ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 2006 z. 512: 439–447

THE INFLUENCE OF MINERAL FERTILIZATION ON CHOSEN INDICATORS OF SOIL FERTILITY

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Introduction

Dynamic changes of soil fertility indicators are determined not only by a type of plants cultivated in monoculture and crop rotation but also by a system of fertilization (conventional, integrated, ecological) and significant differences in the intensity of the organic matter mineralization process. The changes also depend on habitat and climate, being responsible for the soil micro-flora activity [GONET, WEGNER 1993; ŁOGINOW et al. 1991; KOBUS 1995]. In arable lands, soil enzymes are also considered to be an objective and biological fertility indicators and their activity depends on the applied fertilization.

The aim of the research was to define the effect of the thirty-year sequent activity of differentiated nitrogen and potassium fertilization (without organic fertilization and liming) on the changes in the contents of organic carbon and total nitrogen in soil.

Material and methods

The study used soil samples taken from a multi-year static fertilizing experiment established at the Research Station of the Agricultural Department at Wierzchucinek in 1974. Geomorphic experiment fields were situated in boulder clay of the wavy ground moraine and belonged to the bonitation class 3a – good arable soils. A profile sequence of genetic horizons of typical fallow soils is as follows: Ap, Eet, Bt, C. This is loamy sand (with 18% content of particles < 0.02 mm) and, according to the FAO UNESCO soil international classification, it is Albic Luvisols. Basic data characteristic of the soil in 1974 and 2004 are presented in Table 1.

Only differentiated nitrogen (factor 1) and potassium (factor 2) fertilizations were applied in the experiment, using the unified phosphor fertilization without organic one and no liming. The experiment was established by a method of randomized sub-blocks in three replications. A list of cultivated plants (fodder and industrial crop rotation) and the quantity of the applied mineral fertilizer doses are presented in Table 2.

Table 1; Tabela 1

The properties of soils before the experiment began in 1974 and in 2004

Właściwości fizykochemiczne gleby przed założeniem doświadczenia w 1974 roku i w 2004 roku

Parameter; Parametr			Years; Lata	
			1974	2004 A
Organic C; C organiczny		$g \cdot kg^{-1}$	13.00	6.48
Total N; N ogólny		$g \cdot kg^{-1}$	1.03	0.56
Acc. Egner–Riehm (DL) Według Egnera-Riehma	P	$mg \cdot kg^{-1}$	68.80	49.70
	K	$mg \cdot kg^{-1}$	166.70	96.80
Acc. Schachtschabel Według Schachtschabela	Mg	$mg \cdot kg^{-1}$	45.00	20.00
pH_{KCl}			5.9–6.0	3.8–4.8
Hydrolitic acidity; Kwasowość hydrologiczna		$mmol(+) \cdot kg^{-1}$	14.30	24.75
CEC; PWK		$mmol(+) \cdot kg^{-1}$	71.70	66.15

Table 2; Tabela 2

Crop rotation and application of mineral fertilizers ($kg \cdot ha^{-1} \cdot year^{-1}$)

Płodozmian oraz zastosowane nawożenie mineralne ($kg \cdot ha^{-1} \cdot rok^{-1}$)

Crop rotation Płodozmian	N			K				P
	N_1	N_2	N_3	K_0	K_1	K_2	K_3	
Maize green; Kukurydza na ziel.	80	160	240	0	50	100	150	25
Winter rape; Rzepak ozimy	80	160	240	0	50	100	150	25
Winter wheat; Pszenica ozima	50	100	150	0	33	66	100	25
After-crop rye; Żyto na zielonkę	40	80	120	0	25	50	75	25

Soil samples from the experiments were taken after the 30-year studies straight after plant harvesting, pH values were determined in 1 mol $KCl \cdot dm^{-3}$, the organic carbon content by the Tiurin's method and the total nitrogen content by the Kiejdahl's method. To work out statistic results, a variance analysis was applied to a two-factor experiment in the system of dependent variables with the use of Tukey's confidence interval.

