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CHEMICAL COMPOSITION OF PEA (*PISUM SATIVUM* L.) SEEDS DEPENDING ON TILLAGE SYSTEMS

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Abstract

Tillage systems determine conditions for plant growth and development, which undoubtedly influences the crop quality. The present study evaluated the mineral composition and content of phytate phosphorus, protein and starch in pea seeds under the conditions of conventional tillage (shallow ploughing and harrowing after harvest of the previous crop, ploughing in the autumn), reduced tillage (only cultivator after harvest of the previous crop), and herbicide tillage (only Roundup 360 SL after harvest of the previous crop). The study demonstrated a higher content of total ash, phosphorus (P) and potassium (K) in pea seeds from the conventional and reduced tillage systems as well as a higher content of calcium (Ca) in seeds from the reduced tillage compared to the herbicide system. The conventional tillage also increased the content of iron (Fe) compared to the reduced and herbicide systems. In turn, the content of magnesium (Mg) and zinc (Zn) did not depend on the tillage system or the study year, whereas the content of copper (Cu) was significantly higher in the reduced tillage compared to the conventional and herbicide systems. The content of phytate-P in pea seeds was affected only by the study year. The total protein content of pea seeds was similar in all the tillage systems and study years, whereas the starch content was higher in the conventional than in the reduced and herbicide tillage, and was also differentiated by the study year.

Key words: legumes, mineral elements, phytate-phosphorus, soil tillage.

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SKŁAD CHEMICZNY NASION GROCHU SIEWNEGO (*PISUM SATIVUM* L.) W ZALEŻNOŚCI OD SYSTEMU UPRAWY ROLI

Abstrakt

Uprawa roli kształtuje warunki wzrostu i rozwoju roślin, co niewątpliwie wpływa na jakość plonu. W badaniach oceniano skład mineralny, zawartość fosforu fitynowego oraz białka i skrobi w nasionach grochu siewnego w warunkach konwencjonalnej uprawy roli, uproszczonej i herbicydowej. Wykazano, że więcej popiołu ogółem, fosforu (P) i potasu (K) zawierały nasiona grochu z uprawy konwencjonalnej i uproszczonej niż herbicydowej, natomiast więcej wapnia (Ca) zawierały nasiona z uprawy uproszczonej niż herbicydowej. Konwencjonalna uprawa roli wpłynęła również na zwiększenie zawartości żelaza (Fe), w stosunku do uprawy uproszczonej i herbicydowej. Z kolei zawartość magnezu (Mg) oraz cynku (Zn) kształtowała się niezależnie od systemu uprawy roli i lat badań, zaś miedzi (Cu) była istotnie większa w uprawie uproszczonej niż konwencjonalnej i herbicydowej. Na zawartość P-fitynowego w nasionach wpływały tylko lata badań. Zawartość białka ogółem w nasionach grochu była podobna we wszystkich systemach uprawy roli i latach badań, zaś zawartość skrobi była większa w uprawie konwencjonalnej niż uproszczonej i herbicydowej. Cechę tę istotnie różnicowały również lata badań.

Słowa kluczowe: strączkowe, skład mineralny, fosfor fitynowy, uprawa roli.

INTRODUCTION

The objective of a tillage system is to assure optimal conditions for the growth and yielding of plants (Morris et al. 2010). However, solutions applied in crop cultivation practice are not always optimal because their effectiveness is influenced by the interaction of many natural and economic factors of a farm (Gruber et al. 2012). Investigations by Locke et al. (2002) and Woźniak (2012) demonstrated that the no-till system was increasing crop infestation with weeds, which may contribute to yield reduction (Hemmat, Eskandari 2004), and deterioration of crop quality (Woźniak 2013*b*). In studies conducted by Hemmat and Eskandari (2004), the yield of chickpea sown in drylands in a no-till system was significantly higher than in the ploughing, reduced and minimal systems. Also Guy and Cox (2002) achieved higher yields of pea seeds in the no-till than in the conventional system. In turn, in moderately humid soil, the yield of pea was higher in the conventional system than in the reduced and herbicide ones (Woźniak 2013*a*). The tillage system and fertilization also influence the chemical composition of crop (Woźniak, Makarski 2012). In the research by Kraska (2011), the conservative tillage system increased the content of phosphorus and copper in grain of spring wheat, as compared to the ploughing system. In turn, as Woźniak and Makarski (2012) reported, the ploughless tillage system increased the content of ash, zinc and copper in wheat grain, while the ploughing system increased the content of potassium, magnesium and manganese. Woźniak (2013*b*) demonstrated that tillage systems affected the content of protein and ash in grain of durum wheat. In this respect, poorer quality grain was obtained in herbicide tillage rather than in the conventional and reduced systems.

