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Microbial populations and enzymatic activity in soil under winter wheat

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A b s t r a c t. The effect of various winter wheat lines on the total numbers of bacteria and fungi and on the dehydrogenase and respiratory activity of soil was conducted on the basis of a field experiment. The experiment was set up on a grey-brown podzolic soil developed from loess formations with the method of randomized blocks and comprised five treatments. Soil samples for the analyses were taken in the heading, milk and full ripeness phases of winter wheat. It was demonstrated that both the microbial populations and the activity of the studied enzymes in the soil varied in the particular phases of plant growth and development, and depended also on the cultivars and lines of the crop.

K e y w o r d s: soil, microbial populations, dehydrogenase, respiratory activity

INTRODUCTION

The soil, thanks to the complex chemical and biochemical transformations that take place in it, is the natural habitat for plants. The life and activity of soil microorganisms are closely related with the plants that grow in the soil (Montesinos, 2003). Soil microorganisms are the main source of enzymes and also play an important role in the creation of enzymatic activity (Shaw and Burns, 2005). High activity of soil microorganisms indicates good soil quality, but also proper functioning of processes conducted by soil organisms that result in the activation of nutrients for crop plants (Jezierska- Tys and Frąc, 2008; Kucharski, 2007; Martyniuk *et al*., 2007). The activity of soil microorganisms is related mainly with transformations of organic matter with the resultant formation of products of synthesis and decomposition (Janvier *et al*., 2007; Zahir *et al*., 2001). The intensity of the biochemical processes and the levels of the products of microbial activity in the soil may, next to the size of the microbial populations, be accepted as an indicator of the biological activity of soil which is a reflection of its fertility. Soil fertility has an effect on the proper development and yielding of crop plants (Alkorta *et al*., 2003; Bolinder *et al*., 2007; Green *et al*., 2007; Nannipieri *et al*., 2003; Paul and Clark, 2000).

The aim of the study conducted under the conditions of a field experiment was to identify the effect of cultivation of various winter wheat lines and cultivars on the numbers of microorganisms and on the microbiological activity of a grey-brown podzolic soil developed from loess formations.

MATERIAL AND METHODS

The study was conducted on a model of vegetation-type field experiment. The experiment was set up at the Felin Experimental Farm of the University of Life Sciences in Lublin. The experimental plots (10 m^2) were cultivated by traditional plough manner chemical protection of the plant canopy against pathogenic fungi and the most common dicotyledonous weeds, as well as mineral NPK fertilization. The experiment was established on a grey-brown podzolic soil developed from loess. The next plants were investigated:

1. Winter cultivar of common wheat (*Triticum aestivum ssp. Vulgare*): Tonacja.
2. Line of durum winter wheat (*Triticum durum* Desf.): STH 716.
3. Line of durum winter wheat (*Triticum durum* Desf.): STH 717.
4. Line of spelt winter wheat (*Triticum spelta* L.): STH 3.
5. Line of spelt winter wheat (*Triticum spelta* L.): STH 715.

Soil samples were taken from the arable layer of each plot at the various phases of plant vegetation (terms): I – heading phase; II – phase of milk ripeness; III – phase of full ripeness.

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After mixing within each treatment, the soil material was dried and screened through sieves with 2 mm mesh size. These samples were used to take soil for biochemical analyses, while for the microbiological analyses soil suspensions were prepared (10 g of soil + 90 ml of sterile water) and successive decimal dilutions were made. The determination of the total numbers of bacteria, was made with the plate method on a substrate with the soil solution (Rodina, 1968), and of the total numbers of fungi; with the Martin method (1950). The determination of dehydrogenase activity, was done according to the Thalmann method (Thalmann, 1968), and of the respiratory activity; with the method of Rühling and Tyler (1973).

RESULTS AND DISCUSSION

Figure 1a presents the results of determination of the total numbers of bacteria (colony forming unit (cfu)) on all the dates of analyses. The data indicate that in the soil environment under study there was a notable variation in the bacterial populations. On the heading phase, the numbers of bacteria were at a similar level in all the experimental treatments. On II date of analysis (phase of milk ripeness), there appeared a significant increase in the numbers of bacteria in the experimental treatments, except for treatment 4, where a significantly lower number of bacteria was observed. On III date of analysis (phase of full ripeness), a significant decrease in the numbers of bacteria was recorded, compared to the values obtained on the II date of analysis, with the exception of treatment 4. The lowest mean number of bacteria was characteristic of the soil from treatment 4 (Fig. 1b).

