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ORIGINAL RESEARCH PAPER

Evaluation of yielding of mixtures of *Pisum sativum* L. with *Triticum aestivum* L. grown in organic farming

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Abstract

The aim of this study was to determine the productivity and quality of feed obtained from the mixtures of field pea (*Pisum sativum* L.) with spring wheat (*Triticum aestivum* L.), depending on the pea cultivar and its percentage in the weight of sown seeds under the conditions of organic farming. A field experiment was carried out in the years 2011–2013 in a randomized split-plot design with four replications. The first factor was a pea 'Wiato' or 'Tarchalska'. The secondary factor was density of a pea mixture sown: 40, 60, and 80%. The yield of mixture seeds as well as the yield and structure of individual components were evaluated. The contents of crude protein and crude fiber, fat, ash, phosphorus, and potassium were determined in cereal grain and pea seeds.

The examined factors and weather conditions during the growing season had a significant impact on the growth and yield of pea–spring wheat mixtures. The seed yields of the mixtures with the semi-leafless 'Tarchalska' were lower than with 'Wiato' (with bipinnate leaves). Increasing the pea percentage in seed material resulted in lower mixture yields. The percentage of pea seeds (regardless of foliage type) in the mixture yields was significantly lower than the weight of sown seeds. Increasing the pea percentage in the mixture yield positively influenced the contents of protein, fat, and ash but it caused a decrease in the content of fiber. The pea percentage at sowing had little influence on the content of phosphorus in the mixture seed yields, but it slightly increased the content of potassium, regardless of the pea cultivar. The mixtures with the 'Wiato' and 'Tarchalska' cultivars contained a similar amount of protein, fiber, and fat, while the mixtures with 'Tarchalska' accumulated more ash.

Keywords

chemical composition; legume–cereal mixture; organic farming; pea; spring wheat; yield

Introduction

Legume–cereal mixtures are grown mostly in smaller farms which produce feed for their own consumption, or in farms which operate according to the principles of organic agriculture [1]. Such crops have a positive effect on the soil environment and the percentage of legumes in the yield improves the quality of the obtained feed, which is then more effectively used by animals [2]. In addition, legume–cereal mixtures are mostly grown on weaker soils than the soils considered optimal for a given species of legume grown in pure stand. A different type of root system of cereals and legumes

and nitrogen fixation ability improve the efficiency of the use of soil habitat [3,4]. Simultaneously, such mixtures have a higher tolerance to worse habitat and agronomic conditions [5]. Such crops are also an effective method of weed infestation control and reduce the spread of diseases and pests, which is very important in organic production system [6–9]. Mixtures of legumes with cereals create the conditions for the formation of allelopathic interactions that have a significant influence on the subsequent development of stand structure and the percentage of each component in the creation of seed yield. Stable yields and a good pre-crop value for cereals encourage farmers to grow mixtures not only as a source of fodder [10,11]. Cultivation of mixed crops increases protein content in the seeds of the cereal component, the yield of crude protein in the biomass, and the content of this component in the yield of the seeds mixture [7,8,12].

The aim of the study was to determine the productivity and quality of feed obtained from pea mixed with spring wheat as affected by pea cultivar and its percentage in the weight of sown seeds under organic farming conditions.

Material and methods

A field experiment with mixtures of legume–spring cereal was carried out in the years 2011–2013 at the Agricultural Experimental Station in Grabów (Mazowieckie Province), IUNG – PIB Puławy (51°23′ N, 21°38′ E), in a randomized split-plot design with four replications. The first factor was the pea 'Wiato' (with bipinnate leaves) and 'Tarchalska' (semi-leafless). The secondary factor was the pea percentage in the mixture: 40, 60, and 80%. The density of the components in pure stand, for which the density of plants in mixtures was calculated, was as follows: pea – 80 plants per m^2, wheat – 500 plants m^2. The experiment was conducted on the good rye soil complex, class III a. The content of available phosphorus (in mg kg^{-1}) was from 11.5 to 13.8, potassium from 12.6 to 25.7, magnesium from 2.8 to 4.1, and the humus content from 1.34 to 1.39%, while the pH of the soil was slightly acidic (6.0). Before the harvest, the height to the first and last pods and plant height were determined in 10 randomly selected pea plants per each sub-plot. Number of fruiting nodes per plant, number of pods per node, and number of pods and seeds per plant were evaluated. Seed weight per plant and the weight of pods were also determined. After the harvest, the seed yield of the pea–wheat mixture, the percentage of components in the yield, and thousand seed weight were determined at 14% humidity. The contents of total protein, crude fiber, fat, ash, phosphorus, and potassium in wheat grain and pea seeds were also determined. The contents of crude fiber were determined by the weight method, crude fat – by Soxhlet's weight method, total ash – by the weight method at 580°C, phosphorus – by flow analysis (CFA), while the content of potassium – by flow spectrophotometry analysis. The effect of the examined experimental factors on the determined characteristics was statistically analyzed using two-way ANOVA analysis, the half-intervals of confidence being determined by Tukey's test at the 0.05 significance level using STATISTICA 10.0.

