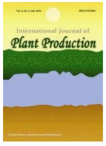

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Influence of catch crop on soil properties and yield of spring barley

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Abstract

Biomass of legumes grown as catch crops improves soil properties and thus soil conditions for following crops. The aim of this study was to evaluate the effect of field pea (*Pisum sativum* L.) grown as a catch crop and used for green manure on soil properties and yielding of spring barley (*Hordeum vulgare* L.). Field experiments were conducted in 2008-2011 in the randomized block design with four replications, in typical black earth. The experimental factor was the time and way of catch crop incorporation: in autumn–with plowing (1); in the spring–with disking (2); control–without a catch crop (3). The soil with the catch crop contained significantly higher mineral nitrogen in the topsoil during tillering of barley than the control. Catch crop caused significant decrease in soil moisture and increase in penetration resistance in the topsoil in autumn. No significant effect of the catch crop on soil moisture during spring barley growing season in the following spring was obtained. Catch crop plowing in autumn caused significant decrease in soil penetration resistance in the 20-30 cm layer in early spring. Catch crop biomass plowed positively affected the number of spikes in sequential spring barley. Leaving pea as mulch for winter caused significant increase in 1000 grain weight compared to the control. Field pea grown as a catch crop for green manure can be recommended for increasing mineral nitrogen concentration and the soil biological activity in the topsoil. However, its influence on spring barley yield in fertile soils is low.

Keywords: Green manure; Spring barley; Soil moisture; Penetration resistance; Mineral N; Soil microbial activity.

Introduction

A catch crop used as green manure is a valuable source of organic matter to the soil. It is particularly important in those areas where, due to low stocking, the production and use of farmyard manure does not allow maintaining the organic matter balance in the soil. According to Shahriari et al. (2011) agricultural practices may play very serious role in organic matter concentration in the soil. Catch crops are valuable source of organic matter (Thorup-Kristensen and Dresbøll, 2010; Piotrowska and Wilczewski, 2012). Moreover, they can contribute to nitrogen supply of following crops through uptake of excess soil mineral nitrogen and through biological N fixation (Doltra and Olesen, 2013). The effect of catch crop on soil properties and yield of following cereals is dependent on the appropriate choice of species and the weather conditions during the catch crop growing and after its harvest. Also the period of catch crop biomass incorporation into the soil is of great importance for the availability of ingredients released in the process of biomass mineralization for the plants. The delay decreases the rate of mineralization and reduces the risk of nitrogen leaching from the soil, especially in seasons characterized by high amounts of rainfall in the autumn and winter (Thorup-Kristensen and Dresbøll, 2010).

Our previous studies (Piotrowska and Wilczewski, 2012) showed a positive effect of pea and oilseed radish plowed in the autumn on the soil enzymatic activity. Particularly strong was the influence of pea on the activity of nitrate reductase, β-glucosidase and alkaline phosphatase measured in August the following year. According to Małecka and Blecharczyk (2008), cultivation of legumes as a catch crop intended for green manure allows achieving high yields of succeeding crops with a significant decrease in the use of nitrogen fertilizer. Shah et al. (2009) stated that the combined application of mineral and organic fertilization is a more effective method of cereal fertilization compared to organic or mineral fertilization applied separately.

The favorable impact of legumes on soil properties is well known. Despite this, farmers managing fertile soils, characterized by a generally high abundance in humus and minerals, are unwilling to grow catch crops intended for green manure. This is mainly due to concerns about excessive drying of the soil in the autumn and, consequently, difficulty in performance of the autumn plowing. Furthermore, the impact of these crops on the fertile soils is not as large as on the poorer quality soils. As shown in this study, a

successful catch crop, both plowed in the autumn as well as left as mulch during the winter and incorporated into the soil in spring, can significantly improve the physical, chemical and biological properties of such soil.
The aim of this study was to determine:
- the impact of manner and time of mixing the catch crop biomass with the soil on the penetration resistance and topsoil moisture of a typical black earth during spring barley growing season;
- to what degree the catch crop influences the microbiological activity of soil as measured by dehydrogenase (DH) and by the level of fluorescein sodium salt hydrolysis (FDAH);
- the response of spring barley to cultivation after a catch crop in conditions of fertile black earth.

