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PREVIOUS CROP VALUE OF POST-HARVEST RESIDUES AND STRAW OF SPRING WHEAT, FIELD PEA AND THEIR MIXTURES FOR WINTER TRITICALE PART I. WEIGHT AND CHEMICAL COMPOSITION OF POST-HARVEST RESIDUES AND STRAW

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Abstract. An experiment was carried out in the years 2004-2007 to examine the value of post-harvest residues (including straw) of spring wheat, field pea, and spring wheat-field pea mixtures preceding winter triticale cultivation. The following parameters were determined at the first stage of the study, conducted in 2004-2006: previous crop post-harvest residues and straw weight, winter triticale grain yield and total nitrogen content in the grain. Field pea provided least residues and straw. By contrast, the spring wheat-field pea mixture with the 75 + 25% proportion of the respective components as well as spring wheat produced most straw. The post-harvest residues and straw of spring wheat-field pea mixtures contained an intermediate amount of macroelements compared with their components cultivated in pure stand. Spring wheat straw accumulated less macroelements, in particular nitrogen, calcium and magnesium, compared with the straw of both field pea and spring wheat-field pea mixtures.

Key words: accumulation of macroelements, content of macroelements, forecrop, legume-cereal mixture, yield of post-harvest residues

INTRODUCTION

A growing proportion of cereals in the cropping system in Poland causes the need for their cultivation in monocrops, in cereal crop rotations with a shortened rotation or in monoculture. The most visible consequence of an excessive concentration of cereals in crop rotation is a decrease in yield of cultivated plants. Basic factors affecting worse yield of cereals in simplified crop rotations are: an increase in weed infestation, higher infestation of crops by culm base diseases, as well as soil sickness [Sadowski and Krześlak 1997, Smagacz 1998, Wanic et al. 2000, Parylak et al. 2006]. One of the ways of smoothing the negative results of the excessive concentration of cereals in crop

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rotation is plant cultivation in mixed stands [Rudnicki and Kotwica 1994, Wanic et al. 1999, Rudnicki and Wasilewski 2000, Wanic et al. 2000, Kotwica 2006]. Mixtures, both intervarietal and interspecific, introduce a substitute of the so-called biodiversity, which breaks the continuity of cereals, thus preventing from biological disturbances in the environment [Wanic et al. 1999, 2000, Wanic and Nowicki 2000].

Large-area no-livestock farms applying cereal crop rotations produce large surpluses of straw. To prevent soil degradation, it is necessary to use some amount of it as a fertilizer [Spiak et al. 2000, Smagacz 2005]. Straw is expected in the first place to have a favorable effect on soil properties, and indirectly, on the growth and yield of plants [Kuduk 1979, 1981, Christensen 1986, Gorzelny 1986, Siuta 1999].

The aim of this study was to estimate the weight of post-harvest residues and straw of the previous crops of winter triticale: spring wheat, field pea and spring wheat-field pea mixtures, and the content and accumulation of macroelements in the biomass of previous crops.

MATERIAL AND METHODS

A field study was carried out at the Agricultural Experimental Station at Zawady (52°06' N; 22°50' E), owned by the University of Natural Sciences and Humanities in Siedlce, in soil formed from heavy loamy sand, classified as the very good rye complex, quality class IVa. The soil was characterized by a moderate abundance in available phosphorus, potassium and magnesium, and neutral pH. In 2004-2006 spring wheat-field pea mixtures for seeds were cultivated, and in 2005-2007, winter triticale was grown in the stand after those mixtures. To estimate the previous crop value of the mixtures, a one-factorial field experiment was established in the randomized complete block design, in three replications. The area of the plot for harvesting was 56 m^2. The experimental factor was the proportion (in % of pure species sowing) of spring wheat (100, 75, 50, 25, 0) and field pea (0, 25, 50, 75, 100) in the mixture. In pure sowing, spring wheat of the cultivar Pasteur was sown at a density of 400 seeds per 1 m^2, and field pea of the cultivar Sokolik (afila type) at a density of 110 seeds per 1 m^2. Each year seeds were sown from 1^{st} to 10^{th} April. Phosphorus and potassium fertilizers were applied in autumn at rates of 19.6 kg $P \cdot ha^{-1}$ and 58.1 kg $K \cdot ha^{-1}$. Nitrogen fertilizers were applied in spring before seed sowing at a rate of 30 $kg \cdot ha^{-1}$ on all the treatments. Additionally, at the stage of shooting of spring wheat, 50 kg $N \cdot ha^{-1}$ was applied under spring wheat in pure sowing and 30 kg $N \cdot ha^{-1}$ under spring wheat-field pea mixture with a proportion of the components 75 + 25%. Weeds were controlled mechanically. Plant harvesting was performed at a single stage in full maturity. The following features of mixtures and pure sowings were estimated in the study: straw yield, the weight of post-harvest residues (stubble, bedding, roots), the content of macroelements (N, P, K, Ca, Mg) in dry weight of post-harvest residues and straw. Samples of post-harvest residues were collected with the hollow method [Batalin 1962] from an area of 0.25 m^2 and a depth of 0.30 m. The total nitrogen content was determined with the Kjeldahl method, phosphorus content – with vanadium-molybdenum method, potassium and calcium content – with flame photometry and magnesium content – with atomic absorption. The amount of macroelements accumulated in post-harvest residues, straw, and in residues together with straw was calculated. Each year of the study the plant number of spring wheat and field pea per 1 m^2 after emergence was similar to the theoretical assumptions.

