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UTILIZATION OF MINERAL PHOSPHORUS FRACTIONS FROM PHOSPHORUS-FERTILIZED SOILS

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Changes of the fertilizer phosphorus in soils constituted a subject of many works, both home [2, 5, 6, 7, 11] and foreign [3, 8, 9 and oth.]. Relatively less investigations were devoted, instead, to the possibility of utilization of phosphorus by plants from its forms developed in consequence of transformation of this element introduced with fertilizers [5, 9, 10].

The aim of the present investigations was to determine the utilization degree of mineral phosphorus fractions from soils fertilized differently within a definite period with this element.

METHODICS

A pot experiment has been established on soils originating from five long-term field experiments (Table 1). In the 12th year of the field experiments samples were taken from the following treatments: P_0 , P_1 , P_2 , P_4 ($P_1=36$ kg P_2O_5 per hectare a year).

In pots three test plants were cultivated, vis.: oats, maize and rye. For each plant the NKMg fertilization and for a half of pots also P fertilization was applied. Results obtained in treatments without phosphorus are presented in the paper. Despite sometimes acid reaction of the soils, no liming was applied, as this fertilization kind could probably result in changes of the initial fractional composition of soil phosphorus. All tests plants were harvested in the period of the maximum phosphorus uptake, i.e. at the panicle-forming stage of oats, flowering of maize and heading of rye. Upon harvesting subsequent plants the soil was turned over, soil samples were taken and the nutrient medium was introduced. The fertilization applied was as follows: 2 g N for oats and maize, 1.25 g N for rye; 1.5 g K_2O for oats and maize, 1.25 g K_2O

for rye, 0.5 g Mg for oats, 1 g Mg for maize.

In initial soil samples and upon harvesting subsequent plants, the content of mineral phosphorus fractions was determined according to the Chang and Jackson's method in modification of Ginsburg and Lebedeva [12]. Total phosphorus determined in mineral soils by the method of burning soil with acids [12].

INVESTIGATION RESULTS

Initial phosphorus fraction content. The differentiated fertilization with phosphorus in field experiments distinctly affected the content of the investigated fractions of this element. The total phosphorus content increased, on the average, by over 30% in the relation to the control treatment. The highest relative phosphorus content increment was found in soils from Bałtów, Borkowice and Krzelów (Table 2).

Increasing rates of phosphorus fertilizers resulted also in changes in the fractional composition of this element. The highest changes in the content of mineral phosphorus fractions were found in soils fertilized with the rates of 72 ad 114 kg P_2O_5 per hectare a year; these changes concerned, as a rule, the fraction of readily soluble phosphorus and the P-Al fraction. The increment of readily soluble phosphorus content was almost fivefold and that of P-Al—over threefold as compared with the control treatment. Analogic increment of the phosphorus bounded with calcium and iron did not exceed 50%. In this connection the mineral phosphorus fraction percentage changed along with increasing fertilization level in favour of readily soluble phosphorus and aluminium-bounded phosphorus. This regularity has been found in all the soils under study, although the differences in the content of particular fractions and their mutual relations were considerable ones. A special attention deserves the soil from Zwoleń, in which the P-Al fraction predominates; it is also an only soil, in which no increment of readily soluble phosphorus in connection with higher rates of this element has been proved. In the soil from Krzelów a considerable percentage of the fraction of phosphorus bounded with calcium was observed, what was justified in connection with the presence of carbonates in it. (Table 1). Also the increment of this fraction in soil was higher under the effect of increasing phosphorus rates as compared with other soils.

Utilization of mineral phosphorus fractions by plants. Upon harvesting subsequent plants a distinct decrease of the readily soluble phosphorus content and of the P-Al fraction was observed, irrespective of the soil kind and the amount of accumulated phosphorus. The content of either fraction significantly decreased along with the cultivation of subsequent test plants. However, the differentiation of the P-Al fraction content caused by the fertilization applied

Table 1

Characteristics of soils used in the experiment

Locality	Soil type	Mechanical composition	pH _{KCl}	Humus %	CaCO ₃ %
Bartów	pseudopodzolic soil	pł	5.15	1.23	-
Borkowice	leached brown soil	pł	5.55	1.21	0.5
Jabłoń	pseudopodzolic soil	płi	4.85	1.50	-
Krzelów	brown rendzina soil	gś	6.55	1.80	8.4
Zwolen	pseudopodzolic soil	pgł	5.00	1.83	-

pł = silt, gś = medium loam, pgł = sandy loam

in field experiments maintained till the end of the investigations. On the other hand, this differentiation in the content of readily soluble phosphorus between fertilizing treatments distinctly decreased. The dynamics of changes in the content of the P-Fe and P-Ca fractions was in most soils relatively weak. Particularly the soils from Bartów, Jabłoń and Zwolen distinguished themselves in this case, as in them often no decrease of the fractions mentioned was found (Figs 1 and 2). In these soils also low yields of crops were obtained (Table 3).