Materials and Methods

Study site and experimental design

The field experiment was performed in the randomized block design with four replications. The plot area was 250 m^2. Field pea grown as a catch crop was sown after the harvest of winter wheat and used as green manure for following spring barley. The factor of the experiment was the manner and time of the catch crop biomass incorporation into the soil: in the autumn–using winter plowing (1); in the spring–using disking (2); control–without catch crop (3).

Agrotechnology

Seeds of field pea 'Wiato' were sown at 150 kg ha^{-1}, to a depth of approximately 5-6 cm in row spacing of 15 cm within 7-13 August in years 2008-2010. Sowing was preceded by performing plowing to a depth of 15 cm. Moreover, the soil was prepared using a cultivator with a crumbler roller. Harvesting of plants in treatment 1 was performed using a sickle bar mower in the period from 15 October to 3 November. Subsequently, soil in treatments 1 and 3 was plowed to a depth of about 27 cm using 4-furrow plow equipped with skimmers. In treatment 2 pea was left uncut over the winter. In spring the biomass was cut and mixed with the soil using disk cultivator.

Spring barley was sown in the period from March 31 to April 3 in years 2009-2011, using a row drill in treatments 1 and 3 and a drill equipped with coulters in treatment 2. Phosphorus (26.2 kg ha^{-1} P) and potassium (66.4 kg ha^{-1} K) fertilization of spring barley was performed in the early spring. Nitrogen (90 kg ha^{-1} N) was applied in two rates of 45 kg ha^{-1} N each. The first rate was broadcast before spring barley sowing (together with phosphorus and potassium) and the second in the shooting phase. After the dispersal of fertilizers, the soil in treatments 1 and 3 was cultivated using a cultivator with the crumbler roller.

Course of field and laboratory studies

After sowing catch crops, the observation of plant growth was conducted. After emergence, plant density was counted (no m^{-2}). After the end of the growing season, the yield of field pea green mass in treatment 1 was determined. The yield of field pea dry weight was determined based on the green mass samples taken from each plot.

Yield of post-harvest residues was determined on the basis of samples taken from 25×25×25 cm soil monoliths. From each plot four samples were randomly collected and screened through a sieve with a mesh size of 4 mm. Subsequently the samples were rinsed in stream of water and dried on the absorbent paper. Next they were weighed, dried in an oven at 50 ^{o}C and reweighed to determine the dry weight yield.

The samples of aboveground biomass and post-harvest residues of pea collected before harvest were assayed for the content of nitrogen, using Kjeldahl method (Batey et al., 1974), phosphorus, using vanadium-molybdenum method (Koter and Panak, 1960), magnesium-colorimetrically with titanium yellow (Bradfield, 1960), potassium and calcium-using flame photometry method (Pickett and Koirtyohan, 1969).

Measurement of soil penetration resistance (PR) was done in the autumn, after the end of the catch crop growth season (October), in the spring before sowing of barley (March), at tillering (May) and shooting stage (June). These measurements were made using a manual penetrometer in soil layers: 0-5 cm, 5-10 cm, 10-15 cm, 15-20 cm, 20-25 cm and 25-30 cm. Simultaneously soil samples were collected from 3 layers (5-15 cm, 25-35 cm and 45-55 cm) to determine the soil moisture. Analysis were performed using drying-weighing method (Craze, 1990). Samples were collected using Kopecki cylinders with a volume of 100 cm^{3}.

Contents of mineral nitrogen were determined in soil samples taken from the topsoil of each plot before sowing of barley, at tillering and shooting stages and after harvest of barley. This analysis was performed in the laboratory of the Regional Chemical-Agricultural Station in Bydgoszcz, using colorimetric methods (Bashour and Sayegh, 2007).

In soil samples collected before sowing, during the growing season and after harvest of spring barley, soil dehydrogenase (DH) activity and the level of fluorescein sodium salt hydrolysis (FDAH) were measured. DH activity was assayed as described by Thalmann (1968). Field–moist soil was mixed with 1% TTC solution (triphenyltetrazolium chloride) and Tris-HCl buffer (100 mM, pH 7.6) was added to Erlenmeyer flask and incubated for 24 h at 30 ^{o}C. After the incubation acetone (analytical grade) was added to each flask and the flask were shaken thoroughly and further incubated at room temperature for 2 h in the dark. The soil suspension was then filtered and the optical density of the triphenylophormazan (TPF) was measured against the blank at 546 nm. One unit of DH activity was defined as mg of TPF released at 30 ^{o}C 24 h^{-1} by 1 kg of dried soil.