Plant losses of field pea in the period from emergence until harvesting in pure sowing did not exceed 15%, and in mixtures with spring wheat they ranged from 8 to 42%, according to the years and the proportions of components.

The detailed methods of the experiment with winter triticale is submitted in the second part of this study [Buraczyńska and Ceglarek 2011].

The experimental data obtained from both experiments was worked out statistically using the analysis of variance method. The significance of differences between the averages was verified with Tukey's test for P = 0.05. The data was calculated with the use of the program SAS.

The air temperature and precipitation in the years of the study were varied (Table 1). In the years 2004, 2005 and 2006 the air temperature was lower than the long-term average by 0.5; 0.4 and 0.2°C, respectively and in 2007, it was higher by 0.5°C. Total precipitation in 2004, 2006 and 2007 exceeded the long-term average by 21.5; 19.4 and 98.0 mm, respectively. The year 2006, however, was characterized by unfavorable distribution of precipitation. In August, precipitation was considerably higher than the long-term average (by 184.1 mm), whereas it was lower in the other months. In 2005, a total precipitation recorded was lower by 55.4 mm than in the long-term period, and the highest precipitation shortage occurred in April, September and October. The season 2006 was particularly unfavorable both for previous crops and for winter triticale, due to the precipitation shortage during their growth and the air temperature in July higher by 2.6°C.

RESULTS

The weight of the post-harvest residues and straw of field pea, spring wheat and spring wheat-field pea mixtures was significantly diversified by the weather conditions and the proportion of components in the mixture (Table 2). The plants lest significantly the largest weight of post-harvest residues and straw in 2004, which was characterized by a higher total precipitation than the long-term average and a lower air temperature in the spring--summer period. In 2006, with low precipitation in the growing season, except for August, plants generated significantly the smallest weight of post-harvest residues and straw. The difference in the weight of post-harvest residues between these extreme years was on average 0.55 $t \cdot ha^{-1}$, and in straw yield 1.54 $t \cdot ha^{-1}$. In the present experiments, spring wheat left the most post-harvest residues and spring wheat and spring wheat-field pea mixture with the proportion of components 75 + 25% – the most straw and post-harvest residues together with straw. A decrease in the proportion of spring wheat in the mixture with field pea from 75 to 50% and from 50 to 25% significantly affected a fall in weight of post-harvest residues (by 0.53 and 0.59 $t \cdot ha^{-1}$, respectively) and straw (by 0.21 and 0.18 $t \cdot ha^{-1}$, respectively). The straw yield of spring wheat-field pea mixtures with the proportion of components 75 + 25% and 50 + 50% did not differ statistically from the straw yield of spring wheat. Field pea generated the significantly smaller weight of post-harvest residues and straw. The post-harvest residue weight of field pea was smaller by 2.09 $t \cdot ha^{-1}$ than the weight of spring wheat residues and, respectively, by 1.82; 1.29; 0.70 $t \cdot ha^{-1}$ than the weight of the residues of spring wheat-field pea mixtures (75 + 25%, 50 + 50%, 25 + 75%). The differences in straw yield were, respectively: 0.46 and 0.57; 0.36; 0.18 $t \cdot ha^{-1}$. The proportion of post-harvest residues in the total dry weight yield (post-harvest residues + straw) of spring wheat accounted for 43.9%, that of field pea – 23.8%, and that of spring wheat-field pea mixtures was within the range 32.4-41.2%.