Legume seeds are rich in mineral elements, but also in phytates (inositol hexaphosphate). These compounds have anti-nutrient properties because they decrease the availability of major minerals, particularly of iron, zinc and calcium (Tavajjoh et al. 2011). They form complexes with iron and zinc, which in some cases may cause deficiency of these elements in human diet (Sandberg 2002). They are the main cause of phosphorus accumulation in plant tissues (Kumar et al. 2010). They are synthesized during seeds maturation and constitute from 60 to 90% of total phosphorus (Loevus 2002). On the other hand, phytates display some beneficial effects as they reduce the risk of ischaemic heart disease, atherosclerosis and diabetes development as well as show antioxidative properties (Kumar et al. 2010).

The aim of the present study was to evaluate the effect of tillage systems on the content of macro- and microelements, phytate phosphorus as well as protein and starch in pea seeds.

MATERIAL AND METHODS

A controlled field experiment was conducted in 2009-2011 at the experimental station in Uhrusk, of the University of Life Sciences in Lublin. The experiment was established on Rendzic Phaeozem soil (IUSS Working Group WRB, 2006) with the particle-size distribution and texture of sandy loam. The content of available forms of phosphorus in the soil reached 214 mg P kg^{-1}, whereas the potassium content was 237 mg K kg^{-1}; the soil had a slightly alkaline pH value (pH_{KCl}=7.2). The content of total N in the soil was 1.03 g kg^{-1}, and that of organic C equalled 7.60 g kg^{-1}. The experiment was carried out in the system of randomized blocks, in 3 replications, on plots with the area of 24 m^2 each. The test plant was the Bohun cultivar pea, cultivated from seeds in three tillage systems: (1) conventional (CT), (2) reduced (RT), and (3) herbicide (HT).

The conventional tillage included shallow ploughing and harrowing after harvest of the previous crop (spring wheat) and ploughing in the autumn. The reduced tillage included only field cultivation after harvest of the previous crop, and herbicide tillage consisted of a treatment with Roundup 360 SL (a.s. glyphosate, 4 L ha^{-1}) after harvest of the previous crop. In the springtime, a cultivation set composed of a cultivator, a string roller and a harrow was used on all the plots.

In each year, pea seeds were sown in the first decade of April, in quantities of 100 seeds per m^2 in row spacing of 20 cm. Fertilization before sowing included 20 kg N ha^{-1}, 17.5 kg P ha^{-1} and 66.5 kg K ha^{-1}. Before sowing, the seeds were dressed with Zaprawa Nasienna T (a.i. carbendazim 20% and thiuram 45%). Karate Zeon 050 CS insecticide (a.i. lambda-cyhalothrin) was applied in a dose of 0.1 L ha^{-1} for pest control, whereas Afalon Dyspersyjny

450 SC (a.i. linuron) in a dose of 1.5 L ha^{-1} directly after sowing and Fusilade Forte 150 EC (a.i. fluazyfop-P-butyl) in a dose of 1 L ha^{-1} after sprouting of monocotyledonous weeds were used for weed control.