Results

In the case of *P. sativum*, the percentage of the components in the mixture and weather conditions had a significant effect on the growth, development, and yield value of the pea–wheat mixtures (Fig. 1). High rainfall in the second and third 10-day periods of July 2011 delayed the harvest. The total mixture yield was greatly affected by heavy rainfall in July which caused lodging in cereals, making it difficult to gather the crops. The weather in the third 10 days of July 2013 was characterized by a small amount of precipitation and a high mean temperature, resulting in reduced soil moisture content.

The highest yields of the mixtures were obtained in the second year of the study (2012), which was significantly determined by a favorable distribution of precipitation

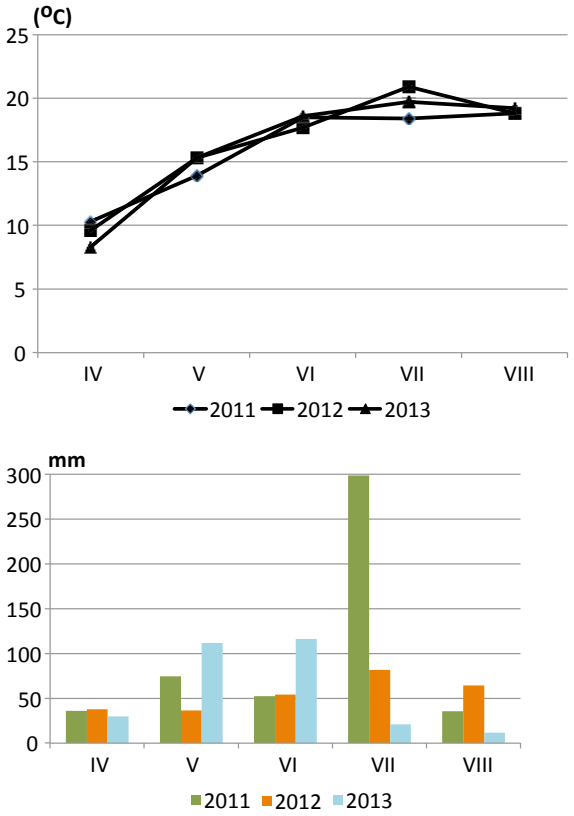

Fig. 1 Weather conditions during the growing period of the pea–spring wheat mixtures.

in June and July and the highest relative humidity during flowering of plants (Tab. 1). In 2011, with not very favorable weather conditions, the obtained seed yields of the pea–cereal mixtures were about 32% lower compared to the yields of 2012. Moreover, in July and early August of that year, a large amount of rainfall caused strong lodging of the plants, which extended the plant maturation period, impeded harvesting, and caused higher seed shedding. In July and August 2013, however, a small amount of precipitation was noted, which adversely affected wheat plants. Under these conditions, cereal plants formed fewer shoots and they were additionally much shorter than in the other years of the study, while the weight of grains was twofold lower.

The average seed yields of the mixtures with the semi-leafless pea 'Tarchalska' were lower than those of the bipinnate leaf pea 'Wiato' (Tab. 1). Increasing the percentage of pea in the weight of sown seeds caused an increase in its percentage in the mixture yields, but only in the third year with favorable weather conditions. However, in the first and second year of the study, an increase in the percentage of pea seeds in the mixture caused a reduction in the yield of the mixtures by 32 and 25%, respectively.