Figure 2a presents the numbers of fungi in the soil of the experimental treatments. On the dates of analyses I, II and III, seasonal variations in the numbers of the studied fungi were observed. The results obtained on I date of analysis (heading phase) indicate a high number of fungi in the soil under the winter spelt line STH 3, while on II (phase of milk ripeness) and III (phase of full ripeness) dates of analyses that number decreased gradually to a minimum in the phase of full ripeness. The number of fungi in the soil under the winter spelt line STH 717 was the lowest on I date of analysis (heading phase), and then increased gradually to a maximum in the final phase of vegetation of the plants (III date of analysis). On the II date of analysis (phase of milk ripeness), in the soil under the winter spelt line STH 715 an increase was observed in the number of fungi (compared to that recorded on the first date of analysis, while on III date (phase of full ripeness) there was a considerable drop in their number in that treatment. In the soil under common winter wheat cv. Tonacja (treatment 1), as well as in that under the durum wheat line STH 716 (treatment 2), the numbers of fungi on I date of analysis (heading phase) was at a similar level to that observed on II (phase of milk ripeness) and III dates of analyses (phase of full ripeness). Analysis of mean values of the fungal populations in the experimental treatments (Fig. 2a) demonstrated a significantly greater

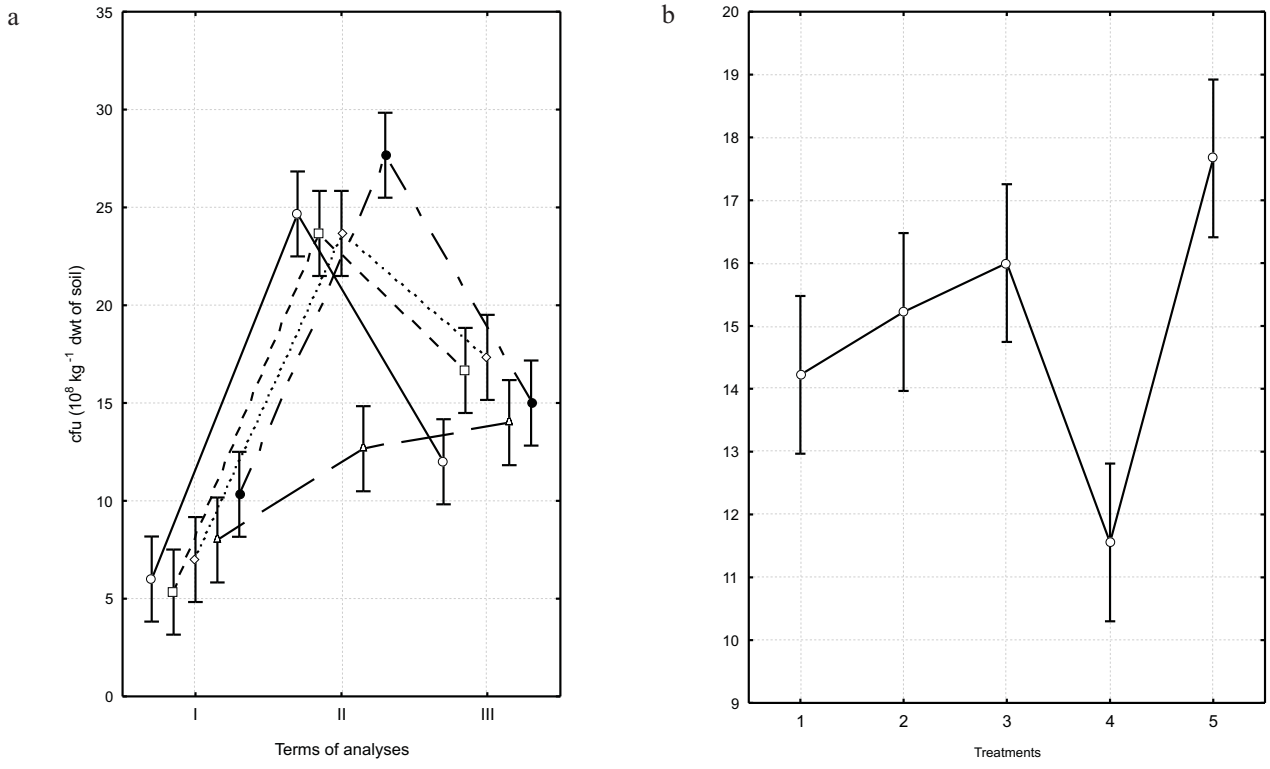

Fig. 1. Total (a) and mean (b) numbers of bacteria treatments: 1 – ○, 2 – □, 3 – ◇, 4 – △, 5 – ●.

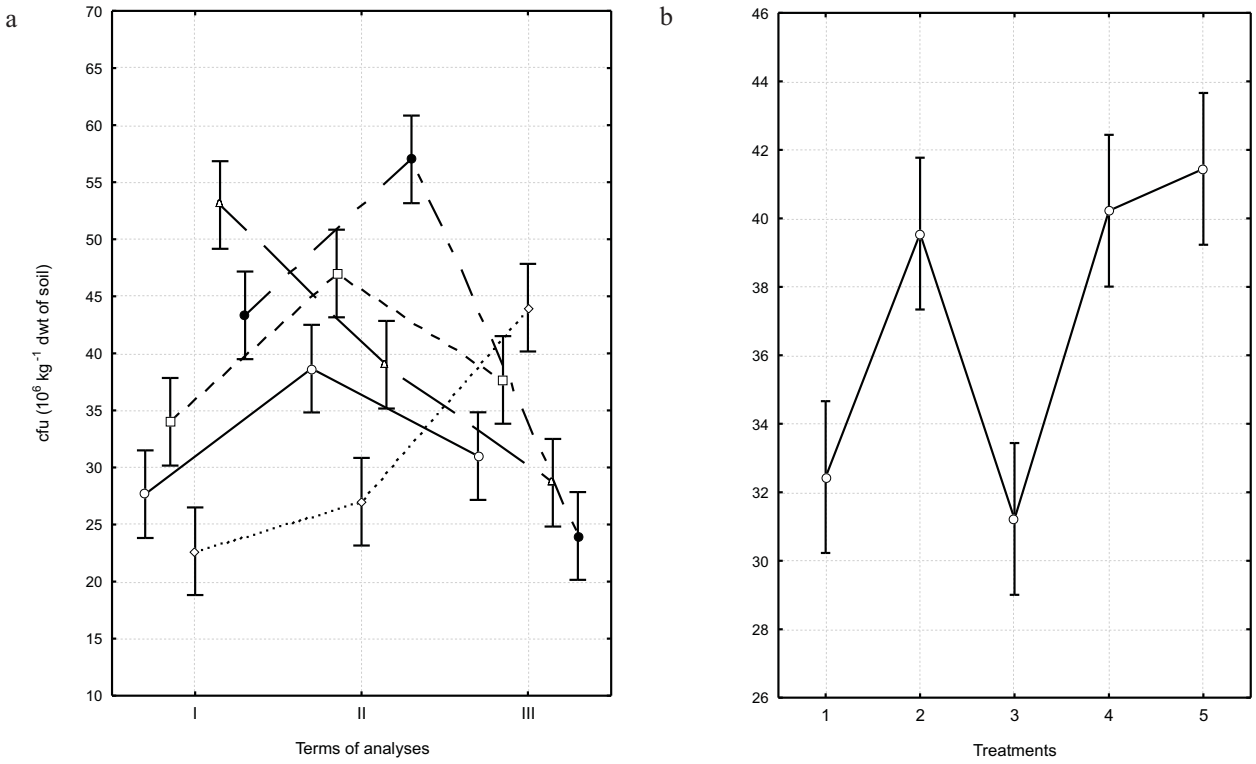

Fig. 2. Total (a) and mean (b) numbers of fungi. Explanations as in Fig. 1.

number of fungi in the soil under the wheat lines STH 716, STH 3 and STH 715. The obtained data indicate that the changes in the numbers of bacteria and fungi were strongly related with the vegetation period of the plants. Changes in the population size of microbial groups under study in the course of the vegetation season were also observed in their study by Frąc and Jezierska-Tys (2008), and those changes depended also on the crop plant and on its phase of growth.