Table 1. Mean air temperature and total rainfall according to the Zawady Meteorological Station
Tabela 1. Średnia temperatura powietrza i suma opadów według notowań Stacji Meteorologicznej w Zawadach

Year Rok	Month – Miesiąc												
	January Styczeń	February Luty	March Marzec	April Kwiecień	May Maj	June Czerwiec	July Lipiec	August Sierpień	September Wrzesień	October Październik	November Listopad	December Grudzień	Mean Średnia
	Temperature – Temperatura, °C												
2004	-5.6	-1.0	2.7	8.0	11.6	15.4	17.5	18.9	13.0	9.4	3.2	1.3	7.9
2005	0.4	-4.0	-0.7	8.7	13.0	15.9	20.2	17.5	15.0	8.5	2.7	-0.9	8.0
2006	-7.7	-4.7	-1.7	8.4	13.6	17.2	22.3	18.0	15.4	9.9	5.0	3.1	8.2
2007	2.7	-2.4	6.3	8.6	14.6	18.2	18.9	18.9	13.1	7.8	0.9	-0.3	8.9
Mean for Średnia z lat 1990-2005	-1.7	-0.9	2.7	8.2	14.2	17.6	19.7	19.1	12.9	8.0	2.6	-2.1	8.4
	Rainfall – Opady, mm												Sum Suma
2004	11.5	21.0	19.6	35.9	97.0	52.8	49.0	66.7	19.5	29.5	20.4	7.6	430.5
2005	13.2	13.2	11.7	12.3	64.7	44.1	86.5	45.4	15.8	0	13.8	32.9	353.6
2006	0.6	8.1	6.7	29.8	39.6	24.0	16.2	227.6	20.9	22.0	22.3	10.6	428.4
2007	86.4	31.8	23.6	21.2	59.1	59.0	70.2	31.1	67.6	16.3	28.3	12.4	507.0
Mean for Średnia z lat 1990-2005	15.7	14.0	20.4	37.4	47.1	48.1	65.5	43.5	47.3	29.0	23.4	17.6	409.0

Table 2. Post-harvest residue dry matter yield and straw yield of spring wheat, field pea and spring wheat/field pea mixtures, $t \cdot ha^{-1}$
Tabela 2. Plon suchej masy resztek pożniwnych i słomy pszenicy jarej, grochu siewnego oraz mieszanek pszenicy jarej z grochem siewnym, $t \cdot ha^{-1}$

Proportion of components in the mixture Udział komponentów w mieszance, %		Residues – Resztki				Straw – Słoma				Residues + straw – Resztki + słoma			
		Year – Rok											
spring wheat pszenica jara	field pea groch siewny	2004	2005	2006	mean średnia	2004	2005	2006	mean średnia	2004	2005	2006	mean średnia
100	0	3.63	3.20	2.86	3.23	4.84	4.11	3.42	4.12	8.47	7.31	6.28	7.35
75	25	3.28	2.96	2.65	2.96	5.01	4.20	3.48	4.23	8.29	7.16	6.13	7.19
50	50	2.72	2.45	2.11	2.43	4.83	4.04	3.19	4.02	7.55	6.49	5.30	6.45
25	75	2.05	1.86	1.61	1.84	4.59	3.87	3.06	3.84	6.64	5.73	4.67	5.68
0	100	1.30	1.11	1.02	1.14	4.42	3.75	2.81	3.66	5.72	4.86	3.83	4.80
Mean – Średnia		2.60	2.32	2.05	2.32	4.73	3.99	3.19	3.97	7.33	6.31	5.24	6.29
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:													
years – lat					0.08				0.10				0.11
proportion of components – udziału komponentów					0.14				0.17				0.23
interaction – interakcji:													
years × proportion of components lata × udział komponentów					0.26				ns – ni				ns – ni

