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ACIDITY OF ARABLE SOILS AFTER LONG-TERM MINERAL FERTILIZATION ON MARKET-ORIENTED FARMS OF WESTERN POMERANIA

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A b s t r a c t. Intensive mineral fertilization and limited liming, applied in the years 1970-1980 on state farms of Western Pomerania, contributed to significant acidity of humus horizon of both the sandy soils and silty light loams. This acidity was found not only within ground moraine but also in depressions of terminal moraine, especially in the surface of humus horizon of soils used for fruit growing.

K e y w o r d s: soil acidity, arable soils, mineral fertilization

INTRODUCTION

Most soils on state farms of Western Pomerania (62 % in Koszalin region, 65 % in Szczecin region) was intensively fertilized with mineral fertilizers in the years 1970-1980. In Szczecin region in the years 1979/80 the amount of fertilizers applied was 281 kg NPK/ha (322.4 kg/ha on state farms). On some farms it was even 750 kg/ha per year [1]. Such intensive fertilization with relatively low level of calcium fertilizers (225.1 kg CaO/ha) resulted in the acidity of arable humus horizon and the appearance of highly acid reaction soils [14] on state farms (15 %) for the first time, in the years 1976-1982. High acid reaction was found not only in sandy loam soil group but also in the soils developed from boulder clay belonging to IIIa land valuation class.

MATERIALS

The experiments were carried out on the following soils: brown-earth soils, within the ground moraine of Gumieniecka Plain, classified as light loams and medium-heavy loams in Ostoja Experimantal Station (RZD Ostoja) owned by Szczecin University of Agriculture; arable rusty-brown soils developed from boulder sands rewashed to a great extent by post-glacial waters, whose lower layers consist of light loams at Lipki Experimental Station (RZD Lipki) of Szczecin University of Agriculture; arable deluvial soils within terminal moraine of Ińsko Upland, developed as a result of water erosion and intensive agricultural practices.

Brown-earth soils of RZD Ostoja belong to III soil valuation class. To notice the changes of soil properties including the reaction change, resulting from their soil utilization for fruit growing, brown arable soils were compared with one another.

The soils under 35-45 year old apple trees, on the so-called herbicide fallow, and the soils under grass for the same period of time were studied separately. During the full fruiting the orchard was fertilized with N-150, P_20_5-80, K_20-180 kg/ha every year.

The compared soil profiles were at the distance of 100-150 m apart and had similar soil texture. In the 35-40 year old apple tree orchard and 15-year old orchard the soil samples of herbicide fallow and grass, from the depth of 0-1, 1-3, 3-5, 5-10, 10-20, 20-30 cm, were taken and examined.

The rusty-brown soils of RZD Lipki were classified as IVa valuation class of arable land. In 1960 Agrometeorological Station was located there. It had six crop rotation field [9] with the same crop rotation for 25 years (without herbicide application and without liming for the first 18 years).

The crop rotation fields were fertilized as follows (kg/ha):
Field I barley - 40 N+90 P+120 K;
Field II potatoes - manure 30 t/ha+60 N+36 P+90 K;
Field III field pea - 10 N+54 P+60 K;
Field IV winter rye - 50 N+54 P+60 K;
Field V maize - manure 15 t/ha+90 N+90 P+150 K;
Field VI red clover.

At the same time, on the adjoining fields to the Experimental Station at Lipki, similar organic fertilization, systematic liming and much higher level of mineral fertilization were used.

The comparison between chemical properties of those soils were based on composite samples and the samples taken from different horizons of soil profiles.

Deluvial soils are represented by the four soil profiles of land depression with different soil texture on a market farm at Dłusko near Węgorzyno. The soils lacking in calcium carbonate (at the depth of 70-150 and even deeper) were intensively utilized and affected by continuous water erosion. Manure was replaced by green manure and ploughing the straw. There was no magnesium fertilizing, rare liming but relatively high mineral fertilization; in the years 1986-1990 about 230 kg NPK/ha on the average (ranging from 50-511 kg/ha) and the N:P:K ratio equal to 1:1.2:1.7.

RESULTS

The obtained results of field and laboratory experiments are presented in Tables 1-4. They show that long-term NPK fertilization without liming contributes to significant acidity of both the sandy (Table 3) and loamy soils (Tables 1,2) utilized either for field crops or fruit growing.