The rate of FDAH was determined according to Adam and Duncan (2001). One g of field-moist soil was placed in an Erlenmeyer flask (50 ml) and treated with phosphate buffer (60 mM, pH 7.6) and fluorescein diacetate (10 mg ml^{-1}) as the substrate. The mixture was then incubated in a rotary shaker for 1 hour at 37 ^{o}C. After the incubation the reaction was stopped by adding the mixture of methyl alcohol and chloroform. Then the soil suspension was centrifuged at 4000 rev min^{-1} for 10-15 minutes and the optical density of the clear supernatant was measured at 490 nm. The same procedure was followed for the controls as for the enzyme assay but the substrate was added to the soil after incubation and immediately prior to stopping the reaction. The FDAH activity was expressed as mg of fluorescein produced at 37 ^{o}C h^{-1} by 1 kg of dried soil.

After the emergence of spring barley, plant density was calculated (no m^{-2}). The number of spikes (no m^{-2}) was determined in samples collected before barley harvesting from an area of 1 m^2 from each plot. Subsequently 20 ears were randomly taken from each sample to determine the number of grains per spike.

Harvesting plants was carried out using the Wintersteiger plot combine. After harvest, the grain and straw yield of barley was determined. Grain samples were collected from each plot to determine its moisture and 1000 grain weight. Grain yield was calculated to 15% humidity.

Statistical analysis of the results

The working hypotheses concerning the effect of catch crop management on studied features were verified using analyses of variance for mixed model. The results concerning the content of mineral N in the topsoil and enzyme activity were subjected to the two-way analysis of variance including the effect of the catch crop and the dates of sampling on these properties. When significant treatment effects were found, Tukey's test at the significance level $P \leq 0.05$ was used to compare treatment means.

Soil and weather conditions

Field studies were carried out in Szadlowice (52° 50' N, 18° 20' E), on a typical black earth, belonging in terms of particle size to the loams, where the fraction <0.002 mm ranged from 6 to 12%. The content of available forms of phosphorus, potassium and magnesium was very high (158, 246 and 115 mg in 1 kg of dry soil respectively). The soil was slightly alkaline (pH in 1 M KCl-7.3).

Precipitation totals during the growth of pea cultivated as a catch crop were varied in years (Table 1). In 2008 and 2010 very high rainfall in August was observed. It provided a good supply of water for germinating pea seeds and contributed to the dynamic development of plants during the formation of rosettes. In 2009 we found a significant lack of rainfall in August and September. However, the water content in the soil before sowing was 9.92%. This was due to the occurrence of high precipitation totals in July that year.

The air temperatures during this period were less variable in years. There were relatively high average monthly temperatures in July and August. September temperatures in 2008 and 2010 were lower and in 2009 higher than the average of the research years. Relatively high temperatures in the first half of October in 2008 occurred.

Weather conditions during the growing season of spring barley were varied in particular years of the study (Table 1). Precipitation was relatively high throughout the study period but its distribution was not properly suited to the needs of spring barley. In 2009, during the tillering and shooting stages, precipitation deficits occurred, while during the formation and maturing of grain water supply was excessive. In the other years, there was a significant shortage of rainfall during the period from tillering to flowering and a substantial part of the rainfall occurred only in plant maturing stage, which made it impossible to fully use the soil fertility.

Table 1. Weather conditions at the experiment site during the trial period.

Month	2008	2009	2010	2011	Mean
	Total monthly precipitation (mm)				
III		39	48	16	34
IV		0	25	6	10
V		47	47	24	39
VI		86	27	42	52
VII	42	124	159	102	107
VIII	98	28	99		75
IX	39	18	70		42
X	60	56	4		40
	Mean air temperature (^{o}C)				
III		3.1	3.2	2.6	3.0
IV		10.5	8.3	10.5	9.8
V		13.1	12.1	14.0	13.1
VI		15.5	17.0	18.4	17.0
VII	19.3	19.0	21.4	18.2	19.5
VIII	18.2	18.7	18.7		18.5
IX	12.6	14.8	12.4		13.3
X	9.1	5.9	6.9		7.3

Results

Yield and chemical composition of field pea grown as a catch crop

Yield of dry matter of pea was varied in years of the study (Table 2). It was the highest in 2008 and the lowest in 2009 and 2010. The content of most macronutrients in pea green matter was higher than in the post-harvest residue (Table 3). Only calcium was accumulated in the post-harvest residue in larger amount than in green matter.

