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STANISŁAW MERCIK

MOST IMPORTANT SOIL PROPERTIES AND YIELDING IN LONG-TERM STATIC FERTILIZING EXPERIMENTS IN SKIERNIEWICE

Department of Agricultural Chemistry, Warsaw Agricultural University

INTRODUCTION

Long-term static experiments are carried out since 1923 at the Prof. M.Górski Experimental Field at Skierniewice belonging to the Department of Agricultural Chemistry of Warsaw Agricultural University. The experiments are, beside the long term experiments in Rothamsted – England (since 1853), Grignon – France (1875), Halle – Germany (1878), Ascov – Denmark (1894), Bad Lauchstädt (1902) and Moscov – Russia (1912), the seventh, static fertilizing experiments in Europe with the longest history [Abstract 1993]. Outside Europe static fertilizing experiments are carried out since the past century in the United States in the State of Missouri "Morrow Plots" since 1888 and in the State of Illinois "Sanborn Field" since 1896.

On the occasion of 70th anniversary of static fertilizer experiments at Skierniewice and 25th anniversary of the static fertilizer experiment at Czarny Potok an international symposium "Long-term static fertilizer experiments" was organized by the Department of Agricultural Chemistry of Warsaw Agricultural University and Agricultural University of Cracow in 1993. To the organizers satisfaction, as many as 85 Polish and foreign publications based on long-term fertilizer experiments, have been submitted. Monographic papers both Polish and foreign ones, with longest history have been published in English in two volumes of "The Symposium Proceedings". The original publications, based on long-term fertilizer experiments, have been published in Polish or English in another two volumes of "The Scientific Papers of Agricultural University in Kraków".

Some results from the long-term static fertilizer experiments carried out interruptedly since 1923 in Skierniewice are quoted in the present paper.

MATERIAL AND METHODS

The soil of the Experimental Field at Skierniewice (70 km south-west of Warsaw) belongs to the type of lessivé of the very good ryeland complex and is assigned to the valuation class of IVa. The content of silt and clay particles (<0.02 mm), in particular genetic horizons is as follow: 15–17% in Ap (0–25 cm), 10–12% in Eet (25–40 cm) and 25% in Bt/C and C (below 40 cm). The humus content in the arable layer varies on particular field within 1.2–1.4%.

The precipitation amount is relatively low (530 mm/year) and its distribution is rather unfavourable for cereals. Precipitation deficiency occurs often in the period of the maximum water requirement for cereals, it is in May and in June. The mean annual temperature for Skierniewice amounts to 7.8°C. The number of days with the mean daily air temperature above 5°C is 215. It is assumed that it would be an average growth period for this region.

The static fertilizing experiments, established in the period 1922–1924 are carried out on 21 fields. Those experiments were established on the initiative of Prof. Józef Mikułowski-Pomorski, who established the field A (Table 1). In the 1923 the management of the Experimental Field was taken up by Prof. Marian Górski, by whom further static experiments on fields E and D were established. All the static fertilizing experiments are carried out on the above field uninterrupted till present. Since 1958 the experiments have been carried out under the care of Prof. S. Mercik. On these fields plants of 3 groups of crop rotation (A,E,D) are cultivated (Table 1). Mineral and organic fertilizers are applied in accordance with an unchanged scheme (Table 1). Fertilizer rates were different in longer periods and increased per 1 ha from 30 kg N, 13 kg P and 26 kg K to the highest ones since 1976 – 90 kg N, 26 kg P and 91 kg K. Lime is applied every 4 years at the rate of 1.6 t/ha CaO. All experiments are carried out in 3 (fields A) or 5 replications (fields E and D).

TABLE 1. The scheme of fertilization and crop rotation of the long-term field experiments since 1923

Field No	Crop rotation	Fertilizer treatments*
A	arbitrary rotation without farmyard	Ca
	manure and without legumes	CaNPK
E	five fields crop rotation: potato (30 t farmyard manure),	NPK
	spring barley, red clover, winter wheat, rye	CaPK
D5	potato in monoculture	CaPN
D6	rye in monoculture	CaKN

*Doses since 1967: Ca – 1.6 t CaO/ha every 4 years; N – 90 kg N/ha; P – 26 kg P/ha; K – 91 kg K/ ha every year; N-NH_4NO_3 .