The relief of the area under investigation causing water erosion and specific circulation of precipitation water favours the transportation of chemical elements from the applied mineral fertilizers into the basin-like land depressions without run-off and at the same time increases leaching of alkaline elements. As a result of all those factors deluvial soils become acid (Table 4).

Intensive mineral fertilization of apple tree orchard on the soil which had neutral reaction at the moment of orchard establishment brought about acid or even very acid reaction of the soil of A_1 horizon after 35-40 years.

The highest acidity was found in the surface layer of horizon A_1 at the depth of 0-20 cm under the so-called herbicide fallow; pH_{KCl} is 3.8-6.1, whereas it ranges from 4.8 to 6.5 at the same depth in the soil under grass. Further analysis show that in herbicide fallow at the depth of 0-15 cm pH_{KCl} decreased to 3.8-4.4, at the depth of 15-30 cm to 4.6-6.6, and 5.6-7.0 at the depth of 30-50 cm.

The acidity of the upper part of soil profile under grass was not so high (pH 4.8-5.8 at the depth of 0-15 cm). Soil acidity is accompanied by lower degree of base saturation with alkaline cations and higher content of exchangeable aluminium. The 15-year period of using land for fruit growing did not cause such significant changes of soil reaction (Table 2).

The problem of high soil acidity under orchards has been raised lately by many scientists [2,4,6-8,10-12]. 13-year studies conducted by Kępka *et al.* [4] are of particular interest. Their findings prove that the application of ammonium nitrate amounting to 240 kg N/ha has a strong acidifying effect. Apart from that the authors warn against the excessive fertilization of orchards, in particular apple tree orchards which have very small nutritional requirements.

Our studies demonstrate that even low rates of NPK (without systematic liming) after 25 years of the same crop rotation brought about quite considerable worsening of Ap soil horizon reaction of the rusty-brown soil within Agrometeorological Station of RZD Lipki (Table 3). The soils of the Station in comparison

Table 1. Some chemical properties of the compared soil at the Agricultural Experimental Station Ostoja (the mean values and pH_{KCl} ranges in the years 1986-1988) after Niedźwiecki [11]

Utilization		Genetic horizon	depth (cm)	Number of samples	C (%)	pH (KCl)	Al-exchangeable (mg/100 g)	Available elements (mg/100 g of soil) K	P	Mg
Arable soil		Ap	0 - 30	28	1.0	6.8 - 7.7	0.0	21.7	24.2	16.1
		Bbr	30 - 50	14		6.5 - 7.4	0.0	9.7	1.1	16.7
Apple-tree orchard (35-40 years old)	herbicides	A1	0 - 15	28	1.4	3.8 - 4.4	2.9	22.6	13.0	10.9
			15 - 30	14	0.8	4.4 - 6.6	0.3	13.4	10.8	11.2
		Bbr	30 - 50	14		5.6 - 7.0	0.1	9.8	1.9	12.0
	grass	A1	0 - 15	28	3.1	4.8 - 5.8	0.9	63.4	23.6	12.2
			15 - 30	14	0.9	6.5 - 7.0	0.1	52.4	14.5	10.2
		Bbr	30 - 45	14		6.5 - 7.0	0.0	13.9	2.9	12.7

Table 2. Soil reaction (pH ranges) and content of available elements (K, P, Mg) in humus horizon of brown earths developed from boulder clay under apple-tree orchard at the Agricultural Experimental Station Ostoja (13.07.1988)