ns – ni – non-significant differences – różnica nieistotna

The content of total nitrogen, phosphorus and potassium in the post-harvest residues and straw of spring wheat, field pea and spring wheat-field pea mixtures was significantly modified by the weather conditions and the proportion of components in the mixture (Table 3). The content of calcium and magnesium in post-harvest residues and straw, in turn, was significantly affected only by the proportion of components in the mixture. In 2006, with the lowest total precipitation and the highest average air temperature from April to July in the year of the study, significantly the largest content of total nitrogen, phosphorus and potassium was observed in post-harvest residues, and of phosphorus and potassium in straw. The total nitrogen content in straw in 2005 and 2006 did not differ significantly. In 2004, when the monthly total precipitation in April, May and June was higher and the air temperature lower than in the other years of the study, significantly the smallest content of total nitrogen, phosphorus and potassium was recorded in post-harvest residues and straw. The post-harvest residues of field pea were characterized by significantly the highest content of total nitrogen, phosphorus, potassium, calcium and magnesium. Also in the straw of field pea the highest content of macroelements was found, except for phosphorus, whose content was at a similar level to the straw of the spring wheat-field pea mixture with the proportion of components 25 + 75%. The total nitrogen content in post-harvest residues and straw of field pea was 2,7 and 1.7 times higher, respectively, then in the residues and straw of spring wheat, and the content of calcium was, respectively, 5.3 and 4.8 times higher. The post-harvest residues and straw of the spring wheat an field pea mixtures (75 + 25%, 50 + 50%, 25 + 75%), in most cases were characterized by an average content of macroelements in comparison with their components sown in pure sowing. Decreasing the proportion of spring wheat and increasing the proportion of field pea in the mixture resulted in a growth in the content of macroelements in post-harvest residues and straw. The differences, however, were not always significant, especially in the content of phosphorus and potassium. The content of phosphorus in the post-harvest residues of spring wheat-field pea mixtures with the proportion of components 75 + 25% and 50 + 50% and of potassium and magnesium in the post-harvest residues of spring wheat-field pea mixture with the proportion of components 75 + 25% did not differ significantly from the content of those elements in the post-harvest residues of spring wheat. Also phosphorus and potassium content in the straw of the spring wheat-field pea mixture with the proportion of components 75 + 25% was similar to the content of those elements in the straw of spring wheat. An effect of the proportion of components in the mixture on the total nitrogen content in straw and and potassium content in post-harvest residues and straw depended on the weather conditions.

The amount of macroelements in the post-harvest residues, straw (Table 4) and post--harvest residues together with straw (Table 5) of spring wheat, field pea and spring wheat-field pea mixtures was determined by the weather conditions and the proportion of components in the mixture. In 2004, the amount of total nitrogen and calcium in post-harvest residues and straw and of phosphorus, potassium and magnesium in straw was significantly the largest. Significantly the smallest amount of macroelements in post--harvest residues, straw and post-harvest residues with straw was found in 2006, when plants left the smallest weight of post-harvest residues and straw. Only the amount of phosphorus in post-harvest residues in 2006 did not differed significantly from the amount of this element in post-harvest residues in 2005.

Table 3. Macroelement content (N, P, K, Ca, Mg) in post-harvest residues and straw of spring wheat, field pea and spring wheat/field pea mixtures, $g \cdot kg^{-1}$ DM
Tabela 3. Zawartość makroskładników (N, P, K, Ca, Mg) w resztkach pożniwnych i słomie pszenicy jarej, grochu siewnego oraz mieszanek pszenicy jarej z grochem siewnym, $g \cdot kg^{-1}$ s.m.

Proportion of components in the mixture – Udział komponentów w mieszance %		Macroelement – Makroskładnik																			
spring wheat pszenica jara	field pea groch siewny	N				P				K				Ca				Mg			
		2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Residues – Resztki																					
100	0	6.31	7.09	7.42	6.94	1.10	1.18	1.27	1.18	5.57	6.21	6.79	6.19	2.11	2.19	2.22	2.17	0.89	1.02	1.10	1.00
75	25	7.76	8.36	8.23	8.12	1.13	1.22	1.33	1.23	5.79	6.46	6.92	6.39	3.24	3.21	2.82	3.09	1.03	1.08	1.15	1.09
50	50	9.61	10.13	10.11	9.95	1.21	1.29	1.38	1.29	6.13	6.64	7.18	6.65	4.56	4.59	4.22	4.46	1.14	1.23	1.27	1.21
25	75	12.53	12.67	13.13	12.78	1.29	1.34	1.48	1.37	6.64	7.02	7.59	7.08	7.06	6.83	6.48	6.79	1.34	1.42	1.45	1.40
0	100	17.92	18.48	20.41	18.94	1.38	1.53	1.69	1.53	7.39	7.78	8.62	7.93	11.20	11.68	11.92	11.60	1.69	1.90	1.92	1.84
Mean – Średnia		10.83	11.35	11.86	11.35	1.22	1.31	1.43	1.32	6.30	6.82	7.42	6.85	5.63	5.70	5.53	5.62	1.22	1.33	1.38	1.31
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:																					
years – lat					0.36				0.08				0.11				ns ni				ns ni
proportion of components udziału komponentów					0.67				0.13				0.32				0.45				0.11
interaction – interakcji:																					
years × proportion of components lata × udział komponentów					ns ni				ns ni				0.39				ns ni				ns ni

