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# THE CONTENT OF AVAILABLE NUTRIENTS IN SOILS DEPENDING ON THE LEVEL OF THEIR ACIDIFICATION

*J. Wiater*

Department of Agricultural Chemistry, University of Agriculture
Akademicka 15, 20-033 Lublin, Poland

A b s t r a c t. The research was made in eight places in Lublin administrative area. Soil samples were taken from the arable layers of 23 productive fields after harvesting rape, careals and potatoes. The influence of the pH value of soil on the content of available phosphorus, potassium and magnesium forms and also on the content of easily hydrolyzable nitrogen. On the basis of the obtained results it was determined that available magnesium and phosphorus contents were directly proportional to the value of the pH of soil. However, it did not influence the content of the available potassium forms. The easily hydrolyzable nitrogen content was negatively correlated with the value of the pH of soil. Apart from the level of soil acidification the level of available nutrients in the tested soils was influenced by the forecrop plants and the level of the applied fertilization.

K e y w o r d s: available nutrients in soils, soil acidification, easily hydrolizable N

## INTRODUCTION

In the climatic conditions of Poland, soil reaction depends, first of all, on the calcium content in it. Together with loosing calcium as the result of uptaking it by plants and elution, its share in the sorptive complex of soil diminishes and it is replaced by hydrogen ions and accompanying ions of aluminium.

Light textured soils which were formed from rocks calcium carbonate scanty with very little buffer capacity are most sensitive to acidification. Light textured soils acidification is not so harmful though, as the acidification of medium and heavy textured soils. The acidification not only causes the unfavourable changes of physical properties of soils, but also it has an effect on chemical properties, including the availability of nutrients.

That is why the research has been made to determine the influence of the level of the acidification of soil on the content of the available forms of basic nutrients.

## MATERIALS

Field research has been made in 8 places in Lublin administrative area in 1991. After harvesting rape, winter and spring wheat, barley, triticale, rye and patatoes, soil samples were taken from the arable layer in 23 productive fields. Farmers were interviewed as to the forecrop of the cultivated plants and their fertilizing (Table 1). The fertilization was differentiated mainly in the respect of forecrop and it was lower than in the previous years mainly for economic reasons.

In the soil samples the following were determined:

- granulometric composition - with Cassagrande - Prószyński's method,
- soil reaction in 1mol KCl $dm^{-3}$,
- available phosphorus and potassium with the method of Egner-Riehm,
- available magnesium with the method of Schachtschabel,

**Table 1.** Forecrop and fertilization of plants where soil samples were collected after harvest

| No. | Locality | Plant | Forecrop | Fertilization (kg/ha) | | |
|---|---|---|---|---|---|---|
| | | | | N | P | K |
| 1 | Babin | rape | Barley | 32 + 120 | 42 | 80 |
| 2 | Czesławice | rape | Alfalfa | 28 | 35 | 125 |
| 3 | Garbów | spring barley | Wheat | 32 | 42 | 80 |
| 4 | Garbów | spring wheat | Sugar beet++ | - | - | - |
| 5 | Garbów | winter wheat | Sugar beet++ | 16 + 51 | 21 | 40 |
| 6 | Garbów | triticale | Barley | 28 + 34 | 37 | 70 |
| 7 | Garbów | potato | Wheat | 28 | 35 | - |
| 8 | Garbów | potato | Maize | 34 | 35 | 60 |
| 9 | Czesławice | potato | Winter wheat | 84 | 35 | 120 |
| 10 | Babin | winter wheat | Sugar beet++ | 56 | 40 | 60 |
| 11 | Bełżyce | barley | Wheat | 23+ ploughed straw | - | - |
| 12 | Bełżyce | rape | Barley | 54 + 92 | 31 | 60 |
| 13 | Bełżyce | potato | Barley | - | - | - |
| 14 | Turka | triticale | Barley | 56 | 20 | 40 |
| 15 | Osówka | winter wheat | Potatoe | 54 | 35 | 60 |
| 16 | Krasienin | winter wheat | Sugar beet++ | 46 | 40 | 75 |
| 17 | Krasienin | triticale | Oats | 45 + 70 | 50 | - |
| 18 | Krasienin | spring wheat | Sugar beet++ | 46 | 40 | 75 |
| 19 | Osówka | rye | Barley | 60 | 28 | 58 |
| 20 | Turka | wheat | Potatoes++ | 34 | 20 | - |
| 21 | Kijany | rye | Triticale | 75 | 30 | 60 |
| 22 | Kijany | triticale | Spring wheat | 46 | 40 | 70 |
| 23 | Bełżyce | winter wheat | Barley | 54 + 92 | 31 | 60 |

