ACTA Scientiarum Polonorum Acta Sci. Pol., Agricultura 13(1) 2014, 21-38

THE EFFECT OF TILLAGE SYSTEMS AND CATCH CROPS ON THE YIELD, GRAIN QUALITY AND HEALTH OF SPRING WHEAT

Piotr Kraska, Sylwia Andruszczak, Ewa Kwiecińska-Poppe, Edward Pałys
University of Life Sciences in Lublin

Abstract. The aim of the research was comparison of the effect of plough tillage and conservation tillage with the use of various catch crops on the yield and grain quality of spring wheat sown in monoculture on rendzina soil. The experiment was set up on rendzina soil with split-plot design in four replications and included plough tillage (A) and conservation tillage, conducted with two methods: with autumn disking of catch crops (B) and with their spring disking (C). At the same time, four methods of regenerating plot in monoculture of spring wheat were conducted in a form of undersown red clover and Dutch ryegrass, as well as catch crops of lacy phacelia and white mustard. The control were plots without catch crops. Plough tillage was favorable for obtaining higher ear density and grain number per ear, which consequently affected increase in the yield of spring wheat grain, compared with conservation tillage. Decrease in the yield of spring wheat grain on plots with conservation tillage, to the highest degree resulted from a decreased ear density. Ear number and grain yield obtained from the plots where stubble catch crops were sown as well as red clover, were significantly higher than on plots after undersown Dutch ryegrass and on the control plots. Better yield of spring wheat on a plot after stubble catch crops and undersown red clover, to a high degree resulted from an increased ear number per unit of area. Tillage systems as well as catch crops did not change significantly 1000 grain weight of spring wheat. Degree of infestation of the spring wheat culm and root with a complex of fungal diseases was not altered by the evaluated tillage systems. Disease index determined for spring wheat on plots after undersown red clover and stubble catch crops as lacy phacelia and white mustard was significantly lower than after undersown Dutch ryegrass and in control without catch crops. The content of total protein and gluten in spring wheat grain as well as sedimentation coefficient did not change under the effect of the applied tillage systems. Application of Dutch ryegrass as a catch crop deteriorated the quality of spring wheat grain.

Key words: catch crops, conservation tillage, disease index, monoculture, plough tillage, spring wheat

Corresponding author – Adres do korespondencji: dr hab. Piotr Kraska, Department of Agricultural Ecology of University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, e-mail: piotr.kraska@up.lublin.pl

INTRODUCTION

More and more frequently in agricultural practice in Poland as well as in the world, plough tillage is replaced with conservation tillage, also defined as preservative or protective tillage [Weber 2002, Dzienia *et al*. 2006]. Zimny [1999] defines conservation tillage as a tillage method using mulching, which aims at protecting the soil against degradation and at maintaining its productivity. Conservation tillage reduces water and wind erosion, and affects the improvement of the quality of soil environment [Tebrügge 2001, Holland 2004, Lal *et al*. 2007, Leys *et al*. 2010, Weber 2010, 2012, Gruber *et al*. 2011, Bielińska and Mocek-Płóciniak 2012, Małecka *et al*. 2012b, Van de Putte *et al*. 2012]. At the same time, decreasing fuel consumption and labor time devoted to carrying out particular tillage activities brings measurable economical benefits [Holland 2004, Dzienia *et al*. 2006, Smagacz 2006]. Introducing reduced tillage, however, may affect decrease in the grain yield of cereal crops [Kraska and Pałys 2002, 2004, Małecka and Blecharczyk 2002, Frant and Bujak 2007, Kraska 2011b, Małecka *et al*. 2012a, Biskupski *et al*. 2012].

In modern agriculture, catch crops are perceived mainly as an important element for the environment and in agricultural practice. To a lesser degree than in the past, they constitute a feed source. Presence of catch crops increases biodiversity in agroecosystems [Jaskulski and Jaskulska 2006, Jaskulska and Gałęzewski 2009, Kwiatkowski 2012]. At the same time, sowing them in crop rotation fits in with a concept of introducing biological diversity into sustainable agriculture [Zając *et al*. 2010].

Large share of cereals in the sowing structure is a factor degrading agricultural ecosystems. It causes unilateral soil depletion of nutrients, increase in the level of weed infestation, and consequently it affects the decrease in the plants' yield [Wesołowski and Kwiatkowski 2000, Woźniak 2000, Kwiatkowski 2009, Woźniak and Haliniarz 2012]. Moreover, cultivation of cereal plants after themselves is connected with the risk of occurring an increased plant infestation with pathogens in the culm [Wesołowski *et al*. 2004, Blecharczyk *et al*. 2006]. In agrocenoses, catch crops may counteract unfavorable changes caused by cereal plant cultivation in monoculture, consisting in the reduction of leaching nutrients, increasing the content of organic matter in the soil and its biological activity [Andrzejewska 1999, Holland 2004, Kuraszkiewicz 2004, Dzienia *et al*. 2006, Pałys *et al*. 2009, Kraska 2011a].

In Poland, introducing reduced tillage under cereal plants is becoming more and more common. However, it is connected with the risk of obtaining lower grain yields. At the same time, mitigating negative effects of cereal cultivation in monoculture after incorporating catch crops is still topical. A hypothesis was assumed that using catch crops in diverse tillage systems may be an effective treatment, which on the yield level equalizes differences in spring wheat sown after itself. In order to verify these assumptions, a study was carried out, whose aim was the comparison of the effect of tillage systems (plough and two conservation ones), as well as of different types of catch crops, on the grain yield and quality, as well as on the degree of infestation of culm and roots with fungal pathogens in spring wheat sown in monoculture on rendzina soil.

MATERIAL AND METHODS

The studies were carried out in the years 2009-2011, with the use of an experiment set up in 2005 at an Experimental Farm Bezek (51°19' N; 23°25' E) of the University of Life Sciences in Lublin. The experimental field was located on medium heavy mixed rendzina soil, formed from cretaceous rock of a granulometric composition of a medium silty loam (granulometric group according to standard BN-78/9180-11). According to a new classification of the Polish Society of Soil Science, it was clay [PTG 2009]. The soil had an alkaline reaction (pH in 1 mole of KCl – 7.35), high content of P – 117.8 and K – 242.4, as well as a very low content of magnesium – 19.0 ($mg \cdot kg^{-1}$ of soil), while the organic carbon content was 24.7 $g \cdot kg^{-1}$.

Long-term two-factorial field experiment was set up with split-plot design in four replications. The area of the plots for harvest was 30 m^2. The first experimental factor were tillage systems: A – plough system and two conservation systems: B – with an autumn and C – with spring disking of catch crops. The second research factor was method of plot regeneration in spring wheat monoculture in a form of various catch crops. Against the background of the control without catch crops, the effect of undersown catch crops (red clover, Dutch ryegrass) and stubble catch crops (lacy phacelia, white mustard) was compared. Red clover Dajana (20 $kg \cdot ha^{-1}$) and Dutch ryegrass 'Mowester' (20 $kg \cdot ha^{-1}$) were sown at the time of sowing spring wheat. However, lacy phacelia 'Stala' (20 $kg \cdot ha^{-1}$) and white mustard cv. Borowska (20 $kg \cdot ha^{-1}$) were sown after harvesting spring wheat, and after conducting post-harvest cultivating measures in mid August. Plot area for harvest was 30 m^2. In 2005, spring wheat was sown as well as all the catch crops, both undersown catch crops and stubble catch crops, and tillage systems were used according to the assumptions of methodology, treating that year as initiatory. Research results obtained in the years 2006-2008, concerning issues presented in the paper, were presented in other studies [Kraska 2010, 2011b, Kraska and Mielniczuk 2012].

