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LONG-TERM INFLUENCE OF CEREAL CROP ROTATION ON THE PROPERTIS OF LIGHT SOIL AND WINTER RYE YIELD

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A b s t r a c t. In the field experiment, the influence of a long-term cereal crop rotation (100% cereals) on the light soil properties and yield of the test plant (winter rye) was investigated. Winter rye cultivation in the cereal crop rotation for more than 25 years caused a relatively unimportant changes of the physical and chemical soil properties. An increase of soil density, decrease of organic carbon and nitrogen content in the soil as well as an increase of fulvic acid content and a decrease of humins in the humus compounds were found. Although there was quite a significant differentiation in the soil conditions, rye yield in the specialised crop rotation, especially in a monoculture, was significantly lower than in the case of a conventional crop rotation.

K e y w o r d s: 100% cereals crop rotation, physical and chemical soil properties.

INTRODUCTION

Cultivation of cereals in the specialised crop rotation is very often due to economical and practical reasons. It occurs specially often on light soils, where the number of species available for cultivation is limited. Currently, the percentage of cereals in the cropping system in Poland amounted to 75%. Due to the developing specialisation in agriculture, a long-term cereal crop cultivation in the specialised crop rotation will increase. A frequent cereal crop cultivation in a monoculture causes a number of unfavourable phenomena, mostly in the biological properties, such as an increase of weed infestation, greater risk of diseases and, as a consequence, a decrease of yield [17]. According to the present researchers, some relatively less important changes in the soil properties take place [1,8-10,13]. However, assessment of the changes in the soil environment under the influence of specialised crop rotation has only been carried out in the recent years [1,8,9,12].

There are only few papers presenting results on the long-term application of the specialised crop rotation [5,6,13].

The aim of the undertaken research was to estimate the influence of a long-term application of the specialised cereal crop rotation on the soil environment and yield of the test plant, i.e. winter rye.

MATERIALS AND METHODS

The present research was based on the static field experiment established in 1971 according to the method of randomised blocks on a 68 m^2 experimental field in four replications. The experiment was established on light alluvial soil with 8-10% of silt and clay. This soil is described as the VI valuation class and belongs to the weak rye complex. All the plants from the planned crop rotation were cultivated each experimental year. The research was undertaken in 1996-1998. The test plant for all the crop rotations was winter rye, var. Dańkowskie Złote. Rye was cultivated in 3 specialised crop rotations with 100% of cereals in the cropping system: 1) rye + stubble crop-spring barley and oat; 2) rye + stubble crop-oat; 3) rye + stubble crop-rye. The control treatment was rye grown in Norfolk type crop rotation with 50% of cereals in the cropping system: potatoes-oat-field pea-rye + stubble crop. In each crop rotation, the stubble crop consisted of a mixture of leguminous plants with sunflower as green manure. The average dry weight yield of the ploughed crop under stubble was 1.06 t ha^{-1}.

Some of the physical soil properties (in the 5-25 cm layer) and chemical soil properties (in the 0-20 cm layer) were determined during rye harvest. Bulk density, total porosity, and actual moisture were established by means of 100 cm^3 cylinders. Soil compaction was measured by a dynamic penetrometer in every 5 cm layer. The nitrogen content was determined by the Kjeldahl's method, and fraction composition of the humus compounds by the method proposed by Miklaszewski [11].

RESULTS

Due to the long-term application of specialised crop rotations, soil properties underwent some relatively insignificant changes (Table 1). Crop rotation modified significantly only bulk density when various cereal species were cultivated. It was on the average 2.9% higher than in the conventional crop rotation in spite of the stubble crop. A significantly higher density was observed only in the case of soil

Table 1. Some physical properties of soil in 5-25 cm layer at harvest time of winter rye (means 1996-1998)

Crop rotation	Bulk density ($g\ cm^{-3}$)	Total porosity (%, v/v)	Moisture (%, v/v)	Compaction (MPa)
Potato Oat Field pea Winter rye + s.c.	1.56	40.3	13.3	0.22
Winter rye + s.c. Spring barley Oat	1.59	39.5	13.2	0.22
Winter rye + s.c. Oat	1.62	38.3	13.9	0.24
Winter rye + s.c. Winter rye	1.55	40.7	13.0	0.25
$LSD_{0.05}$	0.06	1.8	n.s.	n.s.