Dehydrogenases are closely related with the process of respiration of all organisms and they are considered to be an indicator of the microbiological activity of soil (Islam and Weil, 2000; Koper *et al*., 2008; Praveen-Kumar and Tarafdar, 2003). Figure 3a presents the results of determinations of dehydrogenase activity under the culture of various lines and cultivars of winter wheat. Analysis of the results indicates that over the whole period of the study we can observe notable variations in the activity of that enzyme in soil under wheat culture. On I date of analysis (heading phase) the highest activity of the studied enzyme was observed in the soil under the winter spelt line STH 3 (treatment 4) and the lowest in the 3 experimental treatment (line STH 717). In the remaining three experimental treatments the dehydrogenase activity was at a similar level. On II date of analysis (phase of milk ripeness) a significant decrease in dehydrogenase activity was noted in the soil in treatments 1, 2, 3 and 4. On III date of analysis (phase of full ripeness) increased dehydrogenase activity was observed in all the experimental treatments, compared to the results of II analysis (phase of milk ripeness), and that activity was at a similar level in all the treatments. The presented results (Fig. 3b.) concerning the mean values of dehydrogenase activity for the particular experimental treatments indicate significantly the lowest activity of that enzyme in the soil under the winter wheat line STH 717, and the highest in treatments 4 and 5.

The results obtained are in agreement with the research by Natywa *et al*. (2010) where the highest activity of the studied enzyme was recorded in the initial stage of vegetation of the plants *ie* in spring, and in the period of intensive growth of the plants a decrease in dehydrogenase activity was observed in the studied soil. Most probably the decrease in dehydrogenase activity was due to a deficit of substrates for soil microorganisms (Koper *et al*., 2008). The lowering of dehydrogenase activity observed on the second date of analysis was probably related with strong acidity of the soil environment, which is supported by an earlier study by Jezierska-Tys *et al*. (2004).

The respiratory activity of soil of the experimental treatments, as measured by the amount of emitted CO_2, is presented in Fig. 4a. The results presented permit the conclusion that on the first date of analysis (heading phase) the highest amount of emitted CO_2 was recorded for the soil under the winter spelt line STH 3 (treatment 4). In the other experimental treatments the respiratory activity on the first date of analysis (heading phase) was at a similar level. On II analysis (phase of milk ripeness), significantly the highest