In the plough tillage system, preparing the soil for spring wheat started with skimming and harrowing of the field after harvesting the forecrop. In this tillage system before winter both on plots with catch crops and on the control plot, ploughing was conducted to a medium depth. In spring, harrowing was carried out, while cultivating with harrowing before sowing. Nitrogen fertilizers at a dose of 60 $kg \cdot ha^{-1}$ N in a form of ammonium saltpeter were sown in spring, as well as phosphorus fertilizers at a dose of 30.5 $kg \cdot ha^{-1}$ P in a form of triple superphosphate, and potassium fertilizers at a dose of 74.7 $kg \cdot ha^{-1}$ K in a form of 60% potassium salt. The second nitrogen dose of 40 $kg \cdot ha^{-1}$ N was applied at the beginning of shooting (30-33 BBCH development stages). Spring wheat cv. 'Tybalt' was sown in early April at a number of 5 million grains per ha. The grain was dressed with Panoctine 350 SL (170 ml + 400 ml H_2O per 100 kg of grain).

On plots with conservation tillage (B and C), where stubble catch crops were lacy phacelia and white mustard, after harvesting spring wheat grubbing was conducted to a depth of 18-20 cm as well as harrowing. Next, lacy phacelia was sown and white mustard analogically as in the variant with plough tillage. On plot B, catch crops were disked before winter, while on plot C they were left as mulch for winter, and disking was carried out in spring. In the variant with autumn disking of catch crops (B), spring cultivation was the same as in the plough tillage. In the variant with conservation tillage (C) after disking the plot was harrowed in spring, and next, harrowing was repeated before sowing spring wheat.

In the growing season, the program of protecting spring wheat canopy included reduction of weed infestation (Chwastox Extra 300 SL at a dose of 3.5 $dm^3 \cdot ha^{-1}$ – d.m. 300 $g \cdot dm^{-3}$ MCPA) at the stage 23-29 BBCH, and a protective treatment against fungal diseases (Alert 375 SC 1 $dm^3 \cdot ha^{-1}$ – d.m. 125 $g \cdot dm^{-3}$ flusilazole and 250 $g \cdot dm^{-3}$ of carbendazim) at the stage 26-29 BBCH.

Before harvesting spring wheat, the ear number was determined with a frame of an area of 0.5 m^2 at two points on each plot. At the same time, in the ear sample collected from an area of 0.25 m^2 per each plot, grain number was determined per ear as well as the weight of grains per ear. 1000 grain weight was determined in two replications, 500 grains each. Harvest was conducted with a combine harvester at the stage of full maturity. The effect of particular yield components of spring wheat on the difference in the grain yield quantity on experimental plots was determined with the use of a method developed by Rudnicki [2000]. Studies of the health of spring wheat were carried out at the milk stage (73-77 BBCH). 50 culms were randomly collected from each plot. In the laboratory, an evaluation of percentage proportion of culms with symptoms of necrosis was conducted on low internodes of culms and on roots. The degree of infestation was determined according to Eng-Chong Pua with the use of a 5-degree scale [Łacicowa *et al*. 1990]. Next, disease index was calculated according to Mc Kinney`s formula given by Łacicowa [1969]. The total protein and gluten content in the grain, as well as Zeleny sedimentation index was determined with NIR technique, using the phenomenon of light reflection within the range of near infrared of the analyzed substance, with the use of an Omega G computer transmission analyzer of the whole grain (Bruins Instruments, Germany).

Obtained results were elaborated statistically with the analysis of variance. The means were compared with the use of the least significant differences based on Tuckey test ($P \leq 0.05$). Calculations were conducted with the use of statistical program ARSTAT, developed in the Faculty of Applied Mathematics and Information Technology of the University of Life Sciences in Lublin.

Meteorological conditions

Individual years differed with intensification and distribution of rainfall (Table 1). The rainfall total from April to July in all years of research was higher than the long-term total. Rainfall in the month of sowing spring wheat in the years 2009-2011 was definitely lower than in the long-term period. Particularly low was the one in April 2009. In May 2009 and 2010, the rainfall total significantly exceeded the mean from the long-term period for this month. In 2011, the rainfall total in May was lower than the long-term mean. In June, in all years of observation, rainfall was higher than the mean from the long-term period, while especially high rainfall in this month was observed in 2009. In July, very high rainfall occurred in the years 2010-2011, while in 2009 it was visibly lower, compared with the long-term total.

Mean air temperatures in all years of research were higher than the mean from the long-term period. In the month of sowing spring wheat, i.e. in April, air temperature in the subsequent years of observation was higher than the long-term mean (Table 1). In the period of intensive growth in May 2009, mean air temperature was close to the long-term mean, and in the years 2010-2011 it was visibly higher than the mean from the years 1974-2010. Mean air temperature in July in the years 2009-2011 was higher than the mean from the long-term period.

Table 1. Rainfall and air temperature as compared to the long-term mean figures (1974-2010) according to the Meteorological Station at Bezek
Tabela 1. Opady i temperatura powietrza w zestawieniu ze średnimi wieloletnimi (1974-2010) wg Stacji Meteorologicznej w Bezku

Year – Rok	Month – Miesiąc				Total Suma
	April kwiecień	May maj	June czerwiec	July lipiec	
	Rainfall – Opady, mm				
2009	10.1	86.8	180.5	50.8	328.2
2010	20.4	72.4	94.4	156.0	343.2
2011	30.6	40.8	88.5	178.9	338.8
Means for 1974-2010 Średnie z lat 1974-2010	37.9	57.4	76.9	81.6	253.8
	Temperature – Temperatura, °C				Mean – Średnia
2009	11.2	13.0	16.2	19.9	15.1
2010	9.0	14.5	17.6	20.8	15.5
2011	9.9	14.2	18.2	18.8	15.3
Means for 1974-2010 Średnie z lat 1974-2010	7.8	13.5	16.3	18.2	14.0

In order to fully analyze weather conditions, Sielianinow's hydrothermal index (K) was calculated according to Radomski [1987]:

$$K = \frac{P}{0{,}1 \sum t}$$

where:
P – monthly rainfall total, mm,
$\sum t$ – the total of the daily mean air temperature for a particular month, °C.

Values of the Sielianinow's hydrothermal coefficient indicate that a significant water deficiency occurred in April 2009 (Table 2). Evaluation of the values of the hydrothermal coefficient also indicates that in July 2009 there occurred a deficiency in supplementation of plants with water, similarly as in April 2010 as well as in May 2011.