Table 2. Dry matter yield of field pea incorporated into the soil (t ha^{-1}).

Kind of biomass	2008	2009	2010	Mean
Green mass	2.0	1.1	1.8	1.6
Post-harvest residue	1.6	0.9	0.7	1.1
Total biomass	3.6	2.0	2.5	2.7

Table 3. Content of essential macronutrients in the catch crop (% of dry matter).

Kind of biomass	N	P	K	Ca	Mg
Green mass	3.36	0.287	3.21	1.03	0.225
Post-harvest residue	2.06	0.197	2.35	1.27	0.211

Effect of the catch crop on mineral N content and microbiological activity of the topsoil

The soil in catch crop treatments contained a significantly higher mineral nitrogen in the topsoil during the tillering of barley (May) than soil in the control without the catch crop (Table 4). In treatment with catch crop incorporated in spring also at shooting stage (June) the soil contained more mineral N than in the control. For other dates no significant effect of the catch crop on this feature was shown.

Table 4. Content of mineral nitrogen (mg kg^{-1} of dry soil) in the topsoil as dependent on the catch crop management and sampling dates during the experiment (2009-2011).

Catch crop management	Measuring time			
	March	May	June	August
1[&]	$12.3^{B\wedge}$	40.1^{a*A}	16.1^{abB}	11.3^{B}
2	14.3^{BC}	33.1^{bA}	19.6^{aB}	11.3^{C}
3	9.4^{A}	22.9^{cA}	13.9^{bA}	9.6^{A}
Mean	12.0^{C}	32.0^{A}	16.5^{B}	10.7^{C}

[&] 1–catch crop incorporated in autumn, 2–catch crop incorporated in spring, 3–control (without a catch crop). [*] Values followed by different small letter within each column differ significantly at P≤0.05. [^] Values followed by different capital letter within a line differ significantly at P≤0.05.

The content of mineral N in soil was the highest in May (during the tillering of barley), significantly lower in June (at the shooting stage) and the lowest in March and August. In the control treatment differences in the content of mineral nitrogen in the soil at various dates were not statistically confirmed.

The variability of DH and FDAH activities was significantly affected by both catch crop management and sampling dates (Table 5). The DH activity ranged from 13.7 to 23.6 mg TPF kg^{-1} 24 h^{-1} across the investigated period and the activity was significantly varied by the catch crop management as compared with the control soil in all sampling dates. Soil DH activity was affected by the time of catch crop incorporation only in August, being significantly higher when field pea was incorporated in spring compared to the autumn application. The highest DH activity was determined in May followed by the other sampling dates.

The FDAH activity ranged from 39.4 to 70.7 mg F kg^{-1} h^{-1} during the entire experimental period. As compared with the control, the FDAH activity was significantly affected by the catch crop management in all sampling dates. The time of catch crop incorporation did not influence the FDAH activity before sowing of spring barley and after its harvesting, while during tillering (May) and shooting of spring barley (June) the activity was significantly lower in autumn than in spring incorporation time. The highest FDAH activity was noted in May, followed by March and June, while the lowest was in August.

Table 5. Dehydrogenase (DH) activity and fluorescein sodium salt hydrolysis (FDAH) activity as dependent on the catch crop management and sampling dates during the experiment (2009-2011).

Treatment	Measuring time			
	March	May	June	August
	DH activity (mg TPF[$] kg^{-1} 24 h^{-1})			
1[&]	16.1$^{a* B\wedge}$	22.9^{aA}	16.7^{aB}	14.3^{bB}
2	15.7^{aB}	23.6^{aA}	17.2^{aB}	14.5^{aB}
3	14.2^{bB}	20.4^{bA}	14.5^{bB}	13.7^{cB}
Mean	15.3^{B}	22.3^{A}	16.1^{B}	14.2^{B}
	FDAH activity (mg F[#] kg^{-1} h^{-1})			
1	52.4^{aB}	65.4^{bA}	53.9^{bB}	43.5^{aC}
2	54.4^{aB}	70.7^{aA}	57.2^{aB}	43.8^{aC}
3	47.4^{bB}	58.7^{cA}	47.3^{cB}	39.4^{bC}
Mean	51.4^{B}	64.9^{A}	52.8^{B}	42.2^{C}

[&]1–catch crop incorporated in autumn, 2–catch crop incorporated in spring, 3–control (without a catch crop). [*] Values followed by different small letter within each column differ significantly at P≤0.05. [^] Values followed by different capital letter within a line differ significantly at P≤0.05.
[$] –TPF–triphenyl formazan; [#] –F–fluorescein

Effect of the catch crop on some physical properties of the soil

Soil moisture was in the range from 6.8-8.5% in the autumn to 11.3-13.6% in the spring, before barley sowing (Table 6). The catch crop caused a significant decrease in soil moisture of the topsoil in the autumn. In none of the spring measurements was there a significant effect of the catch crop on this feature.