RESULT AND DISCUSSION

PHYSICO-CHEMICAL PROPERTIES OF SOIL

Some physical properties of soil showed considerable differences depending on mineral fertilization, liming and manuring [Kłosowski, Mercik 1980]. Fertilization with farmyard manure leads, as compared to the mineral fertilization (CaNPK), to an increase of exchange capacity, sum of exchange base, capillary water capacity, permeability coefficient and number of crumbs of > 0.25 mm in diameter (Table 2). On the other hand it leads to a decrease of soil bulk density. Liming of soils results also in an increase of exchange capacity, sum of exchangeable base and permeability coefficient.

Application of 20 t/ha farmyard manure every year for 70 years (D5,D6) increased the humus content in soil by 0.36–0.40% as compared to Ca treatment (Table 3). On fields with farmyard manure (rate of 30 t/ha every 5 years) and with leguminous crops, the humus content in soil is by 0.50% higher than on field without legumes and without farmyard manure. Calculation of the balance of organic C showed, that even after 70 years the humification coefficient, expressed by the percentual increase of organic C in soil, in relation to C in farmyard manure, is 4.6–5.8% only.

The lime application every 4 years at the rate at 1.6 t CaO/ha resulted in maintenance of the acidification state of soil at the pH level of 5–6 (Table 3). On unlimed plots and without N fertilization (0,PK) the pH value maintained at the level of about 4.5. On the unlimed plots with the fertilization of N applied as ammonium nitrate in several rates the pH value decreased below 4 and than on those plots a small lime rate was applied.

TABLE 2. Physical properties of soil depending on long-term organic and mineral fertilization, 1980

Properties of soil		Fertilization		
		farmyard manure	CaNPK	NPK
Exchange capacity	[m. e./100 g]	7.01	6.74	4.82
Total exchange base	[m. e./100 g]	6.27	4.98	3.45
Apparent specific gravity	[g/cm^3]	1.75	1.84	1.83
Capillary water capacity	[%]	18.40	16.50	16.60
Permeability coefficient		1.37	1.06	0.77
Aggregates >0.25 mm	[%]	4.60	3.50	3.30

The content of total [Mercik et al. 1993] and readily available nitrogen (Table 3) is only slightly less on the plots without nitrogen than on those with nitrogen fertilization. It follows from the above that nitrogen applied every year to definite plots is taken up by plants or leached, and only in small extend it is accumulated in soil in the form of organic and mineral compounds.

The content of reserve [Mercik et al. 1993] and available phosphorus (Table 3) is much higher in soil fertilized with this element than in unfertilized ones. In soil of plots not fertilized with phosphorus or farmyard manure, the amount of available P distinctly decreased within the last 35 years [Mercik et al. 1993].

TABLE 3. Chemical properties of soil depending on many years fertilization and crop rotation, 1991

Soil properties	Crop rotation (Tab.1)	Fertilization					
		Ca NPK	NPK	Ca PK	Ca PN	Ca KN	Ca farmyard manure
pH in KCl	A	5.8	4.0	6.1	6.0	5.8	–
	E	5.2	4.2	5.4	5.2	4.9	5.3
	D5	5.2	4.0	5.0	4.9	4.9	5.6
	D6	6.1	4.3	6.1	5.5	5.5	6.2
Humus [%]	A	1.06	1.01	0.92	1.01	1.07	0.95
	E	1.56	1.59	1.60	1.56	1.50	1.55
	D5	0.82	0.87	0.68	0.85	0.84	1.21
	D6	1.17	1.07	0.97	1.13	1.08	1.54
Available N [mg/100 g of soil]	A	5.67	5.91	3.49	4.72	4.20	–
	E	7.00	6.56	5.86	7.00	7.00	4.81
	D5	4.72	4.63	3.23	4.75	4.02	4.55
	D6	4.20	5.25	3.50	4.90	5.16	5.51
Available P [mg/100 g of soil]	A	8.4	7.8	11.9	10.2	1.7	–
	E	6.3	5.0	6.0	5.3	2.9	2.1
	D5	7.4	7.3	7.4	7.0	2.5	8.3
	D6	6.7	4.8	7.6	5.0	1.4	5.0
Available K [mg/100 g of soil]	A	11.6	9.8	15.2	4.0	11.5	–
	E	10.9	10.2	13.5	5.4	12.5	5.6
	D5	12.9	11.4	14.9	6.0	11.4	26.5
	D6	8.2	8.2	11.3	3.6	10.4	20.2

No decrease, however, of reserve phosphorus occurred, at the time. It follows from the above, that phosphorus taken up at that time from soil of these plots originates either from forms bounded stronger than the definite reserve forms or from deeper soil horizons. The phosphorus rate as applied in the present experiments (26 kg P per ha) is thus satisfactory for getting high yields and for maintenance of phosphorus content in soil at the suitably high level.