Table 2. Supplementation of plants with water expressed by Sielianinow's hydrothermal coefficient (K)
Tabela 2. Zabezpieczenie roślin w wodę wyrażone współczynnikiem hydrotermicznym Sielianinowa (K)

Year – Rok	Month – Miesiąc			
	April – kwiecień	May – maj	June – czerwiec	July – lipiec
2009	**0.30	2.15	3.72	*0.82
2010	*0.76	1.61	1.79	2.42
2011	1.03	*0.93	1.62	3.07
Means for 1974-2010 Średnie z lat 1974-2010	1.62	1.37	1.57	1.45

*K <1.0 – dry spell – posucha
**K <0.5 – drought – susza

RESULTS AND DISCUSSION

The highest ear density in wheat was observed on plots with plough tillage, significantly lower with conservation tillage, where the catch crops were disked in autumn, and the lowest in the variant with conservation tillage with spring disking of catch crops (Table 3). Similarly, Jaskulski [2000], Małecka and Blecharczyk [2002], Frant and Bujak [2007], Kraska [2011b], Gruber *et al.* [2012] as well as Małecka *et al.* [2012a], after incorporating reduced tillage, found a decrease in the ear density. Ear number per plot after stubble catch crops and after undersown red clover was significantly higher than on the control plots or with undersown Dutch ryegrass. In the subsequent years after sowing spring wheat after itself, it was found that ear number significantly decreased (Table 3).

Table 3. Number of ears per 1 m^2 of spring wheat canopy
Tabela 3. Liczba kłosów na 1 m^2 łanu pszenicy jarej

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	489.0	371.3	340.8	400.4
	red clover koniczyna czerwona	522.3	440.2	406.6	456.3
	dutch ryegrass życica westerwoldzka	450.0	418.0	330.1	399.4
	lacy phacelia facelia błękitna	556.5	443.5	406.8	468.9
	white mustard gorczyca biała	510.0	432.9	421.1	454.7
Year Rok	2009	669.6	558.4	517.4	581.8
	2010	480.3	425.2	399.4	435.0
	2011	366.8	280.0	226.4	291.0
Mean – Średnia		505.6	421.2	381.1	–

$LSD_{0.05}$ – $NIR_{0,05}$

tillage systems – systemy uprawy	31.04
catch crops – międzyplony	46.73
years – lata	31.04

*A – plough tillage – uprawa płużna, B – conservation tillage with autumn disking of catch crops – uprawa konserwująca z jesiennym talerzowaniem międzyplonów, C – conservation tillage with spring disking of catch crops – uprawa konserwująca z wiosennym talerzowaniem międzyplonów

The lowest number of grains per spring wheat ear was found on plots with conservation tillage, where catch crops were disked in autumn (Table 4). Significantly more grains per ear were developed in plants on plots after conservation tillage with spring incorporation of catch crops, while the most on plots with plough tillage. Similarly to the number of grains, the lowest grain weight was determined in ears collected from plots with conservation tillage where catch crops were disked in autumn, whereas significantly higher from plots with plough tillage as well as with conservation tillage and spring disking of catch crops (Table 5). In the research of Kraska [2011b] on the same soil, the number and weight of grains per ear of spring wheat cv. Zebra did not change under the effect of the applied tillage systems.

Table 4. Grain number in ear of spring wheat
Tabela 4. Liczba ziaren w kłosie pszenicy jarej

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	18.4	14.9	17.0	16.8
	red clover koniczyna czerwona	21.6	18.3	18.5	19.5
	Dutch ryegrass życica westerwoldzka	19.9	15.4	18.2	17.8
	lacy phacelia facelia błękitna	18.7	16.5	17.6	17.6
	white mustard gorczyca biała	19.4	17.2	19.2	18.6
Year Rok	2009	17.2	16.3	18.9	17.5
	2010	17.7	16.1	15.8	16.6
	2011	23.8	16.9	19.7	20.1
Mean – Średnia		19.6	16.4	18.1	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 1.25
catch crops – międzyplony 1.88
years – lata 1.25
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 2.86

* explanation in Table 3 – objaśnienia jak w tabeli 3

Table 5. Grain weight in ear of spring wheat, g
Tabela 5. Masa ziaren w kłosie pszenicy jarej, g

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	0.64	0.53	0.59	0.59
	red clover koniczyna czerwona	0.74	0.64	0.65	0.68
	Dutch ryegrass życica westerwoldzka	0.68	0.54	0.63	0.62
	lacy phacelia facelia błękitna	0.65	0.59	0.62	0.62
	white mustard gorczyca biała	0.67	0.62	0.68	0.66
Year Rok	2009	0.59	0.57	0.68	0.61
	2010	0.63	0.60	0.57	0.60
	2011	0.80	0.58	0.66	0.68
Mean – Średnia		0.67	0.58	0.64	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 0.048
catch crops – międzyplony 0.073
years – lata 0.048
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 0.157

* explanation in Table 3 – objaśnienia jak w tabeli 3

The number and weight of grains in ears collected from the control plots without catch crops was the lowest, however only with reference to the plot after undersown red clover this difference was statistically significant (Tables 4, 5). In other studies, Kraska [2011b] did not find an effect of catch crops on the change in the number and weight of grains per ear of spring wheat. The number and weight of grains per ear in 2011 was significantly higher than in the years 2009-2010. It probably resulted from the fact of lower ear density per area of unit in 2011, which in turn resulted in the formation of plumper grains per ear. In 2011, the number of grains per ear of spring wheat was significantly higher on plots with plough tillage than on the plot with conservation tillage. A similar dependence was determined in the same year for the grain weight per ear, but only with reference to conservation tillage with autumn disking of catch crops (Tables 4, 5).

1000 grain weight did not change significantly under the effect of the applied tillage systems or tested catch crops (Table 6). Kraska [2011b] obtained a significantly higher value of 1000 grain weight in the plough tillage system than in the conservation variant of tillage with autumn disking of catch crops. However, sowing catch crops did not change 1000 grain weight, similarly as in the mentioned studies. Also Wilczewski *et al.* [2007] did not find any effect of papilionaceous plants cultivated in stubble catch crops on the number of grains per ear, or 1000 grain weight of spring wheat cultivated after them. In 2010, 1000 grain weight was significantly higher than in the first and last year of research (Table 6).

