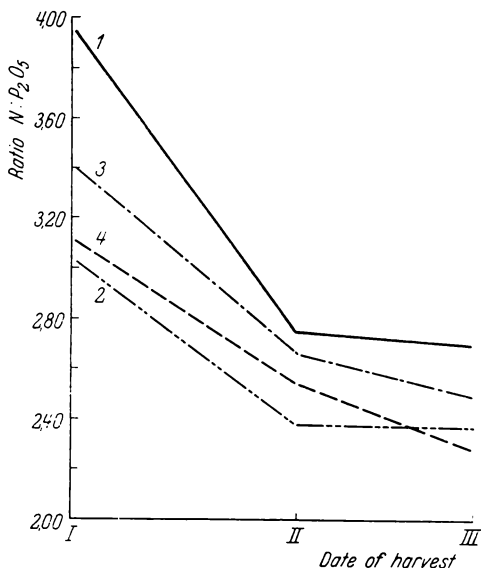


Fig. 2. Average ratio $N:P_2O_5$ in the plants examined

1 — no phosphorus, 2 — calcined phosphate — single dose, 3 — rock phosphate meal — applied every year, 4 — rock phosphate meal given "in storage".

as compared with the ratio with annual doses. The largest differences in the ratio $N:P_2O_5$ in the plants of the particular fertilization series occurred in the initial period of growth (Harvest I). These differences became smaller as the vegetation period became longer. This is to be seen in Fig. 2, which presents the means of the relationships in the values of the ratio $N:P_2O_5$ for all plants investigated. The greatest range in the value of this ratio in the samples of each of the crops (growth phase) was ascertained in oat and wheat, a smaller one in the leaves and tubers of potatoes and it was the smallest in field peas.

EXPERIMENTS ON THE EFFECTIVENESS OF FERTILIZATION "IN STORAGE"
WITH PHOSPHORITE MEAL ANNOFOS AND CALCINED PHOSPHATE
ON MEADOWS

The investigations were conducted in 1959-1961 in 3 localities of the Rzeszów district. The distance between the experimental points did not exceed 3 km, but they differed fundamentally as regards kind and humidity of the soil. Experiment 1 was performed on a fine-sandy medium clay with a low ground-water level, which produced a periodic drought, most frequently after the 1st cut. The soil contained 6.7 mg P_2O_5 and 6.8 mg $K_2O/100$ grams soil after Egner, 4.83 percent organic matter and $pH_{KCl} = 5.9$. In experiment 2 soil conditions were advantageous to the action of the phosphorite meal: organogenic alluvial peat soil, moist, with $pH_{KCl} = 5.6$, contained 10.68 percent organic matter in a layer up to 20 cm deep. It was poor in available phosphorus and potash (5.5 mg P_2O_5 and 2.5 mg $K_2O/100$ grams soil after Egner). The soil in the experiment 3 (a heavy warp soil) had a $pH_{KCl} = 6.3$, a high groundwater level and contained 6.21 percent organic matter and 2.1 mg P_2O_5 and 7.3 mg $K_2O/100$ g soil after Egner. The average altitude of the experimental plots amounted to about 200 m, and the mean of the total precipitation — 685.5 mm (during the vegetation period — April to September — 454 mm).

All the experiments were undertaken in 5 fertilization series: without phosphorus, calcined phosphate and Annofos applied in doses every year and calcined phosphate and Annofos applied once every three

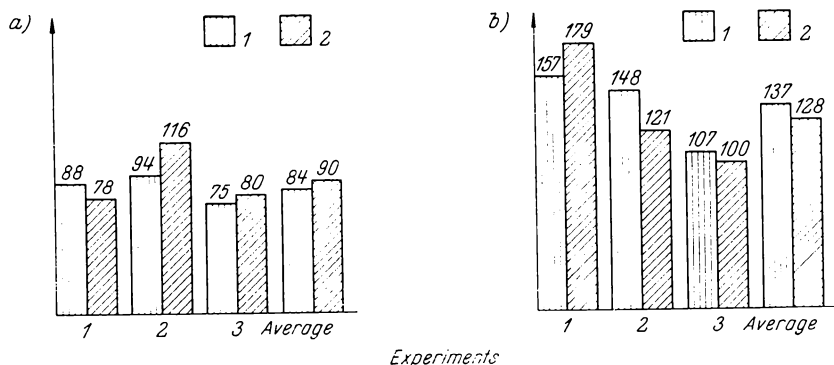


Fig. 3. Relative values of crop increase when fertilized every year or "in storage" (once in three years) with calcined phosphate and rock phosphate meal in three-year meadow fertilizing experiments

- a) — comparison of the effect of fertilization. Crop increase when calcined phosphate = 100;
1 — rock phosphate meal applied every year, 2 — rock phosphate meal given „in storage”
- b) — comparison of systems of fertilizing. Crop increase when fertilization every year = 100;
1 — rock phosphate meal, 2 — calcined phosphate.