Table 3 continued – cd. tabeli 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Straw – Słoma																					
100	0	7.09	7.54	7.79	7.47	1.26	1.34	1.46	1.35	10.54	11.21	11.73	11.16	3.36	3.51	3.56	3.48	1.02	1.16	1.24	1.14
75	25	8.42	8.67	8.62	8.57	1.40	1.40	1.56	1.45	11.36	11.51	12.03	11.63	6.59	6.31	5.58	6.16	1.28	1.43	1.38	1.36
50	50	9.74	10.04	10.05	9.94	1.47	1.54	1.66	1.56	11.41	11.88	12.61	11.97	9.79	9.57	9.05	9.47	1.56	1.70	1.59	1.62
25	75	11.19	11.54	11.58	11.44	1.58	1.67	1.76	1.67	11.93	12.28	13.23	12.48	13.23	12.77	12.75	12.92	1.86	1.97	1.91	1.91
0	100	12.34	13.07	13.54	12.98	1.67	1.78	1.93	1.79	12.34	12.73	14.04	13.04	16.03	16.92	17.41	16.79	2.13	2.29	2.25	2.22
Mean – Średnia		9.76	10.17	10.32	10.08	1.48	1.55	1.67	1.56	11.52	11.92	12.73	12.06	9.80	9.82	9.67	9.76	1.57	1.71	1.67	1.65
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:																					
years – lat					0.21				0.06				0.18				ns ni				ns ni
proportion of components udziału komponentów					0.43				0.12				0.49				0.78				0.16
interaction – interakcji:																					
years × proportion of components lata × udział komponentów					0.86				ns ni				0.56				ns ni				ns ni

ns – ni – non-significant differences – różnica nieistotna
* M – mean – średnia

Table 4. Amount of macroelements (N, P, K, Ca, Mg) in post-harvest residues and straw of spring wheat, field pea and spring wheat/field pea mixtures, $kg \cdot ha^{-1}$
Tabela 4. Ilość makroskładników (N, P, K, Ca, Mg) w resztkach pożniwnych i słomie pszenicy jarej, grochu siewnego oraz mieszanek pszenicy jarej z grochem siewnym, $kg \cdot ha^{-1}$

Proportion of components in the mixture – Udział komponentów w mieszance %		Macroelement – Makroskładnik																			
spring wheat pszenica jara	field pea groch siewny	N				P				K				Ca				Mg			
		2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Residues – Resztki																					
100	0	22.90	22.69	21.22	22.27	3.99	3.78	3.63	3.80	20.22	19.87	19.42	19.84	7.66	7.01	6.35	7.01	3.23	3.26	3.15	3.21
75	25	25.45	24.75	21,81	24.00	3.71	3.61	3.52	3.61	18.99	19.12	18.34	18.82	10.63	9.50	7.47	9.20	3.38	3.20	3.05	3.21
50	50	26.14	24.82	21.33	24.10	3.29	3.16	2.91	3.12	16.67	16.27	15.15	16.03	12.40	11.25	8.90	10.85	3.10	3.01	2.68	2.93
25	75	25.69	23.56	21.14	23.46	2.65	2.49	2.38	2.51	13.61	13.06	12.22	12.96	14.47	12.71	10.43	12.54	2.75	2.64	2.33	2.57
0	100	23.30	20.51	20.82	21.54	1.79	1.70	1.72	1.74	9.61	8.63	8.79	9.01	14.56	12.97	12.16	13.23	2.20	2.11	1.96	2.09
Mean – Średnia		24.70	23.27	21.26	23.07	3.09	2.95	2.83	2.96	15.82	15.39	14.78	15.33	11.94	10.69	9.06	10.57	2.93	2.84	2.63	2.80
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:																					
years – lat					1.07				0.20				0.63				0.76				0.18
proportion of components udziału komponentów					1.68				0.32				1.09				1.25				0.26
interaction – interakcji:																					
years × proportion of components lata × udział komponentów					2.03				ns ni				ns ni				ns ni				ns ni