Table 6. 1000 grain weight in spring wheat, g
Tabela 6. Masa 1000 ziaren pszenicy jarej, g

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy *A	B	C	Mean Średnia
Catch crops Międzyplon	control obiekt kontrolny	34.5	35.1	35.1	34.9
	red clover koniczyna czerwona	34.6	35.0	34.9	34.8
	Dutch ryegrass życica westerwoldzka	33.8	35.4	35.1	34.7
	lacy phacelia facelia błękitna	33.8	34.1	35.0	34.3
	white mustard gorczyca biała	34.7	35.7	34.6	35.0
Year Rok	2009	33.3	34.0	34.6	34.0
	2010	35.8	37.2	36.5	36.5
	2011	33.7	33.9	33.7	33.8
Mean – Średnia		34.3	35.0	34.9	–
$LSD_{0.05}$ – $NIR_{0,05}$					
years – lata		1.11			

* explanation in Table 3 – objaśnienia jak w tabeli 3

Grain yield obtained from plots with plough tillage was significantly higher than on plots with conservation tillage (Table 7). Thus, dependence obtained by Kraska [2011b] recurred in the first three years of observation, but with reference to a different spring wheat cultivar. Similarly, Małecka and Blecharczyk [2002], Frant and Bujak [2007] as well as Haliniarz *et al*. [2013], obtained a higher grain yield of cereals in the plough system, compared with no-tillage system. However, Cantero-Martinez *et al*. [2003] and Małecka and Blecharczyk [2008] state that under conditions of reduced tillage, there is a possibility of obtaining higher grain yields, compared with plough tillage, especially in the dry years. In the discussed experiment, decrease in the grain yield of spring wheat on the plot after conservation tillage mostly resulted from a lower ear density (Table 8). Therefore, spring wheat yields decreased in combination with autumn and spring disking of catch crops, compared with conventional tillage by 0.46 $Mg \cdot ha^{-1}$ and 0.66 $Mg \cdot ha^{-1}$, i.e. 14.0% and 20.2%, respectively. Grain number per ear had a significant contribution in differences in yields between the experimental plots. A lower value of this yield component in no-tillage system resulted in a decrease in the grain yield on average from 0.25 to 0.45 $Mg \cdot ha^{-1}$, i.e. 7.6-13.7%, compared with the plough tillage (Table 8).

Table 7. Grain yield in spring wheat in $Mg \cdot ha^{-1}$
Tabela 7. Plon ziarna pszenicy jarej w $Mg \cdot ha^{-1}$

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	2.99	1.96	1.96	2.31
	red clover koniczyna czerwona	3.79	2.82	2.72	3.11
	Dutch ryegrass życica westerwoldzka	2.93	2.10	2.08	2.37
	lacy phacelia facelia błękitna	3.41	2.58	2.51	2.83
	white mustard gorczyca biała	3.27	2.72	2.86	2.95
Year Rok	2009	3.94	3.13	3.51	3.53
	2010	2.97	2.55	2.28	2.60
	2011	2.93	1.61	1.48	2.01
Mean – Średnia		3.28	2.44	2.43	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 0.241
catch crops – międzyplony 0.362
years – lata 0.241
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 0.552

* explanation in Table 3 – objaśnienia jak w tabeli 3

On plots after catch crops, dependence in the grain yield was similar as with ear density. Grain yields obtained from plots with lacy phacelia, white mustard and red clover sown as catch crops, were significantly higher than on plots with Dutch ryegrass and on the control plot without catch crops (Table 7). Andrzejewska [1999], Jaskulski et al. [2000] and Kwiatkowski [2009] also indicated favorable effect of catch crops on cereal productivity. According to Parylak [1998], regenerating effectiveness of stubble catch crops, expressed with increase in the grain yield, compared with monoculture without catch crops, is visibly higher under conditions of reduced rainfall.

Table 8. Effect of yield components on yield differences in spring wheat cultivated in non--ploughing tillage systems in comparison with plough tillage
Tabela 8. Wkład elementów plonowania w różnice plonów pszenicy jarej uprawianej w systemach bezorkowych w porównaniu z uprawą konwencjonalną

Yield components Elementy plonowania	Tillage systems – Systemy uprawy		Mean – Średnia
	B*	C	
Contribution of yield components to differences in yields, $Mg \cdot ha^{-1}$ Wkład elementów plonowania w różnice plonów, $Mg \cdot ha^{-1}$			
Number of ears per 1 m^2 Obsada kłosów na 1 m^2	-0 .46	- 0.66	- 0.56
Number of grains per ear Liczba ziaren z kłosa	- 0.45	- 0.25	- 0.35
1000 grain weight Masa 1000 ziaren	0.07	0.06	0.06
Total – Suma	- 0.84	- 0.85	- 0.85
Contribution of yield components in relative differences in yields, % Wkład elementów plonowania w różnice względne plonów, %			
Number of ears per 1 m^2 Obsada kłosów na 1 m^2	- 14.0	- 20.2	- 17.1
Number of grains per ear Liczba ziaren z kłosa	- 13.7	- 7.6	- 10.6
1000 grain weight Masa 1000 ziaren	2.1	1.9	2.0
Total – Sum	- 25.6	- 25.9	- 25.7

* explanation in Table 3 – objaśnienia jak w tabeli 3

Compared with the control plots, the highest increase in the yield was obtained on the plot after undersown red clover (34.6%), and next with stubble catch crops of white mustard and lacy phacelia (increase by 27.7% and 22.5%, respectively). On the plot where Dutch ryegrass was undersown as catch crop, grain yield increased only by 2.6% (Table 9). Kwiatkowski [2009] obtained increase in the grain yield of spring barley with an undersown Dutch ryegrass by 3.8%, compared with the control plot without catch crops. In the experiment of Kuraszkiewicz [2004], undersown Dutch ryegrass after ploughing decreased the grain yield in spring barley by 0.22 $Mg \cdot ha^{-1}$, compared with the control plots.

Kraska [2011b], obtained a lower increase in the grain yield of spring wheat on plots with the same soil after catch crops, but a higher yield level of cv. Zebra. It might have resulted from a shorter effect of catch crops on the plot, as they are attributed with plot regenerating properties in cereal cultivation sown after itself. Whereas, the cause of obtaining a lower grain yield in the second three-year period of observation may have been cultivating spring wheat for the subsequent years on the plot after itself. Kuś and Jończyk [2000] as well as Kwiatkowski [2009] think that incorporating catch crops in crop rotation is not able to totally compensate for the yield decrease caused by cereal cultivation in monoculture. In the studies of Gawęda [2009], sowing stubble catch crops to a lesser degree affected the grain yield of spring wheat sown in monoculture. Only, its tendency to increase after catch crops was noted, compared with the control.

In the last year of studies, grain yield obtained on the plot after conservation tillage visibly decreased, compared with the plough tillage. At the same time, in 2009 a significantly higher grain yield was obtained from plots with plough tillage than from plots with conservation tillage where catch crops were disked in autumn, while in 2010 with reference to plots with conservation tillage and spring incorporation of catch crop biomass (Table 7).