Utilization		Depth (cm)	pH H_2O	pH KCl	K (mg/100 g of soil)	P	Mg
Apple-tree orchard (35-40 years old)	herbicides	0 - 1	5.6-6.2	4.9-5.7	32.1	10.9	12.7
		1 - 3	5.7	4.8-4.9	25.9	10.2	11.0
		3 - 5	5.1-5.6	4.3-4.6	20.0	9.6	9.5
		5 - 10	5.7	4.7-4.8	13.9	9.1	10.5
		10 - 20	6.8	5.9-6.1	16.9	11.8	10.5
		20 - 30	7.1-7.3	6.2-6.4	10.0	12.6	8.5
	grass	0 - 1	6.0-6.1	5.5	75.7	23.1	13.2
		1 - 3	6.1	5.5-5.6	71.5	17.6	13.5
		3 - 5	6.3-6.4	5.6-5.7	63.9	18.3	11.7
		5 - 10	6.8-6.9	6.1-6.2	62.3	16.6	11.2
		10 - 20	7.2-7.3	6.3-6.5	63.9	13.9	10.5
		20 - 30	7.3-7.5	6.6	49.0	12.4	9.2
Apple-tree orchard (15 years old)	herbicides	0 - 1	5.8-7.3	4.7-7.1	30.0	12.8	7.0
		1 - 3	5.7-7.4	4.8-7.2	24.6	13.6	6.5
		3 - 5	5.8-7.2	4.6-7.1	27.1	16.9	6.3
		5 - 10	5.8-7.4	4.6-7.2	15.6	20.2	6.3
		10 - 20	6.7-7.5	5.6-7.2	10.5	16.1	5.8
		20 - 30	7.0-7.6	6.6-7.1	8.8	13.3	6.2
	grass	0 - 1	6.8-7.1	6.2-6.7	33.8	20.1	9.2
		1 - 3	6.8-7.2	6.2-6.8	32.4	20.6	8.2
		3 - 5	6.7-7.3	6.0-7.2	25.9	19.2	7.0
		5 - 10	6.8-7.4	6.7-7.2	24.0	22.2	6.8
		10 - 20	7.0-7.3	6.9-7.2	20.3	20.3	6.3
		20 - 30	7.0-7.5	6.9-7.3	17.0	13.6	6.5

with the adjoining, intensively utilized soils of RZD Lipki have in the horizon pH_{KCl} below 4.5 (in the horizon Ap RZD 5.1-7.1) and hydrolytic acidity is higher. Such acidity of Ap horizon and low content of alkaline cations were caused by the lack of liming in the years 1960-1979 and too small rates of $CaCO_3$ and magnesium (1 t/ha every 6 years). It has been also noted by Czuba [3] and Urbański and Bilski [15].

In early glacial moraine landscape, the area

Table 3. Soil reaction (pH ranges), hydrolytic acidity and content of available elements (K, P, Mg) in the compared arable soils at Agrometeorological Station and Experimental Station Lipki (according to soil test 1986)

Study sites	Genetic horizon	Depth (cm)	pH H_2O	pH KCl	Hh mmol(+)/100 g of soil	K	P	Mg
						mg/100 g of soil		
		0-20*	5.1-5.9	4.1-4.6	2.8	10.9	8.7	2.0
Agrometeorological	Ap	0-27	5.3	4.1	3.4	7.4	7.8	1.7
Station	Bbr Bv	27-40	6.5-6.7	5.3-5.4	1.2	9.1	3.6	2.2
Lipki	C	40-65	6.9-7.0	5.9	0.8	5.0	1.5	2.0
	C2	65-95	6.9	5.9	0.9	5.8	1.3	3.7
	C3	95-150	6.9	5.6-6.0	0.7	4.0	1.5	5.0
		0-20*	6.3-7.4	5.1-7.1	1.5	15.6	12.2	5.2
Agricultural	Ap	0-27	6.5-7.0	5.4-6.8	1.0	26.9	12.4	4.6
Experimental	Bbr Bv	27-40	6.8-7.0	6.0-6.5	1.0	13.9	5.5	3.7
Station	C	40-65	6.8-7.0	5.9-6.5	0.7	8.2	1.6	3.8
Lipki	C2	65-80	6.8-7.0	6.0-6.2	0.8	7.6	1.7	1.9
	C3	80-150	6.7-7.1	6.0-6.2	0.8	7.2	2.2	5.5

* - the mean values from 7 composite samples of soil.

of terminal and ground moraine becomes acid, especially in deluvial depressions on the lacking in calcium carbonate slope and top of hills soils.

Even the more heavy soils (Table 4, profile 16) cannot resist the degrading effect of intensive fertilization and increased leaching. Such a heavy soil rich in humus (2.2 %) has even less positive chemical properties than light soils (profiles 4, 10, 11). Relatively stronger acidity of the soil and worse chemical properties result from closed deluvium whose waters run downward by means of specially made drainage.

The above mentioned results of our research on the properties of eroded soils (Table 4) and earlier studies [5] are confirmed by the findings of German soil scientists from the northern part of Germany where in former East Germany intensification of agricultural production was very high.

