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EFFECT OF SOIL MANAGEMENT AND LIMING ON THE CHANGES OF CHEMICAL PROPERTIES OF ACID SOILS IN AN ORCHARD*

J. Szwedo, E. Żmuda

Fruit-Growing Department, University of Agriculture, Kr. Leszczyńskiego 58, 20-068 Lublin, Poland

A b s t r a c t. In the years 1987-1992 field experiments were carried out in five commercial orchards in Poland, growing on acid soils. In these orchards herbicide fallow was kept in the rows of trees and grass between them. In spring 1987, the whole surface of the experimental fields was treated with differentiated doses of calcium (from 750 to 2500 kg CaO/ha). The liming was repeated in spring 1990. The control fields were not limed. Before the beginning of the experiment, i.e. in 1986 and again in 1992 soil samples were taken separately from under the grass and herbicide fallow from the arable and sub-arable layer. The soil in the herbicide fallow strips had lower pH and higher content of available phosphorus and potassium than in grass strips. The content of available magnesium was similar both under grass and herbicide strips. In the soil kept as herbicide fallow and non-limed a distinct decrease in pH and magnesium content occurred within six years of the study. Such process did not take place in soil under grass. Liming caused the increase in soil pH more distinctly under grass than in herbicide strips. The increase in magnesium content was similar in both ways of soil management. Liming did not influence the phosphorus and potassium content under grass and herbicide fallow. The magnesium content lowered as a result of liming, both under grass and in herbicide strips but in sub-arable layer only.

K e y w o r d s: acid soils, liming, chemical properties of soil

INTRODUCTION

The acidification of environment is caused mainly by human activity. Both the development of industry and so far applied agrotechnical measures lead to the grater and greater acidification of soil. A considerable influence on the lowering of the soils reaction has, among others, the nitrogen fertilization and herbicides used until recently in too large dosage, especially in fruit-growing [2,9,11]. The result is often noted low soil pH in Polish orchards [10,12] and, connected with it, the occurrence of the increased level of toxic elements such as Al and Mn and the lowered content of available Ca and Mg in soil [8,11].

Many studies indicate that chemical properties of soil in orchard are differentiated depending on its management. First of all, lower pH in herbicide fallow in the tree-rows in comparison to the soil covered with grass in between the tree-rows [2,4,6,7] as well as the lower content of available Mg in case of herbicide strips [2,6,7] was noted. The content of available K according to many authors [4,7] was higher in the soil under herbicide fallow. However, Komosa [6] proved the advantage of sward over the herbicide fallow in this respect. Many researchers proved [3,5,12] that more available P could be found in soil after chemical weed control in comparison to sward.

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The aim of this research was to determine the effects of liming on the changes in chemical properties of acid soils, taking place in the rows of herbicide fallow and grass in orchards.

MATERIALS AND METHODS

The study was carried out in the years 1987-1992 in five commerical orchards in eastern Poland, located on acid soils (pH 4.0-5.0). In these orchards the strips of herbicide fallow (1.5 m wide) in the tree rows and the mowed and mulched grass sward in between the tree rows (2.5 m wide) were kept. During the study the orchards were fertilized with nitrogen and potassium, uniformly on the whole surface of the experimental area. The fertilizer dosage was determined on the basis of the results of soil and leaf analysis, as recommended for commercial orchards [1]. In August 1986 three experimental fields about 100 m^2 each comprising ten trees growing in two rows, that is 5 trees in each row were selected in all orchards. Soil samples were taken from these fields separately for the herbicide fallow rows and sward from their plough layer (0-20 cm or slightly deeper depending on its thickness) and from the sub-arable layer up to 50 cm deep. In spring 1987 the whole surface of each field was dressed with differentiated dosage of calcium (from 75 to 2500 kg CaO/ha), determined on the basis of soil pH - as recommended for commercial orchards [1].

The same liming combinations were repeated in summer 1990. Control fields were not limed. In August 1992 soil samples were again taken from the tested fields according to the above mentioned method. In these samples and in the initial samples (from 1986) pH was determined as well as the content of available Mg, P, and K. The content of available Mn was determined in the samples from 1992 only. These chemical analyses were made with methods commonly used by the agrochemical stations.

The results were interpreted statistically by means of the double cross-classification. The significance of differences was evaluated with Tukey's T test at the level of significance P=0.05. The values presented in the paper are average from all the orchards.

RESULTS

The soil reaction of all tested orchards was lower in the herbicide strip than grass strip both before liming (1986) and after its applying (1992) (Table 1). It was determined that after six years the pH of soil covered with sward (between the tree-rows) and the pH of non-limed soil was on the same level in the plough and sub-plough layer, however, pH of the non-limed soil but treated with herbicides (in the tree-rows) lowered greatly (0.3-0.5 units) in both layers of the tested soil.