The content of mineral components in pea seeds was established after dry mineralization of the samples at a temperature of 600°C. The resultant ash was dissolved in 5 mL of 6 M HCl, then filled up to the volume of 50 mL with redistilled water. Measurements were carried out with the method of Atomic Absorption Spectrometry with acetylene-air flame excitation in a UNICAM 939 apparatus. Phytate-phosphorus was extracted from ground samples with 5% TCA for 60 min. Then, the extract was centrifuged for 10 min at the speed of 3000 rpm. Phytate-P present in the supernatant was determined with the spectrophotometric method (λ=500 nm) using Wade reagent – 0.3 g $FeCl_3$ $6H_2O$ + 3.0 g sulfosalicylic acid in 1 L (Latta, Skin 1980, Dragičević et al. 2011). The content of nitrogen in pea seeds was determined with the Kjeldahl method and converted into total protein (N x 6.25). The starch content was assayed by shaking the seed samples with a TRIS buffer (pH=9.2) until complete solubilization of protein. The remaining precipitate was hot-dissolved in water. The starch content was determined spectrophotometrically (λ=660 nm) in the form of a complex with iodine.

The results achieved were developed statistically with the analysis of variance method (Anova) in Statistical PL software, whereas significant differences between mean values were evaluated with the Tukey's HSD test, $P<0.05$.

RESULTS

The evaluation of variance components (*F*-Value) demonstrated that the ash content of pea seeds was affected by the study year more than by the tillage system (Table 1). Pea seeds harvested from plots cultivated in the conventional system were characterized by a significantly higher content of total ash than seeds from plots with the herbicide tillage (Table 2). Values of these traits were also differentiated by the study year. A significantly higher ash content was determined in seeds from 2010 than in those from 2009 and 2011. Pea seeds originating from the conventional and reduced

Table 1

F-Value for mineral composition of pea seeds, $P<0.05$

Effects	DF	Ash	P	Phytate-P	K	Mg	Ca	Fe	Zn	Cu
		F-Value								
*TS	2	3.92	10.50	0.96	86.41	1.04	3.76	42.47	2.18	5.21
**Y	2	13.11	4.36	7.10	0.41	2.50	6.29	1.21	0.92	0.54
TS x Y	4	0.61	1.05	0.71	1.11	1.06	0.72	0.23	0.02	0.56

* TS – tillage systems, ** Y – years

Table 2

Content of ash, macroelements and phytate-P in pea seeds

Tillage systems (TS)	Years (Y)			Mean
	2009	2010	2011	
Total ash (%)				
CT	2.90	3.12	2.81	2.94
RT	2.81	3.03	2.80	2.88
HT	2.78	2.90	2.76	2.81
Mean	2.83	3.02	2.79	-
$HSD_{0.05}$ for TS – 0.12 ; Y – 0.12				
P (g kg^{-1} d.m.)				
CT	3.41	3.62	3.90	3.64
RT	3.61	3.63	3.66	3.63
HT	3.17	3.14	3.45	3.26
Mean	3.40	3.47	3.67	-
$HSD_{0.05}$ for TS – 0.25; Y – 0.25				
Phytate-P (g kg^{-1} d.m.)				
CT	1.73	1.72	1.85	1.77
RT	1.72	1.72	1.79	1.74
HT	1.77	1.70	1.94	1.80
Mean	1.74	1.71	1.86	-
$HSD_{0.05}$ for TS – ns ; Y – 0.11				
K (g kg^{-1} d.m.)				
CT	10.26	10.16	10.56	10.33
RT	10.04	10.04	10.37	10.15
HT	8.50	8.43	8.17	8.37
Mean	9.60	9.54	9.70	-
$HSD_{0.05}$ for TS – 0.42 ; Y – ns				
Mg (g kg^{-1} d.m.)				
CT	1.02	1.06	0.97	1.02
RT	1.02	0.94	0.93	0.97
HT	1.03	1.01	0.67	0.90
Mean	1.02	1.00	0.86	
$HSD_{0.05}$ for TS – ns; Y – ns				
Ca (g kg^{-1} d.m.)				
CT	0.67	0.64	0.52	0.61
RT	0.71	0.64	0.62	0.66
HT	0.59	0.62	0.48	0.56
Mean	0.66	0.63	0.54	-
$HSD_{0.05}$ for TS – 0.09; Y – 0.09				