The percentage of pea seeds in the mixture yield was much smaller than this percentage in the weight of sown seeds (Tab. 2). Increasing the percentage of pea seeds in the mixture, regardless of foliage type, increased the percentage of pea seeds in the yield. Seeds of 'Wiato' with bipinnate leaves constituted a larger percentage in the mixture yield than in the case of the semi-leafless cultivar 'Tarchalska' (Tab. 2).

A higher percentage of pea at seeding (irrespective of its cultivar) caused an increase in pea seeds in the yield. The average yield of pea seeds increased with increasing their percentage in the weight of sown seeds (Tab. 3). There were more seeds of 'Wiato' than of 'Tarchalska'.

The percentage of pea seeds in the mixture yield and pea yield was strongly dependent on the morphological characteristics. Increasing the percentage of pea in the mixture resulted in changes in the plant structure. In all the years of the study, the number of nodes with pods and pods per plant in both evaluated cultivars, regardless of the type of foliage, increased with increasing the percentage of pea in the mixture (Tab. 4, Tab. 5). In the first and second year of the study, the 'Wiato' cultivar was characterized by a higher number of nodes with fruiting pods than 'Tarchalska'. In the third year of study (2013), however, the number of pea pods per plant was almost twofold higher than in the first and second year. Both the number of nodes with fruiting pods and number of pods per plant did not vary between the cultivars in the first and third years of the study (2011 and 2013).

In those years of the study, increasing the percentage of pea seeds in the weight of sown seeds resulted in an increase in the weight of seeds per plant in both pea cultivars, regardless of the morphological structure, while in the third year only a slight decrease was observed (Tab. 6). 'Wiato' produced a higher weight of seeds per plant. The highest amounts of seeds per plant were recorded for both pea cultivars in the mixtures with the pea percentage of 80% in the sowing weight (Tab. 7). The thousand seed weight of pea was highest in 2013, but there were no significant differences between the thousand seed weight of the compared cultivars in this year. Significant differences were found only in 2011 and 2012 (Tab. 8). It was found that the higher pea percentage at seeding (irrespective of the cultivar) caused an increase in thousand seed weight of pea. The evaluated cultivars had a similar number of pods per node (Tab. 9). A change in the percentage of legume plants in the mixture stand did not have a significant impact on the number of pods per node.

'Wiato' produced more seeds per pod than 'Tarchalska' (Tab. 10). Small differences in this feature were found between the pea cultivars. Increasing the pea percentage at sowing resulted in a small difference in the number of pods per node and number of seeds per pod. Both evaluated cultivars, regardless of foliage type, formed their first pod at a similar height and produced fruiting parts of similar length (Tab. 11). Weather conditions during the growing season had a significant influence on these studied features. The highest pea plants with the longest fruiting parts were observed in 2013 in which there was a lot of rainfall in June. There were no significant differences in these features between the evaluated pea cultivars.

The mixture composition had only a small influence on the height of wheat plants, thousand grain weight, and weight and number of grains per plant (Tab. 12–Tab. 15). In 2013, a year with a small amount of rainfall in June, the wheat plant had a much worse morphological structure. A slightly greater height of spring wheat was characteristic for the cereal–legume mixture with 'Wiato', whereas the other features, such as number of grains and grain weight per plant, were higher for 'Wiato' only in 2012 and 2013. No significant differences were found between the evaluated cultivars depending on the percentage of pea in the mixture. Increasing the pea percentage in the mixtures had a significant impact on thousand grain weight of spring wheat only in 2013, while significant differences between the evaluated pea cultivars were noted in 2012 and 2013.

The quality of fodder raw material obtained from the pea–wheat mixtures was largely affected by the percentage of seeds of the individual mixture components in the yield. Increasing the pea percentage in the mixture yield positively influenced the contents of protein, fat, and ash, but it reduced the fiber content (Tab. 16–Tab. 18). The mixtures with both 'Wiato' and 'Tarchalska' cultivars contained a similar amount of protein, fat, and fiber, while ash was accumulated in higher amounts by the mixtures with 'Tarchalska', but the differences were not significant. In 2013, seeds from mixed crops contained higher amounts of fiber, fat, and ash compared to the two previous years. Increasing the pea percentage at sowing had a little influence on the phosphorus content in seeds from the mixtures, while the potassium content slightly increased, regardless of the pea cultivar. The mixtures with 'Tarchalska' had slightly higher potassium content than the mixtures with 'Wiato'.