++ farmyard manure.

- easily hydrolyzable nitrogen with the method of Cornfield.

The results were statistically worked out, calculating the correlation coefficients between the soil pH and the content of available nutrients and between the contents of fine particles and available nutrients.

## RESULTS

On the basis of the granulometric composition determination (Table 2) it is possible to state that ten soils are the soils of the kind of clayey silt in the agronomy qualification - heavy soils. The next ten soils are the soils of the kind of loamy silt and silty loam - medium soil. The remaining three soils are of the kind of light textured soils: heavy loamy sand and light loamy sand.

On the basis of the determination of pH values (Table 3) most of the heavy soils should be numbered among the acid ones, and two even to very acid. Only one sample taken after the rape harvest in Babin was neutral. A part of the fields on which soil samples were taken had not been limed for many years. Some other fields had been limed but with too small doses in the relation to the needs.

The soils from the category of medium ones had acid and weak acid reaction, and the soil from Bełżyce, after harvesting barley was of neutral reaction. This soil had been limed before barley cultivation therefore it had much higher pH than soil in other places.

Light textured soils were numbered among the weak acid ones which gives proper conditions for the development of the majority of the plants cultivated on them.

The phosphorus content in the tested soils ranged from 23.0 to 162.5 mg P/kg of soil and was within the class of low availability - 5 soils, and the rest in the class of high and very high availability (Table 3). Mainly soil pH decided about the available phosphorus content in them. The increase in the available phos-

**Table 2.** Mechanical composition of soils

| No. | Locality | Plant | Fraction size (mm) | | | | | | Soil kind |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1-0.1 | 0.1-0.05 | 0.05-0.02 | 0.02-0.05 | 0.005-0.002 | <0.002 | |
| 1 | Babin | rape | 2 | 10 | 44 | 27 | 9 | 8 | clayey silt |
| 2 | Czeslawice | rape | - | 11 | 45 | 25 | 6 | 13 | clayey silt |
| 3 | Garbów | spring barley | - | 11 | 44 | 27 | 9 | 9 | clayey silt |
| 4 | Garbów | spring wheat | 1 | 14 | 44 | 25 | 8 | 8 | clayey silt |
| 5 | Garbów | winter wheat | - | 11 | 45 | 23 | 7 | 14 | clayey silt |
| 6 | Garbów | triticale | 4 | 12 | 46 | 23 | 10 | 5 | clayey silt |
| 7 | Garbów | potato | 5 | 7 | 51 | 23 | 7 | 7 | clayey silt |
| 8 | Garbów | potato | 2 | 14 | 41 | 26 | 10 | 7 | clayey silt |
| 9 | Czesławice | potato | 1 | 14 | 47 | 22 | 9 | 7 | clayey silt |
| 10 | Babin | winter wheat | - | 14 | 46 | 25 | 8 | 7 | clayey silt |
| 11 | Bełżyce | barley | 17 | 15 | 35 | 22 | 7 | 4 | loamy silt |
| 12 | Bełżyce | rape | 35 | 11 | 29 | 13 | 5 | 7 | sandy loam |
| 13 | Bełżyce | potato | 44 | 11 | 22 | 14 | 5 | 4 | send-silty loam |
| 14 | Turka | triticale | 32 | 6 | 32 | 15 | 6 | 9 | light silty loam |
| 15 | Osówka | winter wheat | 24 | 13 | 35 | 17 | 8 | 3 | loamy silt |
| 16 | Krasienin | winter wheat | 9 | 16 | 42 | 22 | 7 | 4 | loamy silt |
| 17 | Krasienin | triticale | 9 | 12 | 46 | 21 | 7 | 5 | loamy silt |
| 18 | Krasienin | spring wheat | 9 | 13 | 44 | 19 | 7 | 6 | loamy silt |
| 19 | Osówka | rye | 19 | 18 | 37 | 16 | 6 | 4 | loamy silt |
| 20 | Turka | wheat | 24 | 11 | 33 | 19 | 7 | 6 | loamy silt |
| 21 | Kijany | rye | 46 | 11 | 23 | 13 | 4 | 3 | heavy loam-silty sand |
| 22 | Kijany | triticale | 51 | 14 | 21 | 10 | 3 | 1 | light loam-silty sand |
| 23 | Bełżyce | winter wheat | 59 | 7 | 23 | 7 | 2 | 2 | light loam-silty sand |