Results and discussion

The way of soil use often affects the properties and processes taking place in it, including the degradation processes. The effect may be also reflected in organic carbon and total nitrogen contents. Mineral and organic fertilizers introduced into the soil may bring strong and short term changes of the organic matter cycle, which accelerates the mineralization process of organic substances or carbon immobilization [KUZYAKOV et al. 2000]. Mineral fertilizers in soil at first intensity the ammonification processes and organic substance decay by limiting the C : N ratio [KUSZELEWSKI, ŁABĘTOWICZ 1986], but after a longer time, they may have an advantageous influence on the carbon content in soil, which is due to the effect on the plant crop growth and on the residue quantity [GONET 1992; WIATER 1997]. The obtained results show an unfavorable effect of applying only mineral fertilization on changes in the fertility soil tested indicators.

The organic carbon content in the tested soil before setting up the experiment amounted to 13 g·kg^{-1} of soil, while in 2004 it ranged from 5.13 to 7.40 g·kg^{-1} of soil (Tab. 1, 3). On the average, the lowest organic carbon content was found in the objects N_1K_1, and the highest one was characteristic of soil taken from the objects N_2K_2. Generally, after 30 years of research, the organic carbon content decreased by 50% as compared to the initial value (1974). It should be mentioned that the changes of the organic carbon content were followed by a significant decrease in the pH value of soil, which in the year of the research ranged from 3.8–4.8 (tab. 1). Literature data show that high doses of nitrogen fertilization acidify soil to a large extent and thus lower the activity of microorganisms, which results in the total carbon loss in soil [JAKUBUS et al. 1999; MURAWSKA et. al. 1993]. The reduction of organic matter in very acid soil was also proved by other authors who claimed that in such soils, among others, humus combination became degraded [MAZUR 1995; KULCZYCKI 2000].

Table 3; Tabela 3

Organic carbon and total nitrogen contents in soil (g·kg^{-1})
Zawartość węgla i azotu w glebie (g·kg^{-1})

Dose of N Dawka N	Total nitrogen; Azot ogólny					Organic carbon; Węgiel organiczny				
	Dose of K; Dawka K					Dose of K; Dawka K				
	K_0	K_1	K_2	K_3	mean średnio	K_0	K_1	K_2	K_3	mean średnio
N_1	0.53	0.55	0.58	0.60	0.56	7.00	5.13	6.23	5.79	6.04
N_2	0.49	0.49	0.60	0.42	0.50	7.28	6.88	7.40	7.09	7.16
N_3	0.61	0.60	0.60	0.66	0.62	6.16	5.15	6.71	6.89	6.23
Mean Średnio	0.54	0.55	0.59	0.56	0.56	6.81	5.72	6.78	6.59	6.48
$LSD_{0.05}$; $NIR_{0.05}$ for; dla:										
– factor I (N dose); czynnik I (dawka N)					0.045					0.227
– factor II (K dose); czynnik II (dawka K)					r.n.; n.s.					0.262
– interaction I x II; interakcja I x II					0.089					0.452

The organic carbon content in the tested samples of fallow soil taken in 2004 was significantly modified by differentiated nitrogen and potassium fertilization (Tab. 3), which is confirmed by other authors [GONET 1992; WIATER 1997]. A significantly higher organic carbon content was noticed after applying the dose N_2 (160 kg N·ha^{-1}) in relation to the object N_1 (80 kg N·ha^{-1}), and the difference between the objects was 18%. The application of the highest dose of nitrogen N_3 (240 kg N·ha^{-1}) made the content of the soil fertility tested indicator lower by 13% as compared to the value found in soil fertilized with N_2 (160 kg N·ha^{-1}).

The application of the increasing dose of potassium (K_1, K_2, K_3) for 30 years significantly differentiated the organic carbon content in the tested soil. A significantly lower organic carbon content in relation to the control was found after applying the smallest dose of potassium K_1 (50 kg K·ha^{-1}). The application of higher potassium doses made an insignificant increase in the organic carbon content in relation to the K_1 potassium dose. It was also proved that the organic carbon content in the arable-humus layer of the tested soil depended on the interaction of all the tested factors. It was stated that the interaction of nitrogen at doses N_1, and N_3 with the smallest dose of potassium K_1 (50 kg K·ha^{-1}) had a significant effect on the decrease of the organic carbon content in the tested soil (Tab. 3).