Tab. 1 Seed yield of the pea–cereal mixture depending on pea cultivar and its percentage in the mixture (t ha^{-1}).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	3.46* ^{c}	3.03 ^{c}	4.66 ^{c}	4.48 ^{c}	2.78 ^{a}	2.68 ^{a}
60	2.78 ^{b}	2.60 ^{b}	4.18 ^{b}	3.97 ^{b}	2.80 ^{a}	2.84 ^{a}
80	2.36 ^{a}	2.05 ^{a}	3.57 ^{a}	3.22 ^{a}	3.08 ^{a}	2.97 ^{a}

* Values followed by a different letter are significantly different ($p < 0.05$).

Tab. 2 Percentage of pea seeds in yield of the mixtures depending on pea cultivar and its percentage in the mixture (%).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	18.6	13.2	12.7	11.1	37.1	31.3
60	39.7	22.9	17.5	15.4	47.8	41.3
80	74.7	25.2	36.9	33.9	53.1	55.3

Source: own study.

Tab. 3 Yield of pea seeds depending on pea cultivar and its percentage in the mixture (t ha^{-1}).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	0.64* ^{a}	0.45 ^{a}	0.59 ^{a}	0.49 ^{a}	1.03 ^{a}	0.84 ^{a}
60	1.09 ^{b}	0.56 ^{ab}	0.73 ^{ab}	0.63 ^{ab}	1.33 ^{ab}	1.17 ^{ab}
80	1.40 ^{c}	0.57 ^{b}	1.32 ^{b}	1.11 ^{b}	1.64 ^{b}	1.64 ^{b}

* See Tab. 1.

Tab. 4 Number of nodes with fruiting pods depending on pea cultivar and its percentage in the mixture (pcs).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	2.35* ^{a}	2.34 ^{a}	2.90 ^{a}	2.20 ^{a}	5.25 ^{a}	5.73 ^{b}
60	2.63 ^{c}	2.44 ^{b}	3.10 ^{a}	2.43 ^{b}	5.58 ^{b}	5.88 ^{c}
80	2.58 ^{b}	2.42 ^{b}	3.95 ^{b}	2.98 ^{c}	5.23 ^{a}	5.38 ^{a}

* See Tab. 1.

Tab. 5 Number of pea pods per plant depending on pea cultivar and its percentage in the mixture (pcs).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	3.94* ^{a}	3.91 ^{a}	4.68 ^{ab}	3.60 ^{a}	8.98 ^{a}	9.80 ^{b}
60	4.46 ^{ab}	4.00 ^{b}	4.63 ^{a}	3.73 ^{b}	9.96 ^{c}	10.10 ^{c}
80	4.55 ^{b}	4.12 ^{b}	5.88 ^{b}	4.78 ^{c}	9.15 ^{b}	9.43 ^{a}

* See Tab. 1.

Tab. 6 Weight of pea seeds per plant depending on pea cultivar and its percentage in the mixture (g).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	3.26* ^{a}	2.47 ^{b}	3.55 ^{a}	2.19 ^{a}	7.97 ^{b}	8.20 ^{b}
60	4.18 ^{c}	2.74 ^{a}	3.57 ^{a}	2.84 ^{b}	8.48 ^{c}	8.62 ^{c}
80	4.09 ^{b}	2.86 ^{c}	4.52 ^{b}	3.66 ^{c}	7.57 ^{a}	7.96 ^{a}

* See Tab. 1.

Tab. 7 Number of pea seeds per plant depending on pea cultivar and its percentage in the mixture (pcs).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	17.20	12.80	21.78	12.25	35.45	38.30
60	20.80	13.70	20.63	12.85	37.60	38.13
80	20.90	14.10	28.98	19.75	34.43	36.95

Tab. 8 Thousand seed weight of pea depending on pea cultivar and its percentage in the mixture (g).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	193* [a]	191 [a]	166 [a]	187 [a]	222 [a]	209 [a]
60	202 [c]	200 [b]	177 [c]	208 [b]	220 [a]	211 [a]
80	199 [b]	207 [c]	169 [b]	212 [c]	221 [a]	216 [a]

* See Tab. 1.