Table 9. Effect of yield components on yield differences in spring wheat cultivated under conditions of sowing catch crops in comparison with cultivation without catch crops
Tabela 9. Wkład elementów plonowania w różnice plonów pszenicy jarej uprawianej w warunkach wysiewu międzyplonów w porównaniu z uprawą bez międzyplonów

Yield components Elementy plonowania	Red clover Koniczyna czerwona	Dutch ryegrass Życica westerwoldzka	Lacy phacelia Facelia błękitna	White mustard Gorczyca biała	Mean Średnia
Contribution of yield components to differences in yields, $Mg \cdot ha^{-1}$ Wkład elementów plonowania w różnice plonów, $Mg \cdot ha^{-1}$					
Number of ears per 1 m^2 Obsada kłosów na 1 m^2	0.37	0.00	0.41	0.37	0.29
Number of grains per ear Liczba ziaren z kłosa	0.44	0.08	0.10	0.28	0.22
1000 grain weight Masa 1000 ziaren	- 0.01	- 0.02	0.01	- 0.01	- 0.01
Total – Suma	0.80	0.06	0.52	0.64	0.50
Contribution of yield components in relative differences in yields, % Wkład elementów plonowania w różnice względne plonów, %					
Number of ears per 1 m^2 Obsada kłosów na 1 m^2	16.0	0.0	17.8	16.0	12.4
Number of grains per ear Liczba ziaren z kłosa	19.0	3.5	4.3	12.1	9.7
1000 grain weight Masa 1000 ziaren	- 0.4	- 0.9	0.4	- 0.4	- 0.3
Total – Suma	34.6	2.6	22.5	27.7	21.8

An analysis of the contribution of individual yield components into yield differences between experimental plots indicated that better spring wheat yields under conditions of cultivating stubble catch crops and undersown red clover, resulted to a large extent from an increase in the ear number per unit of area (Table 9). Increase in the ear density on plots with red clover, lacy phacelia and white mustard resulted in an increase in the grain yield of spring wheat on average from 0.37 to 0.41 $Mg \cdot ha^{-1}$, i.e. 16-17.8%, compared with the control. Moreover, grain number per ear determined an increase in the grain yield on plots with catch crops. Therefore, grain yield of spring wheat increased compared with the control on average from 0.08 to 0.44 $Mg \cdot ha^{-1}$, while contribution of this component was the highest when wheat was cultivated with undersown red clover (19.0%) (Table 9).

Tillage systems had no effect on the degree of infestation of spring wheat with a complex of fungal diseases. However, a tendency of higher values of the disease index was found on plots with conservation tillage where catch crops were disked in spring (Table 10). Kraska and Mielniczuk [2012] obtained a similar tendency with reference to a different cultivar of spring wheat. Reduced tillage used by Kiecana et al. [2002] under spring barley caused deterioration of this plant's health. Also, Pałys *et al*. [2004], Blecharczyk *et al*. [2006] and Małecka *et al*. [2009] obtained a higher value of the disease index in winter rye, winter wheat and winter triticale in no-tillage system, compared with the plough tillage. Weber *et al*. [2001] however, observed a lower index of spring wheat infestation and winter wheat infestation by pathogens damaging culm under no-tillage system, compared with the plough tillage.

Table 10. Values of disease indicators for spring wheat
Tabela 10. Wartości wskaźników chorobowych dla roślin pszenicy jarej

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	20.1	20.1	22.1	20.8
	red clover koniczyna czerwona	15.5	15.3	18.4	16.4
	Dutch ryegrass życica westerwoldzka	20.1	19.8	21.8	20.6
	lacy phacelia facelia błękitna	16.2	17.8	18.0	17.3
	white mustard gorczyca biała	15.6	14.2	16.0	15.3
Year Rok	2009	8.7	6.6	6.5	7.3
	2010	21.4	16.8	20.1	19.4
	2011	22.4	29.0	31.1	27.5
Mean – Średnia		17.5	17.5	19.2	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 2.41
catch crops – międzyplony 3.62
years – lata 2.41
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 5.52

* explanation in Table 3 – objaśnienia jak w tabeli 3

Disease index determined for spring wheat sown after undersown red clover and stubble catch crops of lacy phacelia and white mustard, was significantly lower than on plots without catch crops and after Dutch ryegrass (Table 10). Also, the results obtained by Parylak [2004], Majchrzak *et al*. [2004, 2005], Wojciechowski [2008] and Wojtala and Parylak [2009] were confirmed. While incorporating biomass of stubble catch crops into the soil, especially white mustard, they obtained improvement of health in spring wheat and winter wheat. Similarly, Kwiatkowski [2009], after incorporating catch crops into monoculture of spring barley, obtained a decrease in the infestation index in culm by fungi.

In the subsequent years of observation, value of the disease index increased significantly. The cause of such condition may have been cultivation of spring wheat in monoculture. In the first year of research, in all evaluated tillage systems, the disease index was lower than in the two subsequent years of observation. At the same time, the use of conservation tillage, significantly increased value of the index in every subsequent year of research (Table 10).

The applied tillage systems had no effect on the content of total protein and gluten in the grain of spring wheat cv. Tybalt. A similar dependence was obtained with reference to the sedimentation index. Kraska [2010] in other studies found a higher total protein content in the grain of spring wheat collected from plots with conservation tillage where catch crops were disked in spring, and from plots with plough tillage, than on the plot after conservation tillage with an autumn incorporation of catch crops. Woźniak [2009] however, found that significantly more protein was accumulated in spring wheat grain from the cultivation with plough tillage compared with the no-tillage system.

Spring wheat grain collected from plots with undersown Dutch ryegrass, was characterized by a significantly lower total protein content and sedimentation index than from plots where white mustard, lacy phacelia and red clover were used as catch crops. In the studies of Kwiatkowski [2009], under the effect of a catch crop of white mustard, a tendency was found of an increase in the total protein content in spring barley grain. Gluten content in the dry weight of spring wheat grain obtained from plots where white mustard and lacy phacelia were sown as catch crops, was higher than on plots after undersown Dutch ryegrass (Table 11).

Table 11. Some qualitative traits of spring wheat grain (mean 2009-2011)
Tabela 11. Wybrane cechy jakości ziarna pszenicy jarej (średnio 2009-2011)

Tillage systems Systemy uprawy	Qualitative traits – Cechy jakościowe		
	protein content białko ogólne %	gluten content zawartość glutenu %	sedimentation index wskaźnik sedymentacyjny ml
*A	13.5	28.3	44.3
B	13.6	28.5	45.2
C	13.6	28.5	44.9
$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	ns – ni
Catch crops – Międzyplony			
Control Obiekt kontrolny	13.5	28.4	44.3
Koniczyna czerwona Red clover	13.6	28.5	45.7
Życica westerwoldzka Dutch ryegrass	13.3	27.8	43.5
Facelia błękitna Lacy Phacelia	13.6	28.7	45.1
Gorczyca biała White mustard	13.6	28.7	45.4
$LSD_{0.05}$ – $NIR_{0,05}$	0.25	0.72	1.55

* explanation in Table 3 – objaśnienia jak w tabeli 3
ns – non-significant differences – ni – różnice nieistotne

CONCLUSIONS

1. Grain yield of spring wheat obtained from plots with plough tillage was significantly higher than on plots with conservation tillage. Decrease in the grain yield of spring wheat on plots with conservation tillage resulted to a high degree from a decreased ear density.
2. The lowest number and weight of grains per ear was obtained on plots with conservation tillage with autumn disking of catch crops. 1000 grain weight did not change under the effect of the applied tillage systems and sown catch crops.
3. Incorporation of stubble catch crops and undersown red clover as a factor improving properties of the plot in spring wheat monoculture, significantly increased the grain yield. Ear density determined an increase in the grain yield on plots with catch crops the most.