In the soil from Borkowice a considerable decrease of the P-Fe fraction and in the soil from Krzelów — that of the P-Ca fraction was found (Fig. 2).

The decrements of particular fractions, presented in Fig. 2, in relation to their initial content, amounted in the soils investigated to 73–87.1% of readily soluble phosphorus, to 44.8–49.6% of the P-Al fraction, to

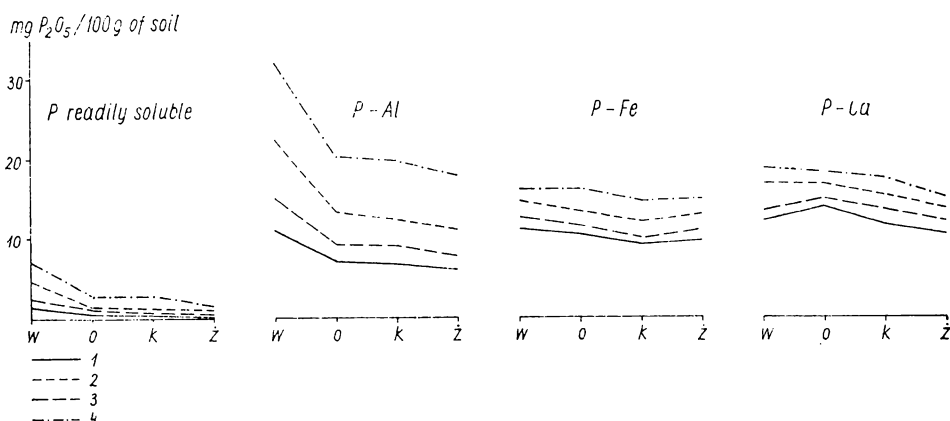
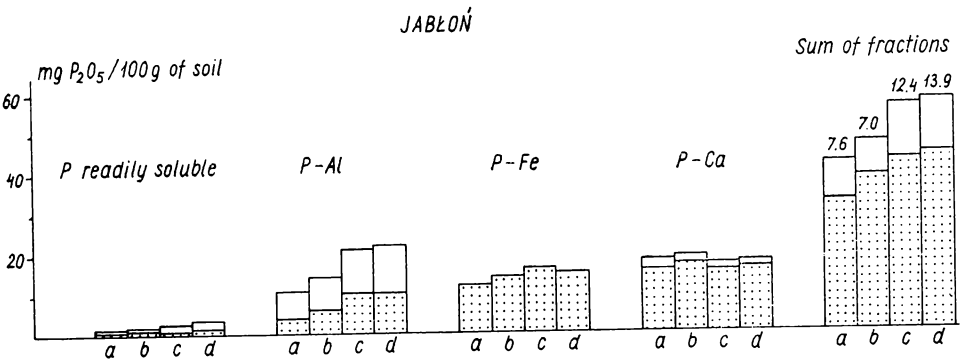
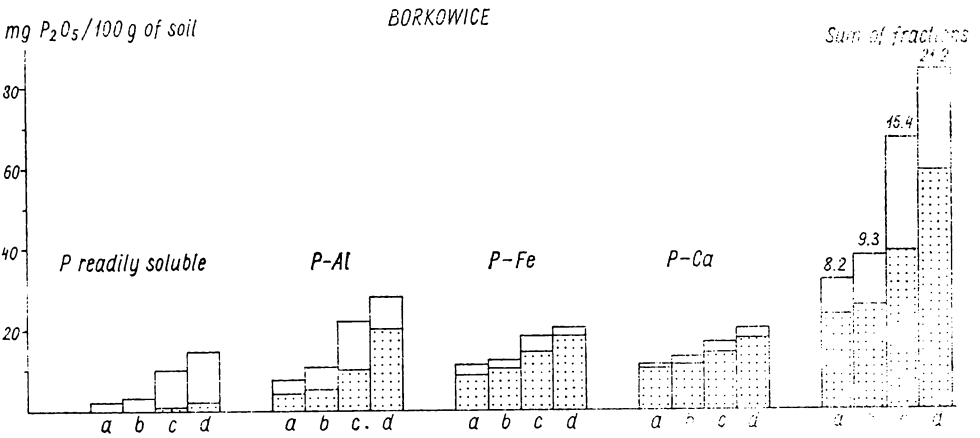
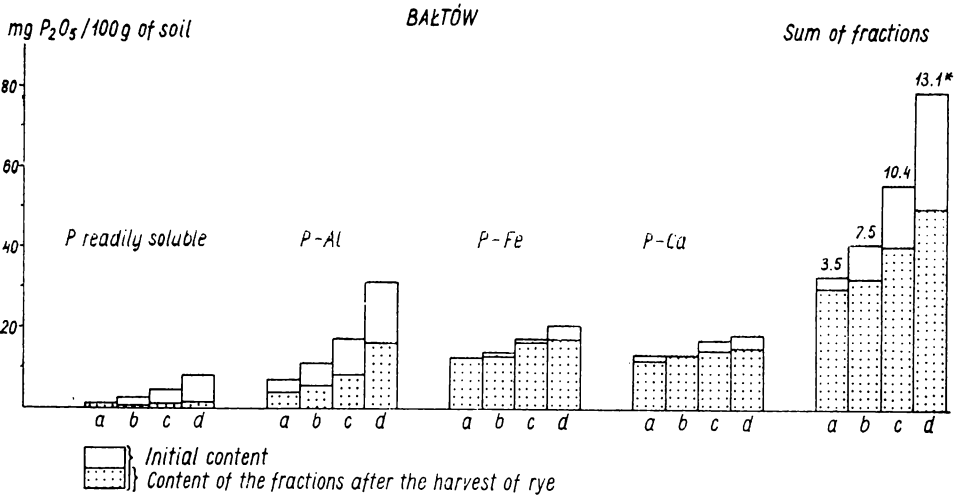