Table 4 continued – cd. Tabeli 4

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Straw – Słoma																					
100	0	34.32	30.99	26.64	30.65	6.10	5.51	4.99	5.53	51.01	46.07	40.12	45.73	16.26	14.43	12.18	14.29	4.94	4.77	4.24	4.65
75	25	42.18	36.41	30.00	36.20	7.01	5.88	5.43	6.11	56.92	48.34	41.86	49.04	33.01	26.50	19.42	26.31	6.41	6.00	4.80	5.74
50	50	47.04	40.56	32.06	39.89	7.10	6.22	5.30	6.21	55.11	47.99	40.23	47.78	47.29	38.66	28.87	38.27	7.54	6.87	5.07	6.49
25	75	51.36	44.66	35.43	43.82	7.25	6.46	5.39	6.37	54.76	47.52	40.48	47.59	60.73	49.42	39.02	49.72	8.54	7.62	5.85	7.34
0	100	54.54	49.01	38.05	47.20	7.38	6.68	5.42	6.49	54.54	47.74	39.45	47.24	70.85	63.45	48.92	61.07	9.41	8.59	6.32	8.11
Mean – Średnia		45.89	40.33	32.44	39.55	6.97	6.15	5.31	6.14	54.47	47.53	40.43	47.48	45.63	38.49	29.68	37.93	7.37	6.77	5.26	6.47
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:					1.19				0.33				1.20				1.92				0.48
years – lat																					
proportion of components udziału komponentów					2.27				0.58				2.42				2.96				0.80
interaction – interakcji:																					
years × proportion of components lata × udział komponentów					3.78				ns ni				4.01				ns ni				ns ni

ns – ni – non-significant differences – różnica nieistotna
* M – mean – średnia

Table 5. Total amount of macroelements (N, P, K, Ca, Mg) in post-harvest residues with straw of spring wheat, field pea and spring wheat/field pea mixtures, $kg \cdot ha^{-1}$

Tabela 5. Łączna ilość makroskładników (N, P, K, Ca, Mg) w resztkach pożniwnych ze słomą pszenicy jarej, grochu siewnego oraz mieszanek pszenicy jarej z grochem siewnym, $kg \cdot ha^{-1}$

Proportion of components in the mixture Udział komponentów w mieszance %		Macroelement – Makroskładnik																			
spring wheat pszenica jara	field pea groch siewny	N				P				K				Ca				Mg			
		2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*	2004	2005	2006	M*
100	0	57.22	53.68	47.86	52.92	10.09	9.29	8.62	9.33	71.23	65.94	59.54	65.57	23.92	21.44	18.53	21.30	8.17	8.03	7.39	7.86
75	25	67.63	61.16	51.81	60.20	10.72	9.49	8.95	9.72	75.91	67.46	60.20	67.86	43.64	36.00	26.89	35.51	9.79	9.20	7.85	8.95
50	50	73.18	65.38	53.39	63.98	10.39	9.38	8.21	9.33	71.78	64.26	55.38	63.81	59.69	49.91	37.77	49.12	10.64	9.88	7.75	9.42
25	75	77.05	68.22	56.57	67.28	9.90	8.95	7.77	8.87	68.37	60.58	52.70	60.55	75.20	62.13	49.45	62.26	11.29	10.26	8.18	9.91
0	100	77.84	69.52	58.87	68.74	9.17	8.38	7.14	8.23	64.15	56.37	48.24	56.25	85.41	76.42	61.08	74.30	11.61	10.70	8.28	10.20
Mean – Średnia		70.58	63.59	53.70	62.62	10.05	9.10	8.14	9.10	70.29	62.92	55.21	62.81	57.57	49.18	38.74	48.50	10.30	9.61	7.89	9.27
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla: years – lat					1.28				0.39				1.15				2.43				0.41
proportion of components udziału komponentów					2.38				0.68				2.23				3.82				0.71
interaction – interakcji: years × proportion of components lata × udział komponentów					3.42				ns ni				3.21				ns ni				ns ni