The issues concerning the effect of mineral fertilization and manure on the changes and content of organic matter in soil are well supported by specialistic literature [ASMUS, VOLKER 1984; ADAMUS et al. 1989]. However, opinion varies as far as the effect of mineral fertilization on the C_0 content is concerned. BECK [1985] and WIATER [1997] stated that mineral fertilization maintained the organic carbon content at a constant level, affecting the harvest by increasing the amount of organic matter in soil in form of after-harvest residues. GONET [1997] claims that mineral fertilization at doses covering the plant needs prevents a humus decrease, particularly in the case of its deficiency. Next, ASMUS and GORLITZ [1978] observed a decrease in the humus content from 31 to 41% after 61 years of the research in sandy soil fertilized with minerals only, which was confirmed by our studies (Fig. 1).

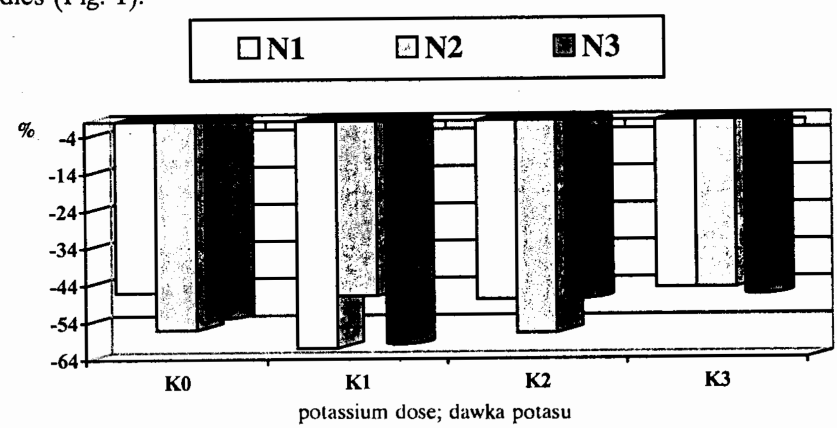

Fig. 1. Relative changes of organic carbon in 1974–2004 with reference to the initial content (1974 – 100%)

Rys. 1. Relatywne zmiany zawartości C organicznego za lata 1974–2004 w stosunku do zawartości wyjściowej (1974 – 100%)

The changes and content of organic carbon in soil are strictly connected with total nitrogen changes. In our research, the total nitrogen content in soil in 1974 amounted to 1,03 g N·kg^{-1} of soil, while in 2004 it ranged from 0,42 to 0,56 g N·kg^{-1} (Tables 1 and 3). After 30 years of the research, the total nitrogen content in the tested soil became reduced by app. 46% in relation to the initial value (Table: 1, 3). The obtained results are consistent with Mazur study (1991), who claims that about 1% i.e. app. 30 kg N·ha^{-1} is mineralized from the total nitrogen amount in soil during one year.

Within 30 years it is supposed that about 1,5% of total nitrogen underwent mineralization, which makes approximately 47 kg N·ha^{-1}.year^{-1}. The range of changes of this form of nitrogen in the tested soil in particular objects was relatively high and it can be explained only by variations appearing as a result of mineralization and immobilization with no organic fertilizer [ŁOGINOW et al. 1991; FOTYMA et al. 1987]. So far, there is no clear opinion on the effect of fertilization on the total nitrogen content in soil. A lot of researchers think that the content of this nutrient is, to a large extent, dependent on the applied natural and mineral fertilizers, causing its significant growth [FOTYMA et al. 1987; MERCIK 1984; ŁOGINOW et al. 1991; Wiater 1997]. However, mineral fertilization leads up to a small increase or stabilization of the total nitrogen content in soil [ASMUS, VOLKER 1984; GRZEBISZ and GAWROŃSKA-KULESZA 1995; GONET 1997]. The applied differentiated nitrogen fertilization significantly determined the N_t in the tested soil. On the average, the highest nitrogen content was found in the object after applying 240 kg·ha^{-1} year^{-1} (N_3), which was approximately 11% and 24% significantly higher than the contents obtained in the objects where 80 and 160 kg·ha^{-1} year^{-1} (N_1 and N_2) were used.