The content of available potassium (Table 3) is much lower in soil of unfertilized plots (2–4 mg) than in that of potassium fertilized ones (8–12 mg K per 100 g). In the period of the last 35 years [Mercik et al. 1993] the available amount of K decreased only slightly in soil of unfertilized plots, but increased in that of fertilized one. It follows, that the K rate applied in this experiments (91 kg K per ha) is satisfactory for getting high yields and improvement of soil richness in this element. Attention deserves over twice higher potassium content in soil fertilized with farmyard manure than in that with mineral fertilization (D5 and D6) although similar potassium amounts with mineral and organic fertilizers are brought into the soil. Thus it can be concluded than a higher content of humus in soil of plots with farmyard manure leads to a reduction of available potassium due to leaching or strong sorption.

The content of exchangeable calcium and magnesium in soil is the lowest in unlimed soil being particularly low at application of N as ammonium sulphate [Mercik et al. 1993].

Long-term static mineral or organic fertilization experiments did not differentiate the content of reserve (extract in 1 M HCl after Rinkins) forms of microelements [Mercik et al. 1992a]. Organic fertilizers, however, resulted in an increase of exchangeable Mn, Zn and Cu forms in soil. The amount of available boron (after Berger-Truog method) was even higher on mineral fertilizers than on farmyard manure.

YIELD OF PLANTS

The highest potato yields were obtained on farmyard manure within the crop rotation with legumes (E), much lower at cultivation without farmyard manure nor legumes (A) and the lowest in monoculture (D), Table 4. A lack of each elements investigated (N, P, K, Ca) led to a considerable decrease of yields, however the efficiency of these elements depended on the crop rotation and thus on the farmyard manure (FYM) application. The strongest effect of these elements was at the potato cultivation in arbitrary rotation without either farmyard manure nor legumes (A). Potato cultivated in monoculture (D) yielded much lower on farmyard manure than on mineral fertilizers, in spite of similar rates of N, P and K brought into the soil.

Higher yields of rye with the CaNPK fertilization are obtained in the 5-fields crop rotation with FYM and legumes (E), than in crop rotation without neither farmyard manure nor legumes (A), Table 4. At a lack of any of basic nutrients in fertilizers, the yields on the field A are distinctly lower, than on the field E. Rye in monoculture (D6) gives the yields only by about 10–15% lower than in arbitrary rotation (A). In the last 20 years, when similar amounts of N, P and K with farmyard manure as well as in mineral fertilizers were brought into the soil, much lower yields were obtained on farmyard manure (by 25–35%). The main cause of such a weak action of farmyard manure in relation to mineral fertilizers is an unsatisfactory supply of rye in nitrogen in the phase of shooting and flowering.

Winter wheat reacted very strongly to the soil acidification, and especially on the field without farmyard manure and legumes (A), Table 5. Winter wheat on the field A reacted most strongly to the deficiency of nitrogen and most weakly to that of potassium. On the other hand at the winter wheat cultivated in the first year after legumes (E) the strongest reaction occurred to the phosphorus deficiency and the weakest one to the deficiency of potassium.

TABLE 4. Potato and rye grain yields (mean of 8 years in t/ha) depending on the many years fertilization and crop rotation, 1984–1992

Fertilization	Potato				Rye			
	A*	E	D	mean	A*	E	D	mean
CaNPK	28.9	36.3	15.8	27.0	4.76	4.70	3.95	4.47
NPK	23.4	34.1	13.9	23.8	4.93	4.63	4.07	4.54
CaPK	12.5	28.8	10.0	17.1	1.93	2.96	2.27	2.38
CaPN	11.4	29.9	12.1	17.8	3.92	4.23	3.34	3.84
CaKN	11.8	31.0	13.5	18.8	2.91	3.93	2.81	3.22
Ca	10.9	23.8	7.9	14.2	1.59	2.77	1.83	2.07
LSD		1.38				0.16		
Mean	16.5	30.6	12.2	–	3.34	3.88	3.03	–
LSD		0.46		0.80		0.06		0.10

*Crop rotation (Table 1)

Barley gave much higher yields in the field E with farmyard manure and legumes than on the field A without neither farmyard manure nor legumes (Table 5). It reacted very strongly to the soil acidification, and particularly on the field without farmyard manure (A). At the lack of any of basic nutrients the yields of barley on the field without farmyard manure (A) are distinctly lower than on field with farmyard manure (E).