ns – ni – non-significant differences – różnica nieistotna
* M – mean – średnia

The post-harvest residues of the spring wheat-field pea mixtures (75 + 25%, 50 + 50%, 25 + 75%) accumulated significantly more of total nitrogen, phosphorus, potassium and magnesium than the post-harvest residues of field pea. The amount of nitrogen accumulated in the post-harvest residues of spring wheat was similar to the amount of nitrogen in the post-harvest residues of field pea. The largest amount of nitrogen was found in the post-harvest residues of spring wheat-field pea mixtures (75 + 25%, 50 + 50%, 25 + 75%); of phosphorus, potassium and magnesium – in the post-harvest residues of spring wheat and the spring wheat-field pea mixture with the proportion of components 75 + 25%, and of calcium – in the post-harvest residues of field pea and the spring wheat-field pea mixture with the proportion of components 25 + 75%. Straw of spring wheat accumulated significantly the least nitrogen, calcium and magnesium. The amount of nitrogen and calcium in the straw of spring wheat-field pea mixtures (75 + 25%, 50 + 50%, 25 + 75%) was significantly smaller, and that of phosphorus and potassium did not differ significantly from the amount of those elements in the straw of field pea. The largest amount of magnesium was accumulated by the straw of field pea and spring wheat-field pea mixture with the proportion of components 25 + 75%. Post-harvest residues together with the straw of spring wheat-field pea mixtures (75 + 25%, 50 + 50%, 25 + 75%) and field pea accumulated significantly more nitrogen, calcium and magnesium than the post-harvest residues with straw of spring wheat. The most nitrogen and magnesium was accumulated in the post-harvest residues with straw of field pea and the spring wheat-field pea mixture with the proportion of components 25 + 75%, and the most calcium – in the post-harvest residues with straw of field pea. The post-harvest residues with straw of field pea, in relation to spring wheat, accumulated significantly less phosphorus and potassium. The most abundant source of phosphorus was the post-harvest residues with straw of spring wheat and spring wheat-field pea mixtures with the proportion of components 75 + 25% and 50 + 50%, and of potassium, the post--harvest residues with the straw of spring wheat-field pea mixture with the proportion of components 75 + 25%. The interaction of years with the proportion of components occurred in the mixture in regard to the amount of total nitrogen in post-harvest residues, straw and post-harvest residues with straw, and of potassium in post-harvest residues and in post-harvest residues with straw.

DISCUSSION

Post-harvest residues of field crops is the constant source of organic matter in soil [Batalin 1962, Římovský 1987, Kozłowa 1997, Malicki 1997, Boligłowa 1998]. The importance of post-harvest residues in the present conditions of plant production is growing. This results mainly from a large proportion of cereals in the cropping system and departing from the application of stable manure, which in turn deepens a deficit of organic substance in soil [Kraska and Pałys 2003]. Under the soil and climatic conditions of the present experiment, the weight of post-harvest residues and straw left depended on the plant species and the proportion of components in the mixture, which coincides with the reports of Batalin [1960, 1962], Paprocki and Zieliński [1966] and Kotecki et al. [2003]. Field pea generated the least of post-harvest residues and straw, while spring wheat left the most post-harvest residues and the spring wheat-field pea with the proportion of components 75 + 25% and spring wheat – the most straw. The dry weight yield of the post-harvest residues and straw of field pea found in the author's study was similar to that obtained by other authors [Batalin 1962, Jasińska and Kotecki 2001]. Also the weight of the post-harvest residues of spring wheat was within the range (3.08-3.84 $t \cdot ha^{-1}$) given by Kozłowa [1997]. Szymona et al. [1983/1984], in the experiment carried out in rendzina, reported a lower weight of post-harvest residues of spring wheat, and a higher weight of field pea than in the study under discussion. In contrast, in the experiment by Boligłowa [1998], carried out in the soil of the good rye complex, the dry weight yield of field pea was lower by 0.50-0.58 $t \cdot ha^{-1}$ than in the author's study. The weight of post-harvest residues and straw of field crops depends among others on the plant species and variety, and on site and cultivation factors [Batalin 1962, Szymona et al. 1983/1984, Kozłowa 1997, Malicki 1997, Kraska and Pałys 2003]. Spring wheat-field pea mixtures left the medium weight of post-harvest residues between their components in pure sowing. Along with a decrease in the proportion of spring wheat and an increase in the proportion of field pea in the mixture a significant fall in the dry weight yield of post-harvest residues and straw of mixtures was observed.

Post-harvest residues, however, are not only the source of organic substance but also of macro- and microelements. Their chemical composition is of large importance. It determines the decomposition of remains by particular microorganisms, which decides on the relation of mineralization to humification processes and the character of humic compounds, as well as on their manurial value and, consequently, in a large degree on the value of plants as an element of crop rotation [Batalin 1962, Římovský 1987, Malicki 1997]. In the present experiment, the post-harvest residues and straw of field pea were characterized by the highest content of macroelements. Increasing the proportion of field pea in the mixture with spring wheat affected a decrease in the content of macroelements in the post-harvest residues and straw of mixtures. It should be noted, however, that in some cases, especially in the content of phosphorus and potassium, the differences were within the margin of experimental error. The smallest content of macroelements was determined in the post-harvest residues and straw of spring wheat. Usually the biomass of legumes contains more nutrients than that of other field crops, which is generally accepted [Batalin 1960, 1962, Chojnacki and Boguszewski 1971, Szymona et al. 1983/1984, Malicki 1997]. The content of nitrogen, phosphorus and potassium in the straw of spring wheat fluctuated around the values given by Chojnacki and Boguszewski [1971]. Also the content of macroelements found in the present study in the post-harvest residues and straw of field pea remained at the level indicated by Jasińska and Kotecki [2001]. The content of mineral elements in the biomass of field crops is modified mainly by soil, climatic and cultivation factors [Chojnacki and Boguszewski 1971, Szymona et al. 1983/1984].