The changes of the total nitrogen in the tested soil can be partially connected with a higher intake of nitrogen by plants and with an intensive process of mineralization. Similar dependences were proved by RABIKOWSKA and WILK [1991] who claimed that the twelve-year nitrogen fertilization at doses from 70-190 kg·ha^{-1} reduced the content of this nutrient in soil. Next, according to KUZYAKOV et al. [2000], mineral and organic fertilizers applied together into soil may strongly change organic matter and for a short period of time. This results in a faster mineralization process of the organic substance – positive priming effect, or in carbon and nitrogen immobilization – negative priming effect.

According to TERELAK and FOTYMA [1986], potassium fertilization significantly differentiates the total nitrogen content in soil, but similar dependences were not stated in the conducted research. However, the interaction of nitrogen and potassium fertilization significantly affected the content of this parameter in soil (Tab. 3).

The obtained results do not confirm the opinion of many authors who claim that, for a given type of soil, the total nitrogen content shows a high stability at a proper mineral fertilization [ASMUS, VOLKER 1984; WIATER 1996]. After 30 years of the research, the applied mineral fertilization probably intensified the process of total nitrogen mineralization, which made a reduction of its content as high as 47% in relation to the initial value. Other authors claim that the total nitrogen content keeps to the level which is much higher in the case when mineral and organic fertilization is applied [KUZYAKOV et al. 2000].

The quantity changes of organic carbon and total nitrogen are reflected by the ratio C : N. Before establishing the experiment (1974), its value amounted to 13 and in the year of conducting the research, it ranged from 9 to 15 (Fig. 2). An insignificant widening of ratio C : N concerned only the objects: N_2K_0, N_2K_1 and N_2K_3, which was probably connected with the decreasing content N_t rather than an increase in C org. in the tested soil, and with a partial process of immobilization. Considering the other objects, the value of calculated relation, ranging within 9–13, shows the dominance of the mineralization process after applying mineral fertilization.

The obtained results are in accordance with many authors who claim that mineral fertilizers in soil intensify initially the processes of ammonification and the organic substance decay, narrowing the ratio C : N [KUSZELEWSKI, ŁABĘTOWICZ 1986].