Table 6. Soil moisture (% of weight).

Treatment	Depth of soil layer (cm)		
	5-15	25-35	45-55
October 2008-2010			
1[&]	8.1[b*]	7.1	6.8
3	8.5[a]	7.2	6.8
Mean	8.3	7.2	6.8
March 2009-2011			
1	12.9	11.6	11.6
2	13.0	11.3	11.8
3	13.6	11.5	11.7
Mean	13.2	11.5	11.7
May 2009-2011			
1	9.6	9.9	10.4
2	9.8	10.3	10.5
3	10.0	10.5	10.4
Mean	9.8	10.2	10.4
June 2009-2011			
1	10.0	9.9	10.7
2	10.0	10.0	10.3
3	10.5	10.1	10.0
Mean	10.2	10.0	10.3

[&] 1–catch crop incorporated in autumn, 2–catch crop incorporated in spring, 3–control (without a catch crop). [*] Values followed by different small letter within column differ significantly at P≤0.05.

Soil penetration resistance in October was in all studied layers significantly higher after the catch crop than in the control (Figure 1A). The topsoil was the most compact prior to sowing spring barley (March) in the treatment where the catch crop was left for the winter in the form of mulch (Figure 1B). Differences in values of this characteristic, as compared to the control and the treatment with the catch crop plowed in, were statistically confirmed for all analyzed depths. The reason for diversity in penetration resistance of soil was the lack of plowing in the treatment with the catch crop left as mulch. There were also differences in soil compactness among the treatments where plowing was carried out in the autumn. In the treatment with the catch crop plowed in, PR in early spring was lower in the layer at a depth of 20-30 cm than in the control without the catch crop.

PR during barley tillering period (May) was significantly higher in the soil with mulch of the catch crop than in the other treatments (Figure 1C). The soil without the catch crop was characterized by the smallest PR of the topsoil. The treatment with the catch crop plowed in had significantly greater PR from 0 to 25 cm as compared with the control. Soil PR in the shooting phase of barley (June) was also the largest in the treatment without plowing and with the catch crop left as mulch (Figure 1D). In layers from 0 to 5 cm and from 10 to 25 cm, PR in the control was significantly lower than at the catch crop plowed in the autumn.