**Table 3.** Soil pH and content of available macronutrients (mg/kg soil)

| No. | Locality | Plant | pH | P | K | Mg | N* |
|---|---|---|---|---|---|---|---|
| 1 | Babin | rape | 6.75 | 162.5 | 412.0 | 24.0 | 123.6 |
| 2 | Czesławice | rape | 4.60 | 49.5 | 345.0 | 45.0 | 145.2 |
| 3 | Garbów | spring barley | 4.08 | 32.5 | 51.0 | 34.0 | 119.7 |
| 4 | Garbów | spring wheat | 5.00 | 42.2 | 236.0 | 22.0 | 119.0 |
| 5 | Garbów | winter wheat | 4.55 | 56.0 | 30.0 | 18.0 | 122.5 |
| 6 | Garbów | triticale | 5.62 | 80.5 | 42.0 | 61.5 | 132.8 |
| 7 | Garbów | potato | 4.17 | 50.5 | 136.0 | 17.5 | 128.4 |
| 8 | Garbów | potato | 5.40 | 59.0 | 42.0 | 72.0 | 119.7 |
| 9 | Czesławice | potato | 5.10 | 75.0 | 414.0 | 86.0 | 132.0 |
| 10 | Babin | winter wheat | 5.42 | 66.5 | 266.5 | 115.2 | 120.0 |
| 11 | Bełżyce | barley | 6.83 | 91.5 | 164.0 | 26.0 | 107.8 |
| 12 | Bełżyce | rape | 5.50 | 81.0 | 218.0 | 41.5 | 100.8 |
| 13 | Bełżyce | potato | 5.50 | 155.5 | 402.0 | 18.5 | 110.9 |
| 14 | Turka | triticale | 4.60 | 70.0 | 116.0 | 42.0 | 147.7 |
| 15 | Osówka | winter wheat | 5.25 | 40.8 | 48.0 | 11.0 | 121.0 |
| 16 | Krasienin | winter wheat | 5.28 | 23.0 | 65.0 | 15.0 | 114.1 |
| 17 | Krasienin | triticale | 5.75 | 125.0 | 80.0 | 40.5 | 98.3 |
| 18 | Krasienin | spring wheat | 4.90 | 39.5 | 42.0 | 16.0 | 115.5 |
| 19 | Osówka | rye | 5.10 | 63.5 | 128.0 | 11.0 | 128.0 |
| 20 | Turka | wheat | 5.55 | 134.0 | 122.0 | 25.0 | 128.8 |
| 21 | Kijany | rye | 6.39 | 150.0 | 230.0 | 28.0 | 113.4 |
| 22 | Kijany | triticale | 5.60 | 75.0 | 158.0 | 22.0 | 122.5 |
| 23 | Bełżyce | winter wheat | 6.50 | 150.5 | 198.0 | 54.0 | 94.5 |

N* - nitrogen easily hydrolyzable.

phorus content in the majority of soils occurred together with the increase of their pH.