The liming of soil kept under grass caused the increase in pH after adding both doses of calcium and in both soil layers, what is more, more visible increase of the reaction and similar for both calcium doses was noted in the plough layer. In the herbicide fallow the action of calcium was less effective; smaller dosage increased pH in the arable layer only and less distinctly than in soil under sward. However, the effect of higher calcium dosage on the increase of pH in the arable layer was significant (0.9 unit); while in the sub-arable layer it was not large (Table 1).

The content of available Mg was similar in soil covered with grass and in bare soil - in the initial soil samples taken in 1986 (Table 1).

In the non-limed fields the level of available Mg in herbicide strips lowered in both soil layers after six years, however, under sward it increased. Liming similarly increased the content of available Mg in the soil under sward and in herbicide fallow. The highest increase occurred under the influence of higher dosages of calcium in the soil plough layer for both systems of its management. Also higher level of available Mg occurred in the soil with higher pH.

The content of available P was always higher in the rows of herbicide fallow, especially in the plough layer of soil. In case of the lack of liming a slight decrease in the content of this element under herbicide fallow and under sward was noted but in the plough layer only. No distinct changes of available P content in limed soil was found; only slight increase of its content in the plough layer occurred independently

Table 1. Soil pH and available Mg content in dependence on soil management system and liming

Years	Treatments											
	Grass strip Arable layer			Grass strip Sub-arable layer			Herbicide strip Arable layer			Herbicide strip Sub-arable layer		
	no lime	low dose of lime	high dose of lime	no lime	low dose of lime	high dose of lime	no lime	low dose of lime	high dose of lime	no lime	low dose of lime	high dose of lime
	pH (1 mol KCl dm^{-3})											
1986	4.6	4.5	5.0	4.3	4.3	4.2	4.4ab	4.2a	4.4ab	4.3	4.3	4.2
1992	4.6	5.2	5.6	4.2	4.5	4.7	3.9a	4.6ab	5.3b	4.0	4.2	4.5
LSD P=0.05		n.s.			n.s.						n.s.	
	Mg (mg/100 g)											
1986	5.9	4.2	5.1	6.4	5.0	5.6	6.7a	5.3a	4.6a	6.8	5.1	4.3
1992	7.2	8.8	12.8	7.2	6.4	8.7	5.4a	8.3ab	14.1b	6.1	5.8	8.6
LSD P=0.05		n.s.			n.s.						n.s.	

a, b - means followed by the same inside of lime doses and years are not significantly different at 0.05 level, n.s. - not significant.

Table 2. Available P and K contents in dependence on soil management system and liming

Years	Treatments											
	Grass strip Arable layer			Grass strip Sub-arable layer			Herbicide strip Arable layer			Herbicide strip Sub-arable layer		
	no lime	low dose of lime	high dose of lime	no lime	low dose of lime	high dose of lime	no lime	low dose of lime	high dose of lime	no lime	low dose of lime	high dose of lime
						P (mg/100 g)						
1986	4.1	3.6	3.6	2.2	2.4	2.4	5.1	4.7	5.0	2.2	1.9	2.6
1992	3.3	3.7	4.4	2.7	2.7	2.7	4.4	4.7	5.8	2.8	3.0	2.8
LSD P=0.05		n.s.			n.s.						n.s.	
						K (mg/100 g)						
1986	14.0	11.5	12.8	8.9	9.2	8.9	18.7	19.5	17.3	13.7	10.7	12.4
1992	8.5	9.4	8.8	5.7	5.6	6.1	14.3	14.9	14.2	10.3	10.0	10.4
LSD P=0.05		n.s.			n.s.						n.s.	

Table 3. Available Mn content in dependence on soil management system and lime (in 1992)

Dose of lime	Arable layer		Sub-arable layer	
	Grass strip	Herbicide strip	Grass strip	Herbicide strip
No lime	134.6	128.4	88.2	100.4
Low dose	146.8	149.4	84.4	87.8
High dose	137.2	127.8	87.2	85.6
LSD P=0.05	n.s.		n.s.	

of its management but after the application of higher doses of calcium.

A higher content of available K in herbicide strips occurred in comparison to sward in both tested soil layers. In non-limed fields the level of this element lowered in both layers and systems of soil management. Similar case occurred in limed soil. This probably resulted from applying lower dosages of potassium during the experiment in comparison to the amount which had been applied before starting the test.

The content of active Mn was similar in soil under grass and under herbicide fallow. In the arable layer more Mn occurred than in the sub-arable layer independently of the soil management. Liming did not cause lowering of Mn content in the arable layer under grass and herbicide fallow, however, in the sub-arable layer it slightly decreased, especially in the soil under herbicide fallow.