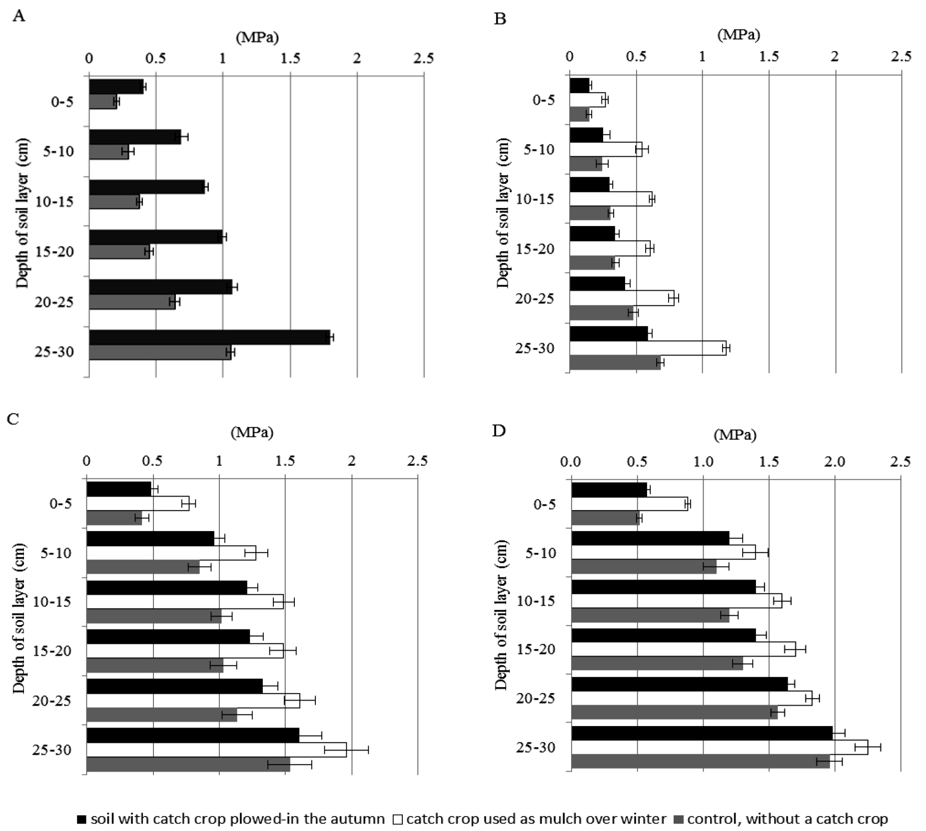

Figure 1. Penetration resistance (PR) of soil, in October (2008-2010), after harvest of the catch crop (A); in March (2009-2011), before sowing of spring barley (B); in May (2009-2011), during spring barley tillering (C) and in June (2009-2011), during spring barley shooting (D). Bars represent 3-year means and Tukey's confidence half intervals at $P \leq 0.05$, expressed in megapascals (MPa).

The yield of spring barley and its structure

The catch crop did not significantly affect the yield of spring barley grain and straw (Table 7). There was a negative effect of mulch on the germination and emergence of barley. The number of plants at this treatment was smaller than with the catch crop plowed in (Table 8). There were found beneficial effects of catch crop biomass plowed on the number of spikes of spring barley. Number of grains per spike was not dependent on the catch crop. Leaving pea as mulch through the winter contributed to a significant increase in 1000 grain weight as compared with the control.

Table 7. Yielding of spring barley grown after the catch crop compared with the control (2009-2011).

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
1[&]	6.25	2.75
2	6.17	2.74
3	6.09	2.63
Mean	6.17	2.71

[&] 1–catch crop incorporated in autumn, 2–catch crop incorporated in spring, 3–control (without a catch crop).

Table 8. Yield components of spring barley grown after the catch crop compared with the control (2009-2011).

Treatment	Number of plants after emergence (no m^{-2})	Number of spikes (no m^{-2})	Number of grains per spike	1000 grain weight (g)
1[&]	318[a]	707[a]	22.5	41.5[ab]
2	298[b]	685[b]	22.8	42.4[a]
3	308[ab]	683[b]	22.7	40.8[b]
Mean	308	692	22.7	41.6

[&]1–catch crop incorporated in autumn, 2–catch crop incorporated in spring, 3–control (without a catch crop). [*] Values followed by different small letter within each column differ significantly at P≤0.05.

Discussion

Yields of crops grown as a catch crop are mainly dependent on rainfall during the period from the beginning of July to the end of August (Wilczewski et al., 2012) and the choice of species (Talgre et al., 2011;

Zaniewicz-Bajkowska et al., 2013). The pea biomass yield obtained in the present study can be considered as typical of legumes grown as a catch crop (Thorup-Kristensen, 1994; Talgre et al., 2011; Wilczewski, 2013). They were smaller than expected under such favorable soil conditions. The limiting factor for the ability to achieve a high yield of biomass was a relatively late time of sowing, resulting from a delay of the wheat harvest and unfavorable thermal conditions in October in 2 out of 3 study years. In order to obtain higher yields, catch crops should be sown in July (Zaniewicz-Bajkowska et al., 2013). Due to the use of intensive cultivation technology of cereals preceding catch crop cultivation, sowing of catch crop on fertile soils in July is currently impossible.

The effect of catch crops on soil moisture was mostly insignificant (except for the autumn date). The reason for the poor impact of catch crop on this feature can be naturally high moisture of black earth and consequently a relatively low susceptibility to moisture changes under the influence of this factor.

The adverse effect of the catch crop on soil moisture in autumn and consequently an increase of the PR confirms to some extent the concerns of farmers about the deterioration of soil properties as a result of growing catch crop. However, in none of research cycles has there been a significant difficulty in execution of autumn plowing. There was also no impact of catch crop on fuel consumption during plowing (data not shown). The soil PR observed in the experiment in autumn, in the treatment with the catch crop, ranged from 0.40 MPa in the 0-5 cm layer to 1.79 MPa in a layer of 25-30 cm. Numerous studies indicate that, in the soil in which the PR is less than 2 MPa there are favorable conditions for the growth of crop roots (Materechera et al., 1991; Hamza and Anderson, 2005; Lipiec et al., 2012).