This interdependence is illustrated by the level of correlation coefficient between these two properties -0.57 (Table 4). The phosphorus fertilizing of the plants cultivated on these soils was too low to influence significantly the content of this component in soils. No significant interdependence was noted between the amount of fine particles and the available phosphorus content in soil.

Among the heavy soils the lowest available potassium content occurred in the soils from Garbów and the majority of them was numbered among the ones with very low potassium availability. The remaining soils belonged to the category of medium, high and very high potassium availability. Among medium soils only the soils from the neighbourhood of Krasienin and one from Osówka had very low potassium content and the rest had high and very high potassium availability. The soils with low and very low availability require potassium fertilizing. Light textured soils were rich in available potassium and not require the increased fertilizing with this component. The potassium content in the tested soils depended mainly on the level of fertilizing with this component as well as on the type of forecrop.

A certain tendency connected with the increase in available potassium content together with the increase in fine particles content is noticeable - the correlation coefficient was 0.28 (Table 4). However, no influence of pH on the available potassium content in soil was noted.

The majority of heavy and medium soils belong to those with low and very low magnesium availability. On the other hand, light textured soils were numbered among those with medium magnesium availability. The available magnesium content in soils depended mainly on their reaction. In the tested soils a certain regularity occurred, i.e., together with the lowering of the soils pH value, magnesium content also decreased. The correlation coefficient between the pH level and magnesium content was 0.43.

**Table 4.** Correlation coefficients between soil pH, content of fine particles and the content of available nutrients

| Nutrient | pH | Fine particles |
|---|---|---|
| P | 0.57 | -0.02 n.s. |
| K | 0.08 n.s. | 0.28 n.s. |
| Mg | 0.43 | 0.22 n.s. |
| N easily hydrolyzable | -0.50 | 0.10 n.s. |

n.s. - not significant.

Easily hydrolyzable nitrogen concentration depended mainly on the kind of soil. The soils which were numbered among the heavy ones contained the highest amount of this form of nitrogen in the arable layer of soil. A bit lower content was noted in medium soils. Fertilizing had a lesser influence on the nitrogen content. The only exception is the soil from Czesławice where there was more nitrogen in comparison to other fields. The forecrop for the rape was alfalfa, hence the soil was rich in nitrogen. It was proved that the content of this form of nitrogen influences the pH level of soil to a great extent. On the other hand the pH level is negatively correlated with the easily hydrolyzable nitrogen coefficient and the correlation coefficient amounts to -0.50.

## DISCUSSION

The results discussed in the present paper gave the information as to the increase of soil acidification in the recent years.

In many farms, not only mineral fertilizing was lowered but also the liming of soils was to a great extent neglected which also contributed to the increase in acidification of not only light soils but also heavy soils. The excessive acidification of heavy soils is a serious degradation factor of these soils. Without the improvement of the reaction of these soils one cannot achieve the productive results even on the medium level. If the soil acidification will procede, it is impossible to cultivate intensive plants and their mineral fertilizing is not effective and sometimes even harmful.

The increase in soil acidification significantly decreased the content of available phosphorus. The availability of phosphorus for plants is dependent on the direction of the fertilizing phosphorus changes in soil. The formation of the phosphorus compounds in soil depends mainly on the soil reaction [5,14], its humidity and kind, as well as the phosphorus fertilization.

The optimal solubility of mineral phosphates keeps in the pH range of 5.5-6.5. The majority of the tested soils had lower pH than 5.5, that is why in many soils low phosphorus content occurred. Many authors [2,5,14] stress the positive influence of acid soils liming on the increase of available phosphorus content in soil.