The static-long-term fertilizing experiments at Skierniewice constitute a testing ground on which also other investigations than those as described above are carried out. In total more than 120 scientific works were published basing on the materials from those experiments. Most important are as below:

• effect of different content of nutrient element in soil on the chemical composition of plants and some of their quality [Mercik et al. 1990; Mercik, Stępień 1991, 1992; Smolarz 1993];

• reaction of particular varieties of cereals, potatoes and berry shrubs to different content of nutrients in soil [Mercik, Barska 1976; Mercik et al. 1978];

• investigations on regeneration of soils inappropriately fertilized for many years [Mercik et al. 1993];

• balance of organic carbon and nutrient elements for longer period [Mercik, Stępień 1992].

TABLE 5. Barley and winter wheat grain yields (mean for 8 years in t/ha) depending on the many years fertilization and crop rotation, 1984–1992

Fertilization	Barley			Winter wheat		
	A*	E	mean	A*	E	mean
CaNPK	4.31	4.93	4.62	3.52	4.39	3.95
NPK	2.24	4.26	3.25	2.31	3.75	3.03
CaPK	2.11	3.56	2.83	2.00	3.48	2.74
CaPN	3.15	4.31	3.73	2.74	4.02	3.38
CaKN	2.93	3.65	3.29	2.22	3.34	2.78
Ca	1.57	2.94	2.07	1.73	2.66	2.19
LSD		0.16			0.19	
Mean	2.72	3.94	–	2.42	3.61	–
LSD		0.05			0.05	

*Crop rotation (Table 1)

CONCLUSIONS

1. Farmyard manure leads, as compared to mineral fertilization, to an increase of humus content, exchange capacity, sum of exchange base, capillary water capacity, permeability coefficient and number of crumbs of > 0.25 mm in dia. Humification coefficient of C FYM is 5–6% only.

2. To maintain for many years the pH values of soil at the level of 5–6 the application of 1.6 t CaO per ha every 4 years, appeared to be satisfactory and do not influence the soil humus content.

3. Differences in the content of available phosphorus, potassium and nitrogen on plots fertilized and unfertilized with those elements are very high for P and K and relatively low for N.

4. Negative consequences of lack of phosphorus or potassium fertilization are much milder in the cultivation of plants with farmyard manure and legumes than without farmyard manure or legumes.

5. Much higher yield of plants was obtained on the fields with crop rotation with farmyard manure and legumes than on the field without FYM or legumes.

6. Rye grown seventy years in monoculture gives only slightly lower (by 10–15%) yields than that cultivated in arbitrary crop rotation. Potato in monoculture are, in turn, much lower than those cultivated in arbitrary crop rotation.

7. At similar N,P,K rates brought into soil with farmyard manure and mineral fertilizers, much higher yields of rye and potato in monoculture are obtained on mineral fertilizers.

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S. Mercik

NAJWAŻNIEJSZE WŁAŚCIWOŚCI GLEBY I PLONOWANIE W WIELOLETNICH STATYCZNYCH DOŚWIADCZENIACH NAWOZOWYCH W SKIERNIEWICACH

Katedra Chemii Rolniczej SGGW w Warszawie

STRESZCZENIE

Wieloletnie statyczne doświadczenia nawozowe prowadzono nieprzerwanie od 1923 r. na Polu Doświadczalnym Szkoły Głównej Gospodarstwa Wiejskiego w Skierniewicach. Na 21 polach z tymi doświadczeniami rośliny uprawia się w 3 grupach zmianowań: w zmianowaniu dowolnym bez obornika i bez motylkowych, w zmianowaniu 5-polowym z obornikiem i rośliną motylkową (ziemniaki, jęczmień, koniczyna, pszenica, żyto) i w monokulturach (ziemniaki, żyto). Nawozy mineralne stosuje się tu na każdym polu według niezmienionego schematu: Ca, CaNPK, NPK, CaPN, CaPK, CaKN. Dawki nawozów mineralnych były różne w 4 dłuższych przedziałach czasowych. Najwyższe dawki stosuje się od 1976 r., a więc na 1 ha: 90 kg N, 26 kg P i 91 kg K. Wapno (CaO) wprowadzane jest co 4 lata w dawce 1,6 t/ha. Z właściwości fizykochemicznych gleby badano: pojemność sorpcyjną, sumę zasad, kapilarną pojemność wodną, współczynnik przepuszczalności, zakwaszenie gleb, zawartość próchnicy oraz zawartość dostępnych form N, P i K oraz określano plony roślin, takich jak: żyto, ziemniaki, pszenica ozima i jęczmień.

Prof. dr Stanisław Mercik
Department of Agricultural Chemistry
Warsaw Agricultural University-SGGW
02-528 Warszawa, Rakowiecka 26/30, Poland