Explanations: CT – conventional tillage, RT – reduced tillage, HT – herbicide tillage, $HSD_{0.05}$ – honestly significant difference, ns – not significant, $P<0.05$

systems contained from 11.3 to 11.7% more phosphorus (P) than seeds from the herbicide tillage. A higher content of phosphorus was noted in the crop of 2011 than of 2009. The evaluation of variance components indicated that the content of this element in pea seeds was influenced by the tillage system more than by the study year. Also, the content of phytate-P was significantly higher in 2011 than in 2009 and 2010, although it was unaffected by the tillage systems. The content of potassium (K) in pea seeds depended only on the tillage system and was 21.3 to 23.4% higher in the conventional and reduced systems compared to the herbicide system. In turn, the content of magnesium (Mg) in seeds was not influenced by the tillage system or by the year. In contrast, the content of calcium (Ca) in pea seeds was observed to depend on both the tillage system and the year. A significantly higher Ca content was determined in seeds harvested from plots with the reduced tillage than in the herbicide system. A higher content of this element was found in pea seeds from 2009 than in those from 2011. The *F*-Value indicated that the calcium content of pea seeds was influenced more by the year than by the tillage system.

The content of iron (Fe) in pea seeds was found to depend only on the tillage system (Table 3). Its higher value (from 20.1 to 26.0%) was determined in seeds harvested from the conventional rather than from the reduced

Table 3

Content of microelements in pea seeds

Tillage systems (TS)	Years (Y)			Mean
	2009	2010	2011	
Fe (mg kg^{-1} d.m.)				
CT	78.43	78.37	77.82	78.21
RT	66.18	65.74	63.48	65.13
HT	64.01	63.03	59.17	62.07
Mean	69.54	69.05	66.82	-
$HSD_{0.05}$ for TS – 4.75; Y – ns				
Zn (mg kg^{-1} d.m.)				
CT	34.04	33.63	35.78	34.48
RT	38.32	36.96	39.67	38.31
HT	36.13	35.90	38.33	36.79
Mean	36.16	35.50	37.93	-
$HSD_{0.05}$ for TS – ns; Y – ns				
Cu (mg kg^{-1} d.m.)				
CT	6.80	6.63	6.88	6.77
RT	8.38	7.72	7.29	7.80
HT	6.87	6.83	6.85	6.85
Mean	7.35	7.06	7.01	-
$HSD_{0.05}$ for TS – 0.90; Y – ns				

Explanations see Table 2

Table 4

F-Value for protein and starch content in pea seeds, $P<0.05$

Effects	DF	Total protein	Starch
		F-Value	
TS*	2	1.52	15.44
Y	2	0.87	24.39
TS x Y	4	2.56	1.75

* TS – tillage systems, Y – years

Table 5

Content of total protein and starch in pea seeds

Tillage systems (TS)	Years (Y)			Mean
	2009	2010	2011	
Total protein (g kg^{-1} d.m.)				
CT	212.8	206.4	199.0	206.1
RT	204.5	218.4	212.5	211.8
HT	209.0	207.6	207.8	208.4
Mean	209.0	210.8	206.5	-
$HSD_{0.05}$ for TS – ns; Y – ns				
Starch (g kg^{-1} d.m.)				
CT	431.2	406.3	348.6	395.3
RT	386.0	330.5	249.8	322.1
HT	383.0	327.8	316.9	342.6
Mean	400.0	354.9	316.9	-
$HSD_{0.05}$ for TS – 34.7; Y – 34.7				

Explanations see Table 2

and herbicides tillage. In turn, the content of zinc (Zn) was unaffected by the tillage system or the study year, whereas the content of copper (Cu) was significantly higher in the reduced tillage than in the conventional and herbicide systems.

The evaluation of variance components (*F*-Value) demonstrated that the starch content of pea seeds was influenced more demonstrably by the study year than by the tillage system (Table 4). The content of protein in pea seeds was similar in all the tillage systems and study years (Table 5). In turn, the starch content was significantly influenced by both the tillage systems and the years. In the conventional tillage, it was higher than in reduced tillage (by 22.7%) and herbicide system (by 15.4%). Its higher value was also noted in the crop from 2009 than in crops from 2010 (by 12.7%) and 2011 (by 26.2%).