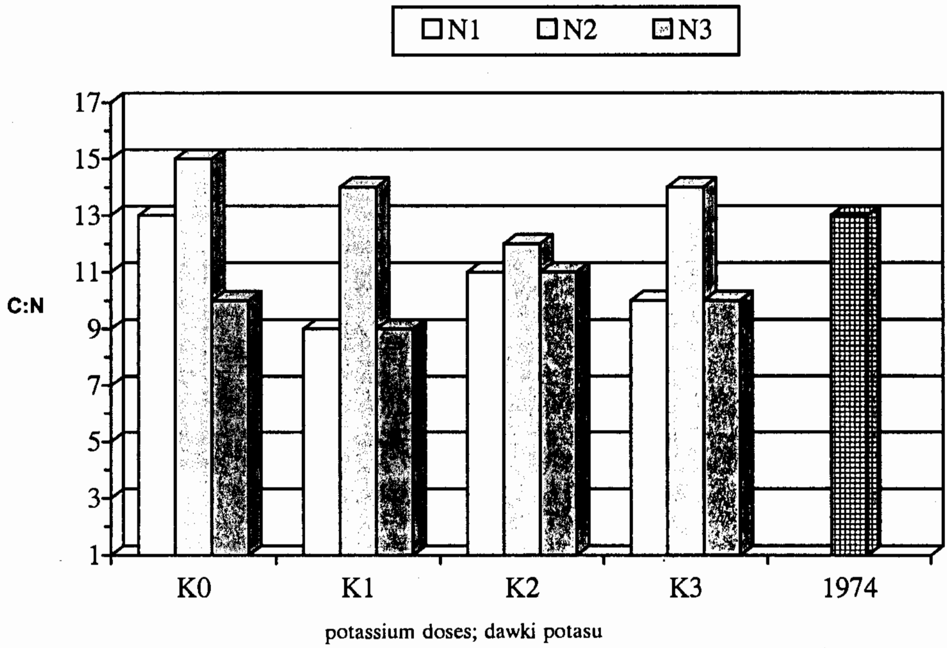

Fig. 2. Changes of values of C : N ratio affected by nitrogen and potassium fertilization

Rys. 2. Zmiany wartości stosunku C : N pod wpływem zastosowanego nawożenia azotem i potasem

Many researchers think that unilateral mineralization of particularly light soils not only accelerates mineralization processes, which, according to some authors, become move intense as nitrogen fertilizer doses get lower [KUSZELEWSKI, ŁABĘTOWICZ 1986; MAZUR 1995] or, according to others [GONET 1992], as they grow, but it also results in the reduction of the organic carbon content and total nitrogen, which has also been proved by our research. The presented results showed that the application of mineral fertilization at doses covering the plants nutritional needs contributed to a decrease in both the organic carbon content and total nitrogen.

Conclusions

1. A sequent result of applying high doses of nitrogen and potassium was soil acidification. After 30 years of research a significant decrease in the pH_{KCl} value with reference to the initial one (1974) was found.
2. Field experiments showed indirectly that changes of the discussed soil fertility indicators (N t and C org.) resulted from the applied doses of nitrogen and potassium and the cultivated plants in crop rotation. A decrease by, respectively: 50% and 46% was stated in the organic carbon and total nitrogen contents with reference to the initial value (1974). However the ratio C : N did not change significantly, which showed the dominance of the mineralization process.

3. The conducted research (2003) based on a multi-year static field experiment proved a significant effect of the applied nitrogen and potassium fertilizers and their interaction with the organic carbon content in the tested soil, and the total nitrogen content was significantly affected only by the diversified nitrogen fertilization and by nitrogen and potassium interaction.

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Key words: long-term field experiments, N and K fertilization, N and C content, C : N ratio

Summary

The aim of the research was to define the effect of the thirty-year sequent activity of differentiated nitrogen and potassium fertilization (without organic fertilization and liming) on changes in the contents of organic carbon and total nitrogen in soil. Field experiments showed indirectly that changes of the discussed soil fertility indicators (N_t and C org.) resulted from the applied doses of nitrogen and potassium and the cultivated plants in crop rotation. A decrease by, respectively: 50% and 46% was stated in the organic carbon and total nitrogen contents with the reference to the initial value (1974). However the ratio C : N did not change significantly, which shows the dominance of the mineralization process

WPŁYW NAWOŻENIA MINERALNEGO NA WYBRANE WSKAŹNIKI ŻYZNOŚCI GLEBY PŁOWEJ

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Słowa kluczowe: wieloletnie doświadczenie polowe, nawożenie N i K, zawartość N i C, stosunek C : N

Streszczenie

Określono wpływ 30 letniego następczego oddziaływania zróżnicowanego nawożenia azotem i potasem (bez nawożenia organicznego i wapnowania) na zmiany zawartości węgla organicznego i azotu ogółem w glebie płowej. Badania polowe wykazały pośrednio, że zmiany omawianych wskaźników żyzności gleby (N og. i C org.) stanowiły wypadkową stosowanych dawek azotu i potasu oraz uprawianych roślin w zmianowaniu. Stwierdzono średnio spadek zawartości węgla organicznego i azotu ogółem odpowiednio o 50% i 46% w stosunku do wartości wyjściowej (1974 r.), natomiast wartość wskaźnika stosunku C : N nie zmieniła się w sposób znaczący co wskazywałoby na przewagę procesu mineralizacji.

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