s.c. - stubble crop; n.s. - not significant difference.

with two-field crop rotation of rye-oat. Total porosity during rye harvesting was lower in the multi-species cereal crop rotations than in the Norfolk rotation by 0.8% in the three-field crop rotation and by 2.0% in the two-field crop rotation (the above differences were statistically significant). Different results were obtained in the one-year winter rye cultivation with stubble crops applied during alternate years. In such a crop rotation, the soil, when compared to the control crop rotation, was characterised by an insignificantly lower bulk density (by 0.7%) and higher porosity (by 0.4%). No distinct influence of the type of crop rotation on the soil moisture during rye harvesting was found. Higher water content (13%) was found in the soil with the highest bulk density, i.e. in the rye-oat crop rotation, and the lowest moisture content was in the rye monoculture where the soil had the lowest bulk density. Also soil compaction did not significantly depend on the type of crop rotation in which rye was cultivated. Nevertheless, a tendency for an increasing soil compaction was found in the crop rotation of a 2-year cycle, especially in the rye monoculture.

The effect of more than 25-year long cultivation of cereals only when compared to the control crop rotation, was a reduction of organic carbon and nitrogen content in soil (Fig. 1). The scale of reduction was higher in the multi-species cereal crop rotations, than in the monoculture. In the two-three-field crop rotations with oat, there was 10.1% and 10.8% less of organic carbon than in the Norfolk

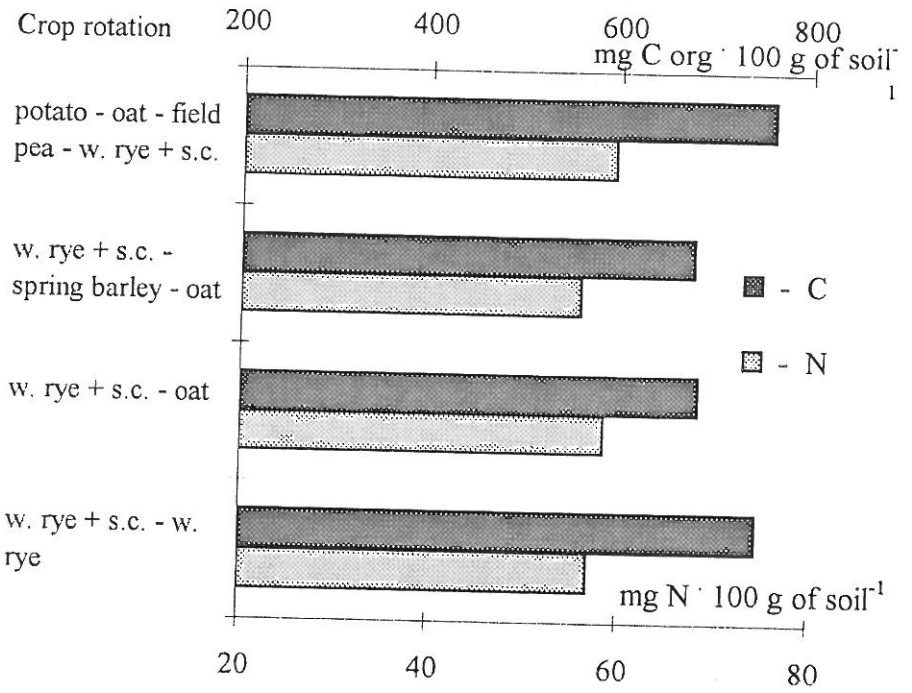

Fig. 1. Organic carbon and nitrogen content in 0-20 cm layer of soil (mean for 1996-1998).

rotation. Whereas in the rye monoculture there was only 2.1% less of organic carbon. The soil nitrogen content in the individual crop rotations was less differentiated and amounted to 56.0 mg/100 g soil in the 3-field crop rotation with rye-spring barley-oat and to 59.5 mg/100 g soil in the conventional crop rotation. From among all the cereal crop rotations, the highest nitrogen content was found in the soil of the two-field crop rotation with oat.