The way of soil cultivation was the main factor influencing the PR of the soil in the spring (before sowing, during tillering and shooting of barley). In all three measurement dates in the spring and at all depths studied, PR of the soil with mulch was significantly greater than in the other treatments. This was due to the lack of autumn plowing in this treatment. Greater PR stated in certain layers in treatment with the catch crop plowed in than in the control without the catch crop may be associated with a better tillering of plants in treatments with the catch crop and thus more intensive water uptake from the soil.

The results confirm that the microbial biomass status expressed as DH and FDAH activities was greater in the plots with catch crop, both incorporated in the autumn and in spring, compared to the control, what confirmed the earlier statements that green manuring generally increased the soil microbial biomass content and activity as compared with no organic amendment (Elfstrand et al., 2007).

Soil microorganisms degrade organic matter through the production of different extracellular enzymes and for this reason after the application of green manures to soil, the enzymatic activity of the soil increases (Tejada et al., 2008). In fact, in this study the activity of FDAH representing the activity of different hydrolytic enzyme activities, such as proteases, esterases and lipases, was higher in catch crop management compared with the control. Additionally, in this study, the field pea biomass could have stimulated the soil microbiological biomass and enzymatic activity through the modification of the chemical properties of the soil, such as an increase in the mineral N content in the topsoil (Table 4). Some earlier studies have documented the stimulation effect of catch crop management on soil FDAH activity (Reddy et al., 2003; Zablotowicz et al., 2010).

The highest enzymatic activity occurred in May can be explained by the enhanced rhizosphere microbial population that accompanies the rapid development of the crop root systems during the growing period (Richardson et al., 2009). Seasonal variation of soil microbial activity are in some degree affected by the weather conditions, especially rainfall and temperature (Gutknecht et al., 2010). As regards however DH and FDAH activities we did not find any marked interaction between the temperature and rainfall levels and the activity data of these properties in the subsequent years of the experiment. It was probable that the activity of studied properties was more affected by the catch crops management or other agents rather than by climatic factors.

Despite of the favorable impact of the catch crop on the content of mineral nitrogen in soil at tillering stage no significant effect of catch crop on the yield of spring barley was stated. Pea grown as a catch crop and used as green manure in poorer soil conditions (Alfisols) significantly increased the yield of grain and straw of cereals (Wilczewski, 2013). The weaker effect of catch crop on the yield of barley in very good soil conditions could be associated with high natural fertility of the soil. Plants grown in the control, without the catch crop, were well stocked with minerals from the soil resources. The content of mineral nitrogen in the soil on which this study was conducted was about 60% higher during the tillering and stem elongation than that in the Alfisols on which the study cited were conducted. The results obtained in the present study and those presented in the available literature show that the impact of the catch crop used as green manure for spring cereals is inversely proportional to the abundance of nutrients present in the soil or supplied with fertilizers (Kwiatkowski, 2008; Wilczewski, 2013).

Strong influence of green manure on the yield of cereals can be expected under the conditions of shortage of readily available nutrient in the soil. After satisfying the plant nutritional requirements of plants from the soil resources or mineral fertilizers, further improvement of the botanical characteristics and yield is difficult to obtain. The impact to the pea biomass was revealed only by an increase in the number of barley spikes in the treatment with the catch crop plowed in the autumn and increase in 1000 grain weight after the spring introduction of biomass to the soil. This effect was not sufficient to achieve an increase in grain yield.

Conclusions

The results obtained indicate that the application of a field pea as green manure can be recommended as a means of increasing mineral nitrogen concentration in the topsoil and the soil biological activity measured as the activity of dehydrogenase (DH) and the fluorescein sodium salt hydrolysis (FDAH) during the growth of plants cultivated in the following year. Both spring and autumn incorporation of catch crop biomass can be recommended as a management tool to improve the status of soil properties during the growth of the sequent crop.

Moreover, the catch crop plowed in autumn has reduced penetration resistance in the layer of 20-30 cm during the early spring (before sowing of spring barley). The negative aspects of the catch crop may include a significant increase in soil penetration resistance and a reduction in topsoil moisture during the autumn (which, however, did not hinder the performance of plowing). The catch crop did not significantly affect the yield of spring barley cultivated in the black earth.

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