Table 3

Average crops of hay (dry mass) from the three-year meadow fertilizing experiments

Fertilization	I-st experiment		II-nd experiment		III-rd experiment	
	q/ha	crop in-crease	q/ha	crop in-crease	q/ha	crop in-crease
Without phosphorus	61.8	-	68.8	-	58.7	-
Calcined phosphate every year	69.5	7.7	78.2	9.4	70.3	11.6
Rock phosphate meal every year	68.6	6.8	77.7	8.9	67.4	8.7
Calcined phosphate fertilized "in storage" *	75.6	13.8	60.2	11.4	70.3	11.6
Rock phosphate meal fertilized "in storage" *	72.5	10.7	82.0	13.2	68.0	9.3
Confidence interval (P = 0.95)	-	2.88	-	3.79	-	2.40

* Fertilized "in storage" - full fertilizer dose given once every three years

years "in storage". The yearly dose of phosphorus amounted to 50 kg/hectare P_2O_5 (calculated according to the total phosphorus content). At the beginning of the experiment, a "storage" dose of both fertilizers meant for three years, that is 150 kg/hectare P_2O_5 , was applied in series 4 and 5. The basic fertilization consisted in: 40 percent potash salt and 25 percent nitrochalk. As regards mineral soils, 80 kg/hectare K_2O and 40 kg/hectare N was applied every year in experiments 1 and 3, and as regards the organo-genic soil — 120 kg/hectare K_2O and 20 kg/hectare N in experiment 2.

Two cuts of hay were harvested each year from every experiment. The mean hay yield from each of the experimental stands (total of 2 harvests) are presented in Tab. 3. In every year of the experiments the yields shaped as depending on the quantity and distribution of precipitation. The highest yields were obtained in the dry stand (exp. 1) during wet years (1960 and 1961) and on very moist soils (exp. 2 and 3) a dry year (1959) was more advantageous.

As indicated by Tab. 2, the highest average hay crops were obtained in experiment 2, on an acid and humid meadow. Fertilization every year with calcined phosphate and phosphorite meal produced the same effect whereas when both these fertilizers were applied "in storage", the action of Annofos was somewhat better.

Figure 3 presents the effectiveness of fertilization with phosphorite meal in relation to the value of calcined phosphate (A) and a comparison of the increase in effectiveness of both fertilizers when used "in storage" (B). In part A, the average values of crop yield increases of 3 years of

experiments obtained consequent to fertilization with calcined phosphate applied every year and "in storage" was adopted as 100 and to these values the effectiveness of Annofos was referred when applied in the same manner. As may be seen, phosphorite meal gave way in a varied degree to the fertilizer action of the calcined phosphate irrespective of the manner of its application, with the exception of experiment 2 on the organogenic soil where fertilization "in storage" with Annofos gave higher yields (116 percent).

When comparing the manner of applying fertilizers — in part *B* of the graph, the yield increases consequent to fertilizing with calcined phosphate and phosphorite meal in annual doses was adopted as 100. As seen, fertilization "in storage" with phosphorus (apart from calcined phosphate in exp. 3) gave a markedly better effect than annual fertilization. The mean increase in effectiveness (from all the experiments) of fertilization "in storage" with Annofos was higher (137 percent) as compared with fertilization "in storage" with calcined phosphate (128 percent).

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FUMAGE PAR LA POUDRE PHOSPHORITE ANNOFOS PAR AVANCE

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R é s u m é

Au cours des observations menées on compara l'efficacité du fumage par la poudre de phosphorite et la basiphosphate „supertomasyna”. La poudre de phosphorite dans les expériences aux champs dans la rotation de Norfolk appliquée en une dose (une fois pour les 4 ans) produit en moyenne un accroissement semblable des récoltes qu'appliqué annuellement. Par contre le fumage par avance dans la culture des céréales était plus profitable que le fumage annuel.