DISCUSSION

As demonstrated in previous investigations (Kraska 2011, Woźniak, Makarski 2012, Woźniak 2013*b*), a tillage system may influence the quality and chemical composition of the crop. In our study, the pea seeds harvested from plots with the conventional tillage contained more ash than those from the herbicide system. This may have resulted from less favorable conditions of pea growth in the herbicide system than in the conventional tillage, which in consequence led to a worse supply of plants with nutrients. Some earlier research by Woźniak (2013*a*) showed that pea seeds harvested from plots with a herbicide system were smaller and their weight was significantly lower compared to seeds from the conventional tillage. It was probably due to the competition of pea plants with weeds, because the herbicide tillage was accompanied by a significantly more severe weed infestation compared to the conventional system (Woźniak 2012). In a study by Wang et al. (2010), the content of ash in pea seeds depended on a study year, plot location and cultivar. In the cited work, the ash content ranged from 2.57 to 2.79%, being slightly lower than in our experiment (2.76 to 3.12%). In the conventional and reduced tillage, the pea seeds were characterized by a higher content of the macroelements: phosphorus (P), potassium (K) and calcium (Ca), and of microelements: iron (Fe) – compared to the herbicide tillage, and copper (Cu) – in the reduced tillage versus the conventional and herbicide systems. According to Amarakoon et al. (2012), the content of microelements in different genotypes of pea cultivated in North Dakota, USA, was variable and ranged from 46 o 54 mg kg^{-1} for iron (Fe), from 39 to 63 mg kg^{-1} for zinc (Zn), and 1350 mg kg^{-1} for magnesium (Mg). In our experiment and in the study by Sandberg (2002), the content of Zn, Mg and Ca in pea seeds was the same, whereas the content of Fe was higher. According to Amarakoon et al. (2012), pea is a good source of Fe, Zn and Mg, but a poor source of Ca. In the research by Kraska (2011), the conservative tillage was observed to increase the content of P and Cu in wheat grain compared to the ploughing system. The latter was increasing the content of K, Mg, Mn and S in the grain, compared to the conservative tillage variants. Woźniak and Makarski (2012) reported that the ploughless tillage increased the content of Zn and Cu in wheat grain, compared to the ploughing tillage. It could be due to the fact that the absorbability of microelements in soils well permeable to air is lower than in soils less permeable to air. In turn, under the ploughing system, the wheat grain was characterized by a higher content of K and Mg. Higher levels of the elements in grain may be explained by their higher availability to plants, because they are more easily translocated into deeper layers of soil (particularly in well-aerated soil) in the ploughing system. This observation was also confirmed in our study on pea, where the content of phosphorus (P) in pea seeds was higher in the conventional and reduced tillage than in the herbicide tillage, whilst the content of phytate phosphorus was at a similar level in all the tillage systems. According to Loewus (2002), over 60% of phosphorus in pea seeds may occur in the form of phytate-P. In our experiment, phytate-P constituted from 47 to 56% of the total phosphorus accumulated in seeds. As reported by Sandberg (2002), the content of phytate-P in pea seeds ranges from 0.6 to 3.30 g kg^{-1}. In our study, the content of phytate-P also fell within this range and spanned from 1.74 to 1.80 g kg^{-1} depending on a tillage system.

The research conducted by Wang et al. (2010) demonstrated significant differences in the content of protein, starch, crude fiber, fat, ash, and phytates in pea seeds depending on a cultivation system and study site. In our experiment, the content of total protein in pea seeds was at a similar level in all tillage systems, whereas the content of starch was higher in seeds harvested from plots with the conventional tillage than in those from the reduced and herbicide systems.

In conclusion, a higher content of total ash, phosphorus (P) and potassium (K) was determined in pea seeds originating from the conventional and reduced systems than from the herbicide tillage, whereas a higher content of calcium (Ca) was assayed in seeds from the reduced than from the herbicide tillage. A higher content of iron (Fe) was found in pea seeds harvested from plots with the conventional tillage than from the reduced and herbicide systems, whereas a higher content of copper (Cu) was noted in seeds from the reduced than from the conventional and herbicide systems. The content of phytate phosphorus was differentiated only by the study years, whereas the content of magnesium (Mg) and zinc (Zn) was not affected by the tillage systems or the study years. The content of total protein in pea seeds was similar in all the tillage systems and all study years, whereas the starch content was higher in seeds from the conventional tillage than from the reduced and herbicide systems.

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