A long-term cereal crop rotation caused significant quality changes of the humus compounds (Fig. 2). In the soil of the cereal crop rotations (100% of cereals) the content of the most labile fractions of fulvic acids increased. In comparison to the Norfolk rotation, the quantity of fulvic acids increased by 4.9% on the average in the multi-species crop rotation and by 1.8% in the rye monoculture. In the crop rotations with different cereal species another negative phenomenon was also observed. Namely, reduction of content of the most stable humin fraction by 1.1 % on the average in comparison to the control crop rotation. Only in the rye monoculture, the quantity of humin acid did not decrease but increased insignificantly by

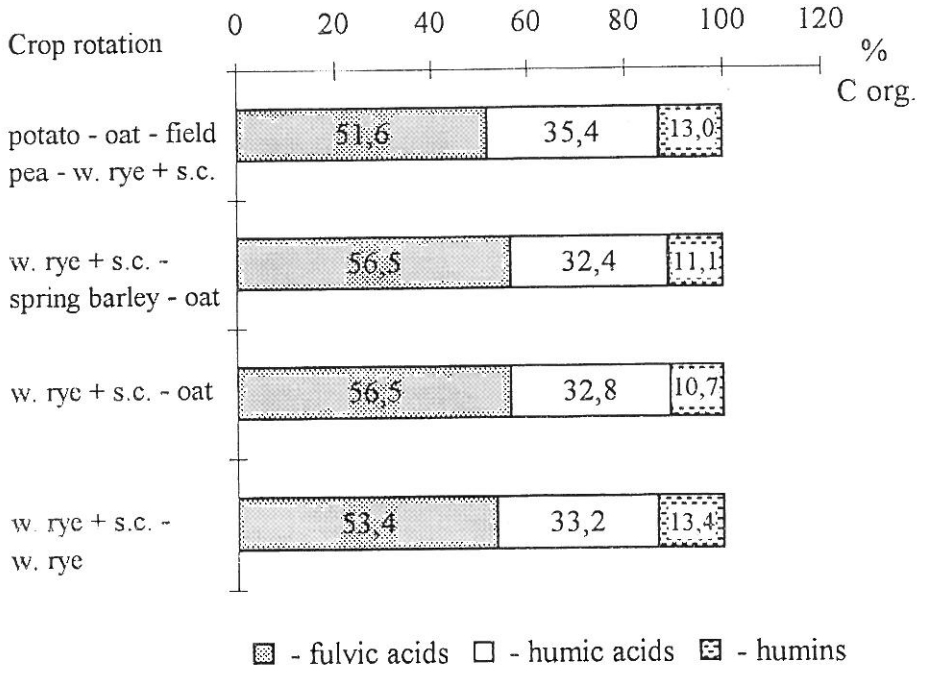

Fig. 2. Basic composition of humus substance (mean for 1996-1998).

0.4%. The humin acid content in the soils in the cereal crop rotations (100% cereal) was similar, but lower than in the soil of the Norfolk crop rotation.

In spite of the relatively small changes in the physical and chemical soil pro-perties, the yield of rye in individual crop rotations was significantly differentiated (Fig. 3). The long-term rye cultivation in the cereal crop rotation created a significant crop reduction of grain and straw. The lowest rye yield was obtained from the monoculture. The average reduction of grain yield was by 38.9% and of straw yield by 29.4% in comparison to the conventional crop rotation. The decrease in the rye yield in the crop rotation with other cereal species was not so significant. When compered with the control crop rotation, grain and straw yield decreased on the average by 10.7% and 8%, respectively. Rotation of rye and oat resulted in an increase of grain yield. The grain yield increase obtained in a such crop succession was only 4.5% lower than the yield obtained from the conventional crop rotation.