Most of the tested soils had high potassium availability. In the hitherto existing literature [6,13,16], many views were presented pertaining to the influence of soil acidification on the content of available potassium forms. Moss [13] stresses that the increase in the pH of soil causes the increase in potassium content, however, Rich and Black [15] state something reverse and they think that liming causes mainly the decrease of the amount of potassium. Terelak and Sadurski [16] did not notice the influence of acid soil liming on the change of available potassium content.

In the research which has been lead by the authors, the results testifying to the lack of significant correlation between the pH of soil and potassium content were obtained. As results from the Polish [8,9,12] and foreign research [11], a certain amount of potassium added to soil in fertilizers can be transferred into a strongly bound form. It is known that the soils of loess origin may strongly bind potassium, but the results of available potassium determination in the tested soils did not confirm this statement fully.

The question of the necessity of magnesium fertilizing remains important, which is confirmed by the carried out research. Magnesium contained in the organic fertilizers and as a by-component of some mineral fertilizers is not sufficient to cover the fertilizing needs and the increase of magnesium availability in soils. Moreover, as Czuba states [3], in the 1980 ties as the result of applying the increased doses of mineral fertilizers (NPK) at similar lack of magnesium fertilizers, the natural resources of magnesium were disturbed especially in the light textured soils. The increasing soil acidification limits, to a great extent, the content of available forms of magnesium [7]. That is why the majority of the tested soils should be limed with the addition of magnesium fertilizers.

The easily hydrolyzable nitrogen content in soils may serve as the index of average ability of supplying the plants with nitrogen by soil. The concentration of this form of nitrogen depended mainly on the kind of soil, which has been earlier noted by other authors [4,10]. Łoginow [10] stresses that the concentration of this form of nitrogen has influence on the species of the cultivated plant. On the basis of easily hydrolyzable nitrogen determination in the tested soils, it is difficult to confirm the above statement.

The negative correlation between the pH of soil and easily hydrolyzable nitrogen content confirms the view formed by Bobrickaja *et al.* [1], that this form of nitrogen can be identified with the nitrogen of fulvoacids. In the tested acid soils and light acid soils, natural conditions conductive to the hydrolysis of stable binds of nitrogen compounds, which is testified by fairly high contents of easily hydrolyzable nitrogen.

## CONCLUSIONS

1. The majority of the tested heavy and medium soils had acid and weak acid reaction and because of their agronomy category demand liming.

2. Phosphorus and magnesium content in soil lowered together with the decrease of pH, and the easily hydrolyzable nitrogen content increased.

3. The acidification of soil did not influence the available potassium content.

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## ZAWARTOŚĆ PRZYSWAJALNYCH SKŁADNIKÓW POKARMOWYCH W GLEBACH W ZALEŻNOŚCI OD STOPNIA ICH ZAKWASZENIA

Badania przeprowadzono w ośmiu miejscowościach woj. lubelskiego. Pobrano próby glebowe z warstwy ornej 23 pól produkcyjnych po zbiorze rzepaku, zbóż i ziemniaków. Badano wpływ wysokości pH gleb na zawartość przyswajalnych form fosforu, potasu i magnezu, a także azotu łatwo hydrolizującego.

W oparciu o uzyskane wyniki stwierdzono, że zawartość fosforu i magnezu przyswajalnego była wprost proporcjonalna do wysokości pH gleb. Natomiast na zawartość przyswajalnych form potasu nie miała wpływu wysokość pH gleb. Zawartość azotu łatwo hydrolizującego była ujemnie skorelowana z wysokością pH gleb. Na poziom przyswajalnych składników pokarmowych w badanych glebach, oprócz stopnia zakwaszenia, miały wpływ rośliny przedplonowe oraz wysokość stosowanego nawożenia.

S ł o w a k l u c z o w e: przyswajalne składniki w glebach, zakwaszenie gleb, N łatwo hydrolizujący.