DISCUSSION

The differentiation of the chemical properties of soil in an orchard depending on its management noted by many researchers was also confirmed by the present study. It proved moreover, that giving up the liming of acid soil kept in herbicide fallow leads to its chemical degradation, i.e., further pH lowering and diminishing the content of available Mg. In soil covered with mowed and mulched sward these disadvantageous processes are very slow; during the six-year study period the decrease in pH and the content of available Mg was not noted, although at the beginning of the study the soil was strongly acid (pH 4.6). Similarly, in the study reported by Glenn *et al.* [2] the reaction of soil kept in sward did not lower after applying lime saltpetre which, however, in herbicide fallow strips caused the lowering of soil pH. The above data are the result of greater sorption capacity of soil under grass, connected with higher humus content. The elution of cations from soil covered with grass is weaker than in case of bare soil, i.e., without plant cover. According to Haynes and Goh [3], the Ca and Mg elution from the soil under sward was 3.5 times lower than from the soil under herbicide fallow. The liming of acid soil proved to be in this study an effective measure causing the increase of both the pH and available Mg content in soil under sward and in the herbicide fallow, however, in case of fallow, the increase in soil reaction only occurred in the layer 30 cm deep while under sward - up to a depth of 50 cm. For the deacidification of deeper layers of soil in the herbicide fallow rows it would be advisable to use higher doses of calcium. Liming did not cause differentiation of P and K content in soil between sward and herbicide fallow which is in agreement with the results obtained by Glenn *et al.* [2] as far as K is concerned. Higher level of these nutrients in soil under herbicide fallow, noted in this test as well as in that by Kępka and Kozanecka [4] and Lipecki *et al.* [7] suggests the possibility of diminishing the fertilization, especially with potassium in the tree-rows growing in herbicide fallow.

In the studies of Neilsen *et al.* [8], Sadowski *et al.* [11] and Kępka *et al.* [4] the content of available Mn decreased together with the increase of soil pH, so similar response was expected in the present experiment as the effect of liming. However, the decrease in the content of this element did not occur neither in soil under grass nor in the arable layer under herbicide fallow which should be explained by the fact that

because of high Mn level (122-134 mg/kg) the range of pH change in soil was insufficient to lower this content. In the sub-arable soil layer, where there was less Mn (88-100 mg/kg) a slight downward tendency occurred after liming.

Summing up, the knowledge of differences in soil fertility resulting from its different management should be utilized for proper programming of orchards fertilization.

CONCLUSIONS

1. Soil in the rows of herbicide fallow had lower pH and higher content of available phosphorus and potassium than in grass sward. Available magnesium and manganese content was similar under grass and herbicide fallow.

2. At the lack of liming of soil kept as herbicide fallow, a distinct lowering of pH and magnesium content occurred within a few years, however, it did not occur under grass.

3. After liming soil pH increased more distinctly in the grass strips than in herbicide fallow; the increase of magnesium was similar at both ways of soil management.

Liming did not influence phosphorus and potassium content in soil under grass and herbicide fallow. Manganese content decreased after liming in the grass strips and in the herbicide fallow but only in the sub-arable soil layer.

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ZMIANY WE WŁAŚCIWOŚCIACH CHEMICZNYCH GLEB KWAŚNYCH POD WPŁYWEM WAPNOWANIA W ZALEŻNOŚCI OD SPOSOBU PIELĘGNACJI GLEBY W SADZIE

Doświadczenia polowe przeprowadzono w latach 1987-1992 w pięciu sadach produkcyjnych w Polsce, rosnących na glebach kwaśnych. W sadach tych utrzymywany był ugór herbicydowy w rzędach drzew i murawa w międzyrzędziach. Wiosną 1987 r. wysiano na całą powierzchnię poletek doświadczalnych zróżnicowane dawki wapna (od 750 do 2500 kg CaO/ha). Wapnowanie powtórzono wiosną 1990 r. Kontrolą były poletka nie wapnowane. Przed rozpoczęciem badań tj. w 1986 r. i ponownie w 1992 r. pobrano próby gleby osobno spod murawy i ugoru herbicydowego z warstwy ornej i podornej. Gleba w pasach ugoru herbicydowego charakteryzowała się niższym pH oraz wyższą zawartością przyswajalnego fosforu i potasu niż w pasach murawy. Zawartość przyswajalnego magnezu była podobna pod murawą i ugorem herbicydowym. W glebie utrzymywanej w ugorze herbicydowym i nie wapnowanej nastąpiło w ciągu sześciu lat wyraźne obniżenie pH i zawartości magnezu natomiast nie zaznaczyło się to w glebie pod murawą. Pod wpływem wapnowania wzrosło pH gleby, wyraźniej pod murawą niż w pasach herbicydowych; wzrost zawartości magnezu był podobny przy obu sposobach pielęgnacji gleby. Wapnowanie nie miało wpływu na zawartość fosforu i potasu w glebie pod murawą i ugorem herbicydowym. Zawartość manganu obniżyła się w wyniku wapnowania, zarówno pod murawą, jak i w pasach herbicydowych ale tylko w podornej warstwie gleby.

S ł o w a k l u c z o w e: gleby kwaśne, wapnowanie, właściwości chemiczne gleb.