4. Tillage systems had no significant effect on the value of the index of spring wheat infestation with pathogens damaging culm and roots. Stubble catch crops of white mustard and lacy phacelia and an undersown catch crop of red clover significantly decreased value of the infestation index in the culm and roots of spring wheat, compared with the combination where the Dutch ryegrass was sown as a catch crop, and with control plots without catch crops.

5. The use of an undersown catch crop of Dutch ryegrass resulted in a deterioration of the quality parameters in spring wheat grain.

REFERENCES

Andrzejewska J., 1999. Międzyplony w zmianowaniach zbożowych [Intercrops in cereal crop rotations]. Post. Nauk Rol. 1, 19-31 [in Polish].

Blecharczyk A., Sierpowski J., Sawinska Z., 2006. Wpływ systemów uprawy roli na występowanie chorób w monokulturze pszenicy ozimej [Impact of tillage systems on diseases in continuous cropping of winter wheat]. Progr. Plant Prot./Post. Ochrony Rośl. 46(2), 677--680 [in Polish].

Bielińska E.J., Mocek-Płóciniak A., 2012. Impact of the tillage system on the soil enzymatic activity. Arch. Environ. Protect. 38(1), 75-82.

Biskupski A., Włodek S., Sekutowski T., Smagacz J., 2012. Effect of tillage systems and straw fertilization on the grain yield and selected indicators of cereals and physical properties of soil. Acta Sci. Pol., Agricultura 11(3), 17-29, www.agricultura.acta.utp.edu.pl

Cantero-Martinez C., Angas P., Lampurlanés J., 2003. Growth, yield and water productivity of barley (*Hordeum vulgare* L.) affected by tillage and N fertilization in Mediterranean semiarid, rainfed conditions of Spain. Field Crops Res. 84, 341-357.

Dzienia S., Zimny L., Weber R., 2006. Najnowsze kierunki w uprawie roli i technice siewu [The newest trends in soil tillage and techniques of sowing]. Fragm. Agron. 23(2), 227-241 [in Polish].

Frant M., Bujak K., 2007. Wpływ uproszczeń w uprawie roli i poziomów nawożenia mineralnego na plonowanie pszenicy jarej [The influence of reduced tillage and level of fertilization on yielding of spring wheat]. Fragm. Agron., 24(1), 49-57 [in Polish].

Gawęda D., 2009. Wpływ międzyplonów ścierniskowych na plonowanie pszenicy jarej uprawianej w monokulturze [Influence of stubble crops on the yielding of spring wheat grown in monoculture]. Zesz. Prob. Post. Nauk Rol. 542, 147-156[in Polish].

Gruber S., Möhring J., Claupein W., 2011. On the way towards conservation tillage-soil moisture and mineral nitrogen in a long-term field experiment in Germany. Soil Till. Res. 115/116, 80-87.

Gruber S., Pekrun C., Möhring J., Claupein W., 2012. Long-term yield and weed response to conservation and stubble tillage in SW Germany. Soil Till. Res. 121, 49-56.

Haliniarz M., Bujak K., Gawęda D., Kwiatkowski C., 2013. Response of spring wheat to reduced tillage systems and to different levels of mineral fertilization. Acta Sci. Pol., Agricultura 12(3), 13-24, www.agricultura.acta.utp.edu.pl

Holland J.M., 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agric. Ecosystems Environ. 103, 1-25.

Jaskulska I., Gałęzewski L., 2009. Aktualna rola międzyplonów w produkcji roślinnej i środowisku [Role of catch crops in plant production and in the environment]. Fragm. Agron. 26(3), 48-57 [in Polish].

Jaskulski D., 2000. Wpływ ilości i sposobów umieszczenia w glebie biomasy łubinu żółtego na wschody i początkowy wzrost pszenicy ozimej i jęczmienia jarego [Impact of the amount of yellow lupin biomass and method of its application on the emergence and initial growth of winter wheat and spring barley]. Zesz. Nauk. ATR Bydgoszcz, Rolnictwo 45, 39-46 [in Polish].

Jaskulski D., Jaskulska I., 2006. Bioróżnorodność agroekosystemów i krajobrazu rolniczego a polowa produkcja roślinna [Field crop production and the biodiversity of agricultural landscape and agroecosystems]. Post. Nauk Rol. 4, 43-57 [in Polish].

Jaskulski D., Tomalak S., Rudnicki F., 2000. Regeneracja stanowiska po pszenicy ozimej dla jęczmienia jarego przez rośliny międzyplonu ścierniskowego [Regeneration of the stand after winter wheat for spring barley with catch crop plants]. Zesz. Probl. Post. Nauk Rol. 470, 49-57 [in Polish].

Kiecana I., Pałys E., Mielniczuk E., Kraska P., 2002. Wpływ sposobu uprawy roli i poziomu nawożenia na zdrowotność siewek jęczmienia [The effect of tillage systems and fertilization levels on the health of barley seedlings]. Zesz. Nauk. AR im. H. Kołłątaja w Krakowie, Rolnictwo 82, 59-63 [in Polish].

Kraska P., 2010. Jakość ziarna pszenicy jarej uprawianej w monokulturze w zależności od konserwujących wariantów uprawy roli oraz międzyplonów [Grain quality of spring wheat cultivated in monoculture depending on the conservation tillage variants and catch crops]. Biul. IHAR 256, 55-71 [in Polish].

Kraska P., 2011a. Effect of conservation tillage and catch crops on some chemical properties of rendzina soil. Acta Sci. Pol., Agricultura, 10(3), 77-92.

Kraska P., 2011b. Konserwująca uprawa roli oraz międzyplony jako czynniki kształtujące plon ziarna pszenicy jarej odmiany Zebra uprawianej w monokulturze [Conservation tillage and catch crops as factors creating the grain yield of spring wheat cv. Zebra cultivated in monoculture]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 66(1), 8-23 [in Polish].

Kraska P., Mielniczuk E., 2012. The occurrence of fungi on the stem base and roots of spring wheat (*Triticum aestivum* L.) grown in monoculture depending on tillage systems and catch crops. Acta Agrobot. 65(1), 79-90.

Kraska P., Pałys E., 2002. Wpływ sposobów uprawy roli, poziomów nawożenia i ochrony roślin na niektóre elementy plonowania żyta ozimego w płodozmianie na glebie lekkiej [The influence of soil tillage systems, fertilization and plant protection levels on some yielding constituents of winter rye growing in crop rotation on light soil]. Pam. Puł. 130/I, 393-402 [in Polish].

Kraska P., Pałys E., 2004. Wpływ systemów uprawy roli, poziomów nawożenia i ochrony roślin na plonowanie jęczmienia jarego [The influence of tillage systems, fertilization and plant protection levels on the yielding of spring barley]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(1), 197-204 [in Polish].

Kuraszkiewicz R., 2004. Następczy wpływ wsiewek międzyplonowych na plonowanie jęczmienia jarego na glebie lekkiej [The residual effect of undersown crops on the yielding of spring barley on light soil]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(4), 1815--1821 [in Polish].

Kuś J., Jończyk K., 2000. Regenerująca rola międzyplonów w zbożowych członach zmianowania [Regenerative potential of intercrops in cereal sequences of the crop rotation]. Zesz. Prob. Post. Nauk Rol. 470, 59-65 [in Polish].