The acidity of deluvial soils of Western Pomerania is not very common. Despite the growing tendency of lowering pH the process can be neutralized effectively when soils located on slopes and top of the hills contain $CaCO_3$.

With continuous influx of calcium carbonate from slops to land depressions the soil reaction remains neutral or alkaline and in some cases free calcium carbonates can precipitate in the form of concretions. In such cases even intensive fertilization and precipitation leaching cannot change the chemistry of soil solution.

CONCLUSIONS

1. Long-term mineral fertilization applied in the amount of over 300 kg/ha with limited liming or without liming caused (mainly on market-oriented farms) quite considerable acidity of arable-humus soil horizon especially under orchard.

2. Soil acidity is usually accompanied by lower degree of base saturation with alkaline cations higher content of exchangeable aluminium and high content of available potassium and phosphorus.

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Table 4. Chemical properties of deluvial soil developed under influence of water erosion processes and intensive agricultural practices at market-oriented farm Dłusko

Locality profile No.	Genetic horizon	Depth (cm)	Silt and clay <0.02 mm (%)	pH		Hh (mmol(+)/ /100 g of soil)	Al-exchangeable (mg/100 g)	Available elements (mg/100 g of soil)		
				H_2O	KCl			K	P	Mg
	Ap	0 - 30	16	5.5	4.2	3.9	5.0	8.6	7.4	1.7
	A	30 - 45	13	5.5	4.2	2.5	3.3	10.8	5.0	1.6
Dłusko 4	A	45 - 70	14	5.1	4.0	2.4	2.3	12.9	3.5	1.8
	Cg	70 - 130	15	5.2	4.3	2.0	1.5	12.6	0.9	1.3
	C2g	130 - 150	24	5.2	4.3	2.7	4.6	9.3	0.3	6.4
	Ap	0 - 30	14	5.5	4.3	4.1	4.8	6.8	6.0	1.4
Dłusko 10	Eet	30 - 70	15	5.2	4.1	2.3	3.2	5.0	3.5	1.0
	Btg	70 - 105	25	5.3	4.0	2.2	4.1	8.5	2.8	3.2
	Cgg	105 - 145	23	5.4	4.4	2.3	2.6	4.6	1.7	11.5
	Ap	0 - 30	11	5.5	4.2	4.4	4.6	10.3	6.6	4.0
	A	30 - 60	13	5.7	4.3	4.0	4.1	6.6	5.5	3.8
Dłusko 11	Cg	60 - 80	12	5.7	4.2	2.9	2.8	6.1	3.6	3.6
	Cg	80 - 110	10	5.2	4.0	3.0	2.4	6.1	3.7	3.2
	Cgg	110 - 150	11	5.8	4.6	2.4	4.5	6.0	1.4	4.0
	Ap	0 - 30	38	5.1	4.0	8.2	4.9	19.1	11.5	4.5
	A	30 - 60	48	5.0	3.8	9.2	5.2	7.0	8.5	3.6
Dłusko 16	A	60 - 90	56	4.6	4.0	15.3	7.0	12.3	12.8	1.8
	A	90 - 110	37	5.0	3.9	14.8	6.7	6.6	4.8	3.0
	Cgg	110 - 150	34	5.2	4.1	8.5	4.8	4.6	2.7	3.8

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ZAKWASZENIE GLEB UPRAWNYCH PO WIELOLETNIM INTENSYWNYM NAWOŻENIU MINERALNYM W WARUNKACH GOSPODARKI WIELKOTOWAROWEJ NA POMORZU ZACHODNIM

W gospodarce uspołecznionej Pomorza Zachodniego intensywne nawożenie mineralnych gleb uprawnych stosowane w latach 1970-1980 przyczyniło się, przy ograniczonym wapnowaniu, do znacznego zakwaszenia poziomu akumulacyjnego nie tylko gleb piaszczystych lecz także gleb o składzie mechanicznym glin pylastych. Zakwaszenie to uwidoczniło się zarówno w obrębie moreny dennej, zwłaszcza w powierzchniowej części poziomu próchnicznego gleb sadowniczych, jak i w obniżeniach terenowych moreny czołowej.

S ł o w a k l u c z o w e: kwasowość gleb, gleby orne, nawożenie mineralne.