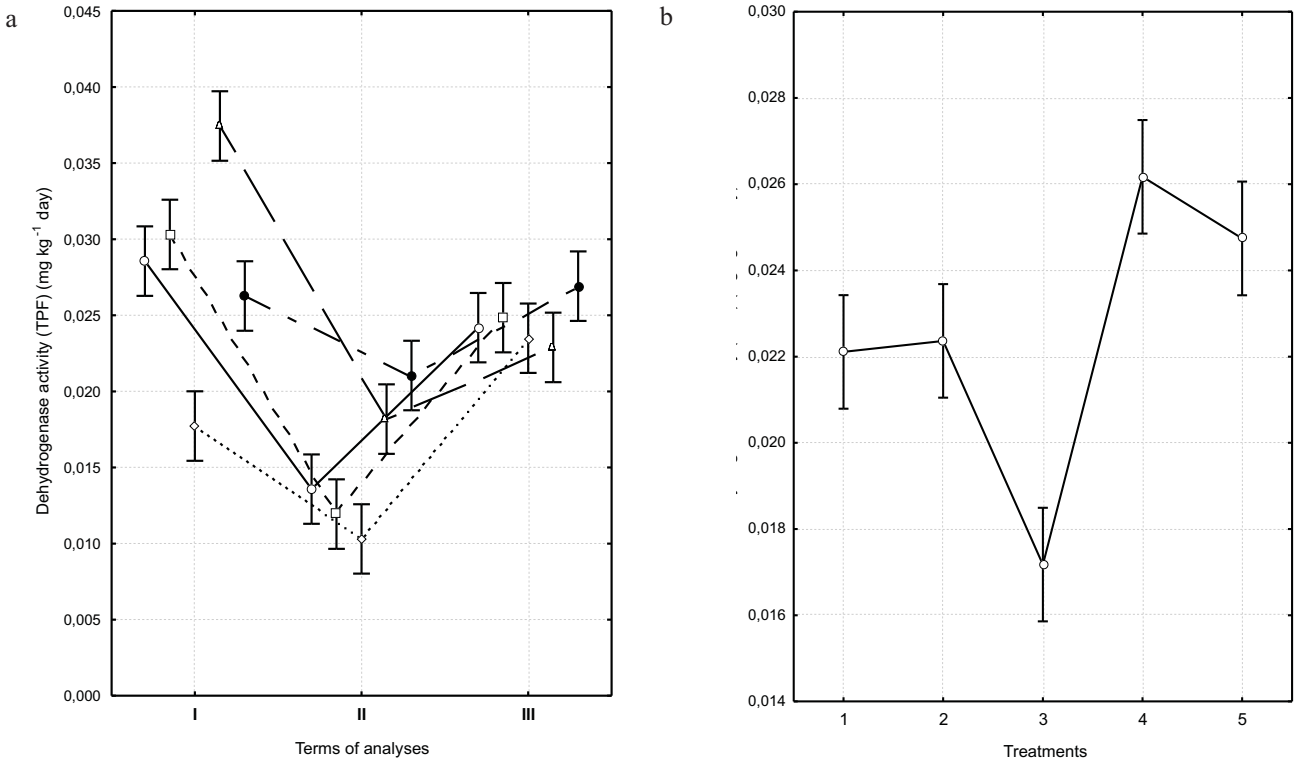

Fig. 3. Dehydrogenases activity (a) mean values of dehydrogenases activities (b). Explanations as in Fig. 1.