Kwiatkowski C., 2009. Studia nad plonowaniem jęczmienia jarego nagoziarnistego i oplewionego w płodozmianie i monokulturze. [Studies on the yielding of naked and husked spring barley in crop rotation and monoculture]. UP Lublin, Rozpr. Nauk. 336, 5-117 [in Polish].

Kwiatkowski C.A., 2012. Rola międzyplonów we współczesnym rolnictwie [The role of cover crops in modern agriculture]. Studia i Raporty IUNG-PIB 28(2), 79-95 [in Polish].

Lal R., Reicosky D.C., Hanson J.D., 2007. Evolution of the plow over 10,000 years and the rationale for no-till farming. Soil Till. Res. 93, 1-12.

Leys A., Govers G., Gillijns K., Berckmoes E., Takken I., 2010. Scale effects on runoff and erosion losses from arable land under conservation and conventional tillage: The role of residue cover. J. Hydrol. 390, 143-154.

Łacicowa B., 1969. Metoda laboratoryjna szybkiej oceny odporności jęczmienia na *Helminthosporium sativum* P.K.Et B. [A laboratory method for rapid determination of barley resistance to *Helminthosporium sativum* P.K.Et B.] Biul. IHAR 3-4, 61-62 [in Polish].

Łacicowa B., Kiecana I., Pięta D., 1990. Choroby podsuszkowe jęczmienia jarego (*Hordeum sativum* L.) uprawianego w lubelskiem [The incidence of common root and stem rot diseases of spring barley (*Hordeum sativum* L.) in Lublin region]. Rocz. Nauk Rol., Seria E, Ochrona Roślin 20(1/2), 7-15 [in Polish].

Majchrzak B., Chodorowski B., Okorski A., 2005. Choroby podstawy źdźbła pszenicy ozimej uprawianej po roślinach przedplonowych z rodziny *Brassicaceae* [Stem base diseases of winter wheat grown after forecrops of the family *Brassicaceae*]. Acta Agrobot. 58(2), 307-318 [in Polish].

Majchrzak B., Okorski A., Chodorowski B., 2004. Zdrowotność korzeni i podstawy źdźbła pszenicy jarej uprawianej po różnych przedplonach [Sanitary state of roots and culm base of spring wheat cultivated after varied predecessors]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(4),1779-1788 [in Polish].

Małecka I., Blecharczyk A., 2002. Wpływ systemów uprawy roli na plonowanie zbóż i właściwości gleby [Effect of tillage systems on cereal yield and soil properties]. PTPN, Pr. Kom. Nauk Rol. Kom. Nauk Leśn. 93, 79-87 [in Polish].

Małecka I., Blecharczyk A., 2008. Effect of tillage systems, mulches and nitrogen fertilization on spring barley (*Hordeum vulgare*). Agron. Res. 6(2), 517-529.

Małecka I., Blecharczyk A., Sawinska Z., Dobrzeniecki T., 2009. Porażenie pszenżyta ozimego przez grzyby chorobotwórcze w zależności od systemu uprawy roli [Effect of tillage systems on health status of winter triticale]. Progr. Plant Prot./Post. Ochrony Rośl. 49(4), 1758-1761 [in Polish].

Małecka I., Blecharczyk A., Sawinska Z., Piechota T., Waniorek B., 2012a. Plonowanie zbóż w zależności od sposobów uprawy roli [Cereals yield response to tillage methods]. Fragm. Agron. 29(1), 114-123 [in Polish].

Małecka I., Swędrzyńska D., Blecharczyk A., Dytman-Hagedorn M., 2012b. Wpływ systemów uprawy roli pod groch na właściwości fizyczne, chemiczne i biologiczne gleby [Impact of tillage systems for pea production on physical, chemical and microbiological soil properties]. Fragm. Agron. 29(4), 106-116 [in Polish].

Pałys E., Kiecana I., Kraska P., Mielniczuk E., Cegiełko M., 2004. Wpływ systemów uprawy roli oraz poziomów nawożenia i ochrony żyta ozimego na porażenie podstawy źdźbła przez grzyby chorobotwórcze [The influence of tillage systems and fertilization and plant protection levels on winter rye stem base infection by pathogens]. Progr. Plant Prot./Post. Ochrony Rośl. 44(2), 1001-1003 [in Polish] .

Pałys E., Kuraszkiewicz R., Kraska P., 2009. Następczy wpływ wsiewek międzyplonowych i roślin ochronnych na chemiczne właściwości gleby lekkiej [The residual effect of undersown crops and nurse crops on chemical properties of light soil]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 64(4), 81-92 [in Polish].

Parylak D., 1998. Międzyplony ścierniskowe jako czynnik regeneracyjny w monokulturze pszenżyta ozimego uprawianego na glebie lekkiej [Stubble catch crops as regenerative factor in winter triticale monoculture grown on light soil]. Zesz. Prob. Post. Nauk Rol. 460, 709-718 [in Polish].

Parylak D., 2004. Possibilities of root and stem base diseases limitation in continuous wheat under conventional tillage and no-tillage system. J. Plant Prot. Res. 44, 2, 141-146.

Polskie Towarzystwo Gleboznawcze, 2009. Klasyfikacja uziarnienia gleb i utworów mineralnych – PTG 2008 [Particle size distribution and textural classes of soils and mineral materials – classification of Polish Society of Soil Science 2008]. Rocz. Gleb. 60, 2, 5-16 [in Polish].

Radomski Cz., 1987. Agrometeorologia [Agrometeorology]. PWN Warszawa [in Polish].

Rudnicki F., 2000. Wyznaczanie wpływu poszczególnych elementów plonowania na różnice plonów między obiektami doświadczalnymi [Estimation of individual yielding constituents effects on yield difference between experimental treatments]. Fragm. Agron. 17(3), 53-65 [in Polish].

Smagacz J., 2006. Ocena produkcyjno-ekonomiczna różnych systemów uprawy roli. [Productive and economic evaluation of different soil tillage systems]. Prob. Inż. Rol. 1, 55-62 [in Polish].

Tebrügge F., 2001. No-tillage visions – protection of soil, water and climate and influence on management and farm income. [In:] Conservation Agriculture, A WorldWide Challenge. Proc. of the First World Congress on Conservation Agriculture of FAO-ECAF, Madrid, Spain, 1, 303-316.

Van de Putte A., Govers G., Diels J., Langhans Ch., Clymans W., Vanuytrecht E., Merckx R., Raes D., 2012. Soil functioning and conservation tillage in the Belgian Loam Belt. Soil Till. Res. 122(1), 1-11.

Weber R., 2002. Wpływ uprawy zachowawczej na ochronę środowiska [The influence of conservation tillage on environment protection]. Post. Nauk Rol. 1, 57-67 [in Polish].

Weber R., 2010. Wpływ okresu stosowania systemów bezpłużnych na właściwości gleby [Soil properties as affected by duration of using no-tillage systems]. Post. Nauk Rol. 1, 63-75 [in Polish].