Fig. 1. Dynamics of the mineral phosphorus fraction content in soil kg P₂O₅/ha/year: 1—0, 2—36, 3—72, 4—144; w—initial content of the fractions, o—content of the fractions after the harvest of oats, k—content of the fractions after the harvest of maize, z—content of the fractions after the harvest of rye



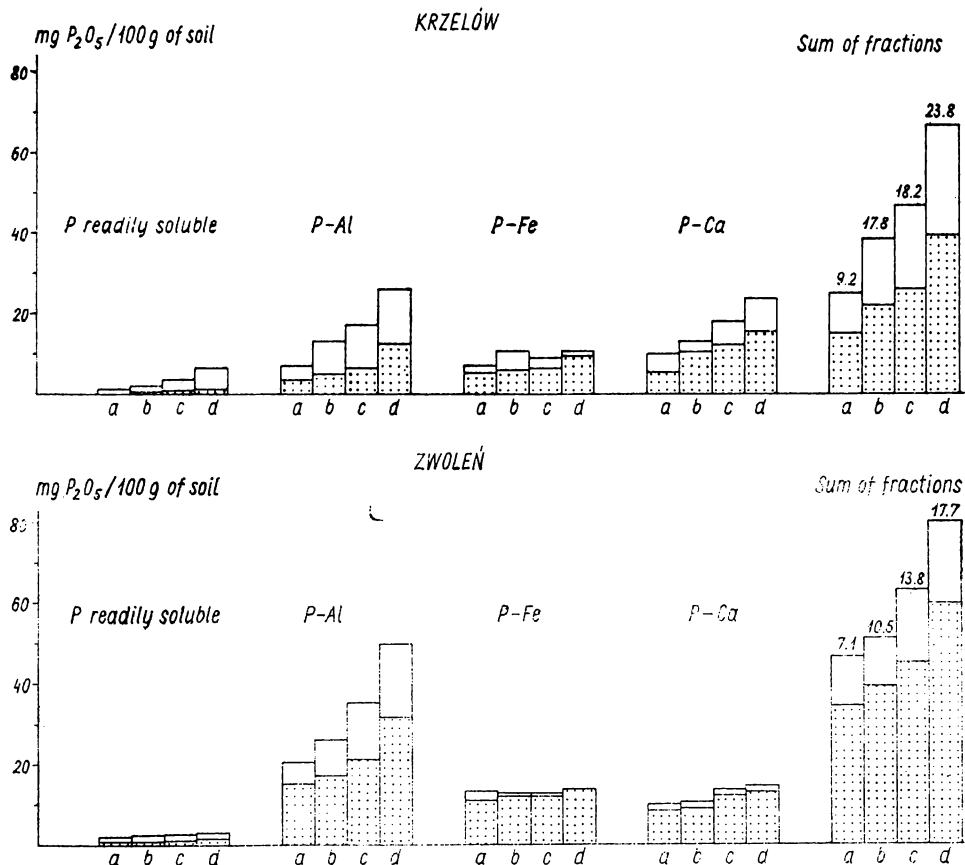


Fig. 2. Balance of mineral phosphorus fractions

kg PO/ha/year: a—0, b—36, c—72, d—144; *—phosphorus uptake in mg P_2O_5 /100 g of soil

1.5–22.3% of the P-Fe fraction and to 0.1–10.7% of the P-Ca fraction. It may be presumed that along the same line particular mineral phosphorus fractions would constitute a worse and worse phosphorus source for plants.