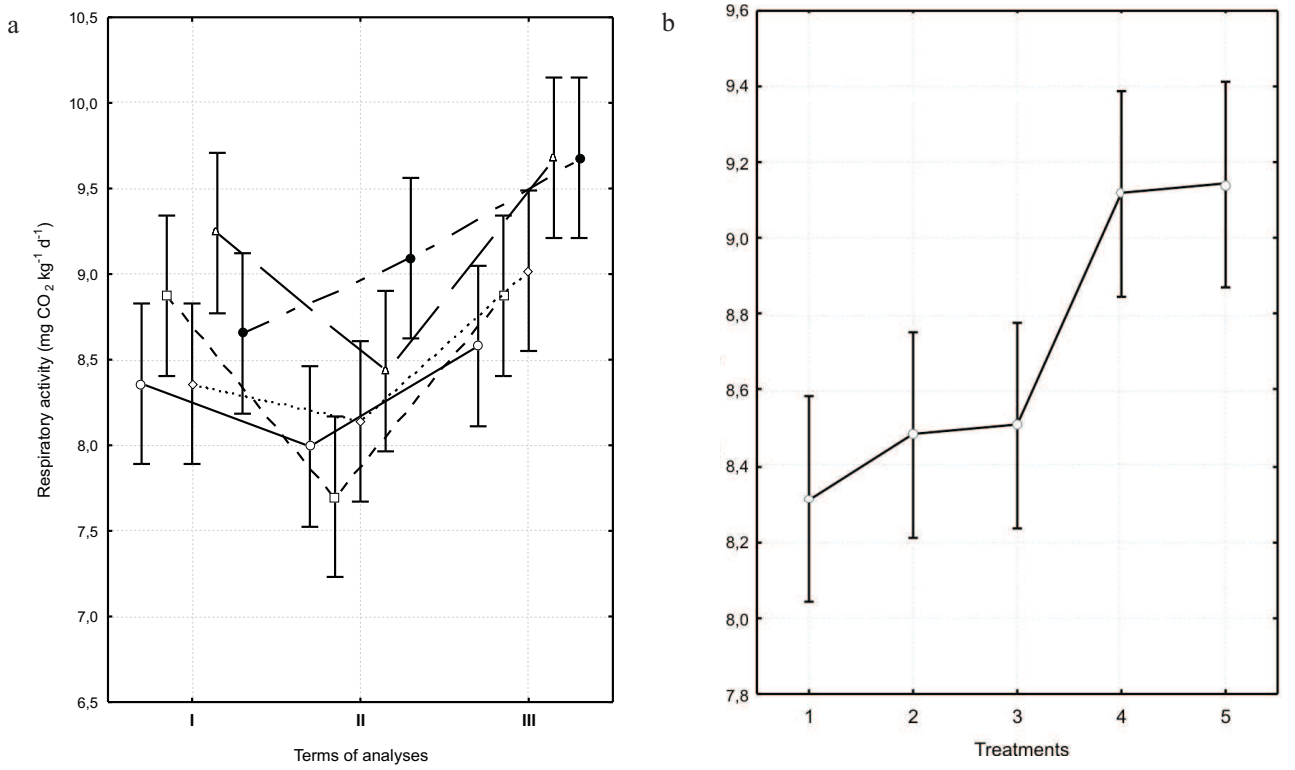

Fig. 4. Respiratory activity in soil (a), mean values respiratory activities in soil (b). Explanations as in Fig. 1.

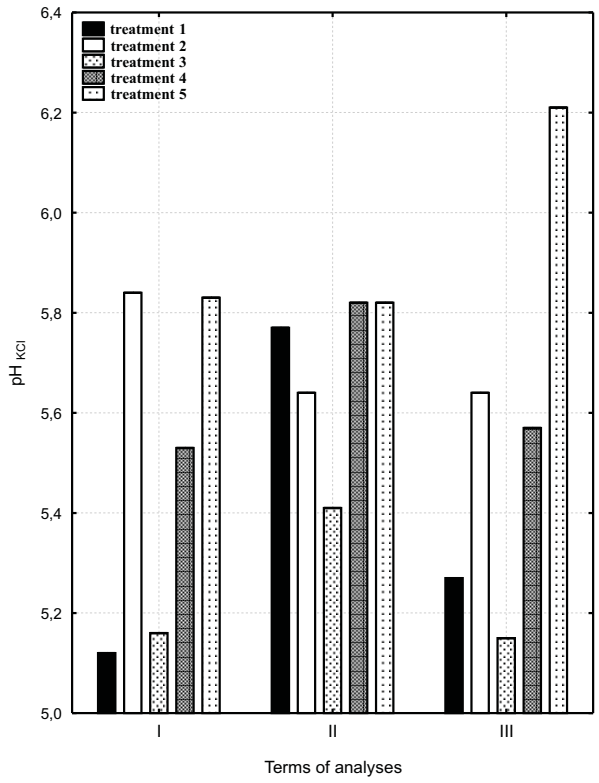

Fig. 5. pH_{KCl}.

respiratory activity was recorded in treatment 5 (line STH 715), and the lowest in the soil under line STH 716 (treatment 2). On III analysis the lowest amount of emitted CO_2 was observed in the treatment 1 (cv. Tonacja), and the highest in treatments 4 (line STH 3) and 5 (line STH 715). The greatest amounts of emitted CO_2 were observed on III of analysis (phase of full ripeness). Analysis of mean values of the amounts of emitted CO_2 for the experimental treatments (Fig. 4b) shows that significantly the highest respiratory activity was characteristic of the soil under wheat lines STH 3 and STH 715. Those authors attribute that effect to the content in soil of easily oxidised carbon compounds that permit high activity of heterotrophic microorganisms in the final phase of plant vegetation.

Changes in soil reaction under the culture of various cultivars and lines of winter wheat are presented in Fig. 5. The data obtained indicate that the wheat lines and cultivar grown in the field experiment did not have any significant effect on changes in the reaction of the grey-brown podzolic soil developed from loess. On I analysis (heading phase) the highest value of pH was noted in treatments 2 (line STH 716) and 5 (line STH 715). On the II date of analysis (phase of milk ripeness) the lowest reaction was characteristic of the soil from treatment 3 (line STH 717). On the third date of analysis (phase of full ripeness) the highest value of pH was recorded in treatment 5 (line STH 715).

CONCLUSIONS

1. Changes in the numbers of the microbial groups under study during the vegetation period of the plants depended on the lines and cultivar of winter wheat, and on the phase of its growth.

2. The studied winter wheat cultivar and lines had no effect on the respiratory activity of the soil.

3. The dehydrogenase activity of the soil was significantly affected by the cultivar and the lines of winter wheat, as well as by the dates of analyses.

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