Weber R., 2012. Uprawa bezpłużna zbóż po przedplonach zbożowych. [No-tillage cereal cultivation after cereal forecrops] Studia i Raporty IUNG-PIB 28(2), 125-139 [in Polish].

Weber R., Hryńczuk B., Runowska-Hryńczuk B., Kita W., 2001. Influence of the mode of tillage on diseases of culm base in some winter wheat varieties, oats and spring wheat. J. Phytopathology 149, 185-188.

Wesołowski M., Kiecana I., Stępień A., Mielniczuk E., 2004. Porażenie przez choroby jęczmienia jarego uprawianego w monokulturze jako mieszaniny odmian [Disease infestation of spring barley cultivated in monoculture as a mixture of cultivars]. Progr. Plant Prot./Post. Ochrony Rośl. 44(2), 1205-1207 [in Polish].

Wesołowski M., Kwiatkowski C., 2000. Plonowanie i zachwaszczenie mieszanek międzyodmianowych jęczmienia jarego w kilkuletniej monokulturze [Yielding and weed infestation of inter-variety mixtures of spring barley in many year monoculture]. Rocz. AR w Poznaniu, Rolnictwo 58, 135-144 [in Polish].

Wilczewski E., Skinder Z., Lemańczyk G., 2007. Wartość wybranych roślin motylkowatych uprawianych w międzyplonie ścierniskowym na glebie lekkiej. Cz. III. Wpływ następczy dla pszenicy jarej. [Value of selected papilionaceous crops grown in stubble intercrop on light soil. Part III. After-effect for spring wheat]. Acta Sci. Pol., Agricultura 6(1), 45-56, www.agricultura.acta.utp.edu.pl [in Polish].

Wojciechowski W., 2008. Następczy wpływ międzyplonów ścierniskowych na zdrowotność pszenicy uprawianej w krótkotrwałej monokulturze [Aftercrop effect of stubble intercrops on health status of wheat growing in short-term monoculture]. Progr. Plant Prot./Post. Ochrony Rośl. 48(1), 381-384 [in Polish].

Wojtala L., Parylak D., 2009. Skuteczność zapraw nasiennych, międzyplonu i poziomu nawożenia azotowego w ograniczaniu porażenia pszenicy ozimej przez patogeny podstawy źdźbła [Effectiveness of seed treatment, stubble crop and level of nitrogen fertilization in reducing winter wheat infection with root and stem base pathogens]. Progr. Plant Prot./Post. Ochrony Rośl. 49(2), 769-772 [in Polish].

Woźniak A., 2000. Plonowanie pszenicy jarej i pszenżyta jarego w płodozmianie i monokulturze [Yielding of spring wheat and spring triticale in crop rotation and in monoculture]. Biul. IHAR 215, 81-90 [in Polish].

Woźniak A., 2009. Jakość ziarna pszenicy jarej odmiany Koksa w różnych systemach uprawy roli [Grain quality of spring wheat cv. Koksa in different tillage systems]. Acta Agroph. 14(1), 233-241 [in Polish].

Woźniak A., Haliniarz M., 2012. The after-effect of long-term reduced tillage systems on the biodiversity of weeds in spring crops. Acta Agrob. 65(1), 141-148.

Zając T., Oleksy A., Klimek A., Pluta A., Kołodziejczyk M., 2010. Yield of winter wheat as a cover crop, undersowns and stubble crops with regard to nitrogen accumulation. Acta Sci. Pol., Agricultura 9(3), 83-96, www.agricultura.acta.utp.edu.pl

Zimny L., 1999. Uprawa konserwująca [Conservation tillage]. Post. Nauk Rol. 5, 41-52 [in Polish].

WPŁYW SYSTEMÓW UPRAWY ROLI ORAZ MIĘDZYPLONÓW NA PLON I JAKOŚĆ ZIARNA ORAZ ZDROWOTNOŚĆ PSZENICY JAREJ

Streszczenie. Celem badań było porównanie wpływu uprawy płużnej oraz konserwującej z wykorzystaniem różnych międzyplonów na plon i jakość ziarna oraz zdrowotność roślin pszenicy jarej wysiewanej w monokulturze na glebie rędzinowej. Schemat doświadczenia założonego na glebie rędzinowej metodą split-plot w czterech powtórzeniach uwzględniał uprawę płużną (A) oraz uprawę konserwującą prowadzoną dwoma sposobami: z jesiennym talerzowaniem międzyplonów (B) oraz z wiosennym ich talerzowaniem (C). Jednocześnie zastosowano cztery sposoby regeneracji stanowiska w monokulturze pszenicy jarej w postaci wsiewek międzyplonowych koniczyny czerwonej i życicy westerwoldzkiej oraz międzyplonów ścierniskowych facelii błękitnej i gorczycy białej. Obiekt kontrolny stanowiły poletka bez międzyplonów. Płużna uprawa roli sprzyjała uzyskaniu większej obsady kłosów, liczby ziaren w kłosie, co w konsekwencji przełożyło się na zwiększenie plonu ziarna pszenicy jarej w porównaniu z uprawą konserwującą. Obniżenie plonu ziarna pszenicy jarej w obiektach uprawy konserwującej wynikało w największym stopniu ze zmniejszonej obsady kłosów. Liczba kłosów oraz plon ziarna uzyskany z poletek gdzie wysiewano międzyplony ścierniskowe oraz wsiewkę śródplonową z koniczyny czerwonej były istotnie większe niż w stanowisku po wsiewce z życicy westerwoldzkiej i poletkach kontrolnych. Lepsze plonowanie pszenicy jarej w stanowisku po międzyplonach ścierniskowych i wsiewce międzyplonowej z koniczyny czerwonej wynikało w dużym stopniu ze zwiększonej liczby kłosów na jednostce powierzchni. Systemy uprawy roli oraz międzyplony nie zmieniały istotnie masy 1000 ziaren pszenicy jarej. Stopień porażenia podstawy źdźbła i korzeni pszenicy jarej przez kompleks chorób grzybowych nie był różnicowany przez oceniane systemy uprawy roli. Wskaźnik chorobowy określony dla pszenicy jarej w stanowiskach po wsiewce międzyplonowej koniczyny czerwonej oraz międzyplonach ścierniskowych z facelii błękitnej i gorczycy białej był istotnie mniejszy niż po wsiewce z życicy westerwoldzkiej i kontroli bez międzyplonów. Zawartość białka ogólnego i glutenu w ziarnie pszenicy jarej oraz wskaźnik sedymentacji nie zmieniały się pod wpływem zastosowanych systemów uprawy roli. Zastosowanie życicy westerwoldzkiej jako wsiewki międzyplonowej pogarszało jakość ziarna pszenicy jarej.

Słowa kluczowe: uprawa konserwująca, uprawa płużna, monokultura, międzyplon, wskaźnik chorobowy, pszenica jara

Accepted for print – Zaakceptowano do druku: 18.03.2014

For citation – Do cytowania:

Kraska P., Andruszczak S., Kwiecińska-Poppe E., Pałys E., 2013. The effect of tillage systems and catch crops on the yield, grain quality and health of spring wheat. Acta Sci. Pol., Agricultura 13(1), 21-38 .