Upon setting up the initial state of sums of particular fractions, phosphorus uptake by plants corresponding with them and total decrements of the content of particular fractions, the balance of mineral phosphorus forms in the pot experiment has been obtained (Fig. 2). The values of decrements of fraction sums exceeded in most cases the phosphorus uptake by crops. In such a way the balance differences would be most probably connected with the phosphorus degradation process in soil. This process ran probably also during the vegetative experiment. Such hypothesis is corroborated by the fact of usually proportional increase of the balance difference along with the rise of the phosphorus fertilization level as applied earlier.

Table 2

Initial content of the phosphorus compounds /in mg P₂O₅ per 100 g of soil/

Soil	Fertilization, kg P ₂ O ₅ per hectare a year	Total phosphorus	Phosphorus fractions after Chang and Jackson				Sum of fractions
			readily soluble	P-Al	P-Fe	P-Ca	
Bartów	0	95.2	0.6	7.5	12.2	13.3	33.6
	36	98.2	2.4	11.4	13.5	13.7	41.0
	72	104.8	4.5	16.9	17.2	16.9	55.5
	144	132.0	7.9	31.9	20.4	18.6	78.8
Borkowice	0	75.2	2.2	7.6	10.8	11.5	32.1
	36	78.4	2.7	10.8	12.4	12.2	38.1
	72	86.8	10.1	22.0	17.9	16.8	66.8
	144	117.6	14.7	28.5	20.2	19.9	83.8
Jabłoń	0	95.2	1.0	10.4	12.6	17.8	41.8
	36	98.5	1.4	13.6	13.8	18.5	47.3
	72	110.4	2.1	20.8	16.1	16.9	55.9
	144	112.8	2.5	22.3	15.0	17.8	57.6
Krzelów	0	106.0	0.8	7.2	7.0	9.8	24.8
	36	112.0	2.2	13.0	10.3	13.1	38.6
	72	115.2	3.7	17.0	8.9	17.5	47.0
	144	146.8	6.7	25.7	10.7	23.5	66.6
Zwoleń	0	128.4	2.1	20.7	15.4	10.2	46.4
	36	130.4	2.2	25.9	12.7	10.4	51.2
	72	142.0	2.2	35.3	12.8	13.8	64.1
	144	166.4	2.6	49.5	13.5	14.4	80.0

Table 3

Yields of plants in g of dry matter per pot /sum of oats + maize + rye/

Soils	Fertilization level - kg P ₂ O ₅ per hectare a year				Mean	LSD
	0	36	72	144		
Bartów	52.2	110.9	141.6	149.5	113.6	17.5
Borkowice	140.2	145.0	181.7	178.7	161.4	
Jabłoń	119.2	107.7	143.2	145.6	128.9	
Krzelów	119.1	194.4	181.9	194.9	172.4	
Zwoleń	111.4	140.9	147.1	164.0	140.8	

CONCLUSIONS

1. In consequence of a long-term fertilization with phosphorus a considerable accumulation of this element in soil is taking place. The fertilizer phosphorus residues occur mainly in the form of the P-Al fraction and the fraction of readily soluble phosphorus.

2. The availability of phosphorus fractions to plants decreases along the line: readily soluble P > P-Al > P-Fe > P-Ca.

3. The phosphorus degradation process in soil is of long duration and its course should be taken into account in any attempts of balancing of mineral forms developed in consequence of deposition of this element in soil.

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WYKORZYSTANIE MINERALNYCH FRAKCJI FOSFORU
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Streszczenie

Doświadczenie wazonowe założono na glebach z pięciu wieloletnich doświadczeń polowych. Glebę pobrano z obiektów stosowanych w doświadczeniach polowych: P₀, P₁, P₂, P₄ (P₁=36 kg P₂O₅/ha rocznie).

W doświadczeniu wazonowym nie stosowano nawożenia fosforem, jedynie N, K i Mg; uprawiano kolejno po sobie trzy rośliny: owies, kukurydzę i żyto. Przed założeniem doświadczenia i po sprzęcie każdej rośliny oznaczano w glebie zawartość mineralnych frakcji fosforu metodą Changa i Jacksona.

Pozostałości nawozowe fosforu zostały zidentyfikowane głównie w postaci frakcji: fosforu łatwo rozpuszczalnego (ekstrakcja 0,5 N NH₄Cl) i P-Al (ekstrakcja 0,5 N NH₄F). Frakcje te wykazywały również największą dynamikę w doświadczeniu wazonowym i stanowiły najlepsze źródło fosforu dla uprawianych roślin.

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