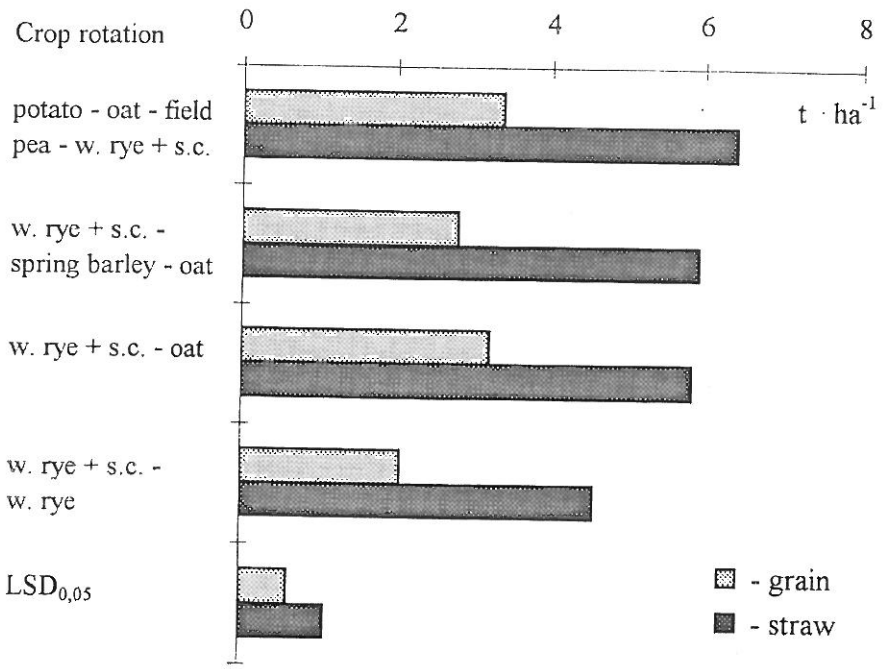

Fig. 3. Yields of winter rye (mean for 1996-1998).

DISCUSSION

Changes in the soil environment caused by an over 25-year long application of specialised cereal crop rotations were relatively small and related more to the chemical than physical soil properties. Baranowski and Pabin [1], Krężel *et al.* [6] and Kuś [9] did not observe any significant influences on the physical properties of the light soil when testing crop rotation with a high number of various cereals in the cropping system. In separate tests, the tendency towards an insignificant soil density increase in the multi-species cereal crop rotations was observed. That confirmed observations by Jabłoński and Mrówka [4] and Krężel *et al.* [6]. Higher increase in the bulk density and soil porosity measurements in the rye monoculture and Norfolk crop rotation were probably caused by frequent ploughing-in of the stubble crop mass with a significant amount of main crop residues. This has also been suggested

by Kundler *et al.* [7]. A clear influence of cereals in the crop rotation on the soil moisture has not been proved. It has also been suggested by Krężel *et al.* [6].

As result of a long-term rye cultivation in the cereal crop rotation, a decrease in organic carbon content was observed. Simultaneously Siuta [13] and Turski and Flis-Bujak [16] did not see any significant influence of the sole cereal cultivation on the organic substance content in the soil.

The observed reduction of organic carbon contents in the cereal crop rotations was higher in the case of multi-species crop rotations than in the rye monoculture. According the Romek and Michalcewicz [12], it could be caused by a yearly introduction of high quantities of crop residues. A long-term application of the specialised crop rotation on the light soil resulted in visible changes of organic substance quality. In the cereal crop rotations, an increased content of humic acids and together with a reduced humin content was found. Giegużyńska *et al.* [2] and Krężel [5] paid attention to the detrimental contents of humus compounds. In the opinion of Szajdak *et al.* [15] and Turski and Flis-Bujak [16] even 75% of cereals in the cropping system causes an increase of the mobile humus forms with a simultaneous decrease of humins and ulmins content. In spite of a relatively small changes in the chemical and physical soil properties, rye cultivated in the cereal crop rotations gave significantly lower yields than in the conventional crop rotation. Grodziński and Gołovko [3], Romek and Michalcewicz [12] and Smyk [4] suggest that the reason for a decrease in the cereal yield in the frequent monoculture cultivation should be sought in the onset of biological changes and phenomena of the alleophatic nature.

CONCLUSIONS

1. Over 25-year long rye cultivation in 100% cereal crop rotation caused relatively insignificant changes in the examined physical and chemical soil properties.

2. An insignificant increase of soil density, decrease of organic carbon and nitrogen content in the soil, as well as an increase in the quantity of fulvic acid with a simultaneous decrease in the quantity of humins in the humus compounds resulted from the application of long-term crop rotations with various cereals species.

3. The scale of detrimental changes in soil properties was smaller in the monoculture with every other year intervals for ploughing under of stubble aftercrops than in the multi-species cereal crop rotations.

4. In spite of the minimum differences in the soil conditions, rye yield in the specialised crop rotations, especially in the monoculture, was significantly lower than in the conventional crop rotation with 50% of cereals.

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