Dans les observations sur la dynamique du prélèvement du phosphore par les plantes dans diverses phases de leur développement le fumage par la poudre de phosphorite par avance favorisait en une plus large mesure que le fumage annuel un prélèvement harmonieux du phosphore et de l'azote assurant aux plantes une quantité suffisante d'aliment phosphorique dans les premiers stades de leur développement.

Au cours des expériences dans les prairies le fumage par avance tant par la poudre de phosphorite que par la basiphosphate „supertomasyna” était plus efficace que le fumage par doses annuelles.

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DIE VORRATSDÜNGUNG MIT POLNISCEM ROHPHOSPHATMEHL
„ANNOFOS”

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Z u s a m m e n f a s s u n g

Es wurden die Untersuchungen durchgeführt, in welchen man die Effektivität der alljährlichen und Vorratsdüngung mit Rohphosphatmehl und polnischem Glühphosphat („Supertomasyna”) verglich. Das Rohphosphatmehl in der innerhalb der Norfolk Fruchtwechsel geführten Feldversuchen, bei einmaliger Einbringung desselben für ganze Fruchtfolge (jede 4 Jahre) gab im Durchschnitt ähnliche Mehrertäge wie bei dessen alljährigen Einbringung. Die Vorratsdüngung war, dagegen, beim Getreideanbau günstiger als die alljährige.

In den Untersuchungen über die Dynamik der Phosphoraufnahme durch die Pflanzen in verschiedenen Entwicklungsphasen derselben, trug die Vorratsdüngung mit Rohphosphatmehl im grösserem als die alljährliche Grade einer harmonischen Phosphor- und Stickstoffaufnahme bei, indem sie den Pflanzen genügende Phosphormengen in frühen Entwicklungsphasen sicherte.

In den Wiesenversuchen erwies sich die Vorratsdüngung, sowohl mit Rohphosphatmehl als auch mit Glühphosphat „Supertomasyna”, effektiver als die alljährliche Düngung.

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NAWOŻENIE MĄCZKĄ FOSFORYTOWĄ ANNOFOS NA ZAPAS

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Streszczenie

Przeprowadzono badania, w których porównywano efektywność corocznego i zapasowego nawożenia mączką fosforytową i supertomasyną. Mączka fosforytowa w doświadczeniach polowych w płodozmianie norfolkskim zastosowana jednorazowo na całe zmianowanie (raz na 4 lata) wywołała przeciętnie podobne przyrosty plonów jak przy stosowaniu corocznym. Natomiast nawożenie na zapas przy uprawie zbóż było korzystniejsze od nawożenia corocznego.

W badaniach nad dynamiką pobierania fosforu przez rośliny w różnych fazach ich rozwoju nawożenie mączką fosforytową na zapas sprzyjało w większym stopniu niż nawożenie coroczne harmonijnemu pobieraniu fosforu i azotu zabezpieczając roślinom dostateczną ilość pokarmu fosforowego we wczesnych stadiach rozwoju.

W doświadczeniach łąkowych zapasowe nawożenie zarówno mączką fosforytową, jak i supertomasyną było efektywniejsze od nawożenia dawkami corocznymi.

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УДОБРЕНИЕ ФОСФОРИТНОЙ МУКОЙ АННОФОС ПРО ЗАПАС

Кафедра Агрoхимии, Высшая Сельскохозяйственная Школа, Краков

Резюме

Проводили исследования, в которых сравнивали эффективность удобрения фосфоритной мукой и супертoмасшлаком, вносимых ежегодно или про запас. В полевых опытах фосфоритная мука применяемая в норфольском севообороте однократно весь плодосмен (раз на 4 года) давала в среднем подобные прибавки урожая, как и при ежегодном применении. Однако для зерновых культур удобрение про запас оказалось эффективнее ежегодного.

Согласно исследованиям по динамике усвоения фосфора растениями в разных фазах развития, удобрение фосфоритной мукой про запас способствовало более гармоническому поступлению фосфора и азота в растения, лучше их обеспечивая питательными элементами в ранних стадиях развития.

В луговых опытах удобрение про запас как фосфоритной мукой так и супертoмасшлаком было более эффективным, чем удобрение ежегодно вносимыми дозами.