Under the conditions of the present experiment, the post-harvest residues and straw of spring wheat, field pea and mixtures of these plants accumulated mainly nitrogen, potassium and calcium, and considerably less phosphorus and magnesium, the plants accumulated mainly nitrogen, potassium and calcium, and considerably less of phosphorus and magnesium, which is similar to the reports by Batalin [1962], Szymona et al. [1983/1984], Malicki [1997] and Jasińska and Kotecki [2001]. The largest amounts of nitrogen were accumulated by the post-harvest residues of spring wheat-field pea mixtures, while of phosphorus, potassium and magnesium – the post-harvest residues of spring wheat and spring wheat-field pea mixtures with the proportion of components 75 + 25%, and calcium – the post-harvest residues of field pea and spring wheat-field pea mixture with the proportion of components 25 + 75%. By contrast, the post-harvest residues of field pea accumulated the least macroelements, except for calcium. The amount of macroelements in straw was on average about two- three times larger than in post-harvest residues. The straw of field pea and spring wheat-field pea mixtures accumulated more macroelements than the straw of spring wheat. The amount of macroelements observed in the post-harvest residues and straw of field pea did not differ considerably from the amount given by Batalin [1962] and by Jasińska and Kotecki [2001]. The post-harvest residues of spring wheat accumulated similar amounts of nitrogen, phosphorus and potassium to those in the study by Kozłowa [1997].

CONCLUSIONS

1. Under the soil and climatic conditions of this experiment field pea left about three times less weight of post-harvest residues than spring wheat. The largest amount of straw was provided by the spring wheat-field pea mixture with the proportion of components 75 + 25% and spring wheat in pure sowing.

2. Post-harvest residues and straw of spring wheat-field pea mixtures accumulated the average content of macroelements in comparison with their components in pure sowing. Growing of the proportion of field pea in the mixture with spring wheat increased the content of macroelements in post-harvest residues and mixture straw, but the differences were not always significant.

3. The weight of nitrogen and calcium accumulated in the post-harvest residues of spring wheat-field pea mixtures was larger or similar, and that of phosphorus, potassium and magnesium was smaller or similar to the weight of those elements in post-harvest residues of spring wheat. Straw of spring wheat gathered less macroelements, especially nitrogen, calcium and magnesium, than the straws of field pea and spring wheat-field pea mixtures.

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WARTOŚĆ PRZEDPLONOWA RESZTEK POŻNIWNYCH I SŁOMY PSZENICY JAREJ, GROCHU SIEWNEGO ORAZ ICH MIESZANEK DLA PSZENŻYTA OZIMEGO CZ. I. MASA I SKŁAD CHEMICZNY RESZTEK POŻNIWNYCH I SŁOMY

Streszczenie. W doświadczeniach przeprowadzonych w latach 2004-2007 badano wartość przedplonową dla pszenżyta ozimego resztek pożniwnych oraz resztek pożniwnych łącznie ze słomą następujących roślin: pszenicy jarej, grochu siewnego i mieszanek pszenicy jarej z grochem siewnym. W pierwszym etapie badań zrealizowanych w latach 2004-2006 określono: masę resztek pożniwnych i słomy roślin przedplonowych, zawartość oraz nagromadzenie makroskładników w biomasie. Najmniej resztek pożniwnych i słomy pozostawił groch siewny. Najwięcej słomy dostarczyła mieszanka pszenicy jarej z grochem siewnym o udziale komponentów 75 + 25% oraz pszenica jara. Resztki pożniwne i słoma mieszanek pszenicy jarej z grochem siewnym charakteryzowały się pośrednią zawartością makroskładników między ich komponentami w siewie czystym. Słoma pszenicy jarej zgromadziła mniej makroskładników, zwłaszcza azotu, wapnia i magnezu, od słomy grochu siewnego i mieszanek pszenicy jarej z grochem siewnym.

Słowa kluczowe: kumulacja makroskładników, mieszanka strączkowo-zbożowa, plon resztek pożniwnych, przedplon, zawartość makroskładników

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