Tab. 9 Number of pods per node depending on pea cultivar and its percentage in the mixture (pcs).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	1.67* [a]	1.67 [a]	1.62 [a]	1.57 [a]	1.71 [a]	1.71 [a]
60	1.70 [a]	1.64 [a]	1.49 [a]	1.50 [a]	1.79 [a]	1.72 [a]
80	1.77 [a]	1.70 [a]	1.49 [a]	1.60 [a]	1.75 [a]	1.76 [a]

* See Tab. 1.

Tab. 10 Number of seeds per pod depending on pea cultivar and its percentage in the mixture (pcs).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	4.37* [a]	3.27 [a]	4.64 [b]	3.37 [a]	3.95 [b]	3.91 [b]
60	4.66 [c]	3.42 [a]	4.50 [a]	3.46 [b]	3.78 [a]	3.78 [a]
80	4.59 [b]	3.42 [a]	4.95 [c]	4.18 [c]	3.77 [a]	3.92 [b]

* See Tab. 1.

Tab. 11 Height to the first pod and plant top and length of the fruiting part of the stem (cm).

Year	'Wiato'			'Tarchalska'		
	height to:		length of the fruiting part of the stem	height to:		length of the fruiting part of the stem
	first pod	plant top		first pod	plant top	
2011	60* [b]	81 [b]	5 [a]	63 [b]	74 [b]	6 [a]
2012	45 [a]	56 [a]	6 [a]	44 [a]	51 [a]	5 [a]
2013	64 [b]	95 [c]	28 [b]	63 [b]	100 [c]	31 [b]

* See Tab. 1.

Tab. 12 Height of spring wheat plant depending on pea cultivar and its percentage in the mixture (cm).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	88* [a]	84 [b]	73 [a]	75 [a]	69 [b]	67 [a]
60	87 [a]	81 [a]	72 [a]	73 [a]	67 [a]	67 [a]
80	86 [a]	83 [b]	74 [a]	72 [a]	70 [b]	67 [a]

* See Tab. 1.

Tab. 13 Thousand grain weight of wheat (g).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	41.2* [a]	41.4 [a]	41.4 [a]	35.9 [b]	20.0 [b]	19.5 [c]
60	41.8 [a]	41.7 [a]	38.9 [a]	37.0 [b]	21.1 [c]	18.0 [a]
80	39.9 [a]	42.3 [a]	39.6 [a]	38.9 [b]	19.5 [a]	18.8 [b]

* See Tab. 1.

Tab. 14 Number of wheat grains per plant (pcs).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	67.4* [b]	77.2 [a]	67.6 [a]	59.4 [a]	51.4 [a]	45.8 [a]
60	67.8 [b]	78.1 [b]	71.0 [b]	66.5 [b]	53.5 [c]	46.9 [b]
80	64.5 [a]	83.4 [c]	73.5 [c]	71.3 [c]	52.1 [b]	48.8 [c]

* See Tab. 1.

Tab. 15 Weight of wheat grains per plant (g).

Pea percentage (%)	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	2.76* [c]	3.13 [a]	2.33 [a]	2.04 [a]	1.00 [a]	0.81 [a]
60	2.63 [b]	3.09 [a]	2.56 [b]	2.46 [b]	1.10 [b]	0.83 [a]
80	2.56 [a]	3.19 [b]	2.90 [c]	2.77 [c]	0.99 [a]	0.88 [b]

* See Tab. 1.

Tab. 16 Concentrations of crude protein and fibre in mixture seeds depending on pea cultivar and its percentage in the mixture (%).

Pea percentage (%)	Crude protein						Fiber					
	2011		2012		2013		2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	15.6* [a]	16.6 [a]	15.3 [a]	14.9 [a]	17.8 [a]	16.8 [a]	1.59 [c]	1.69 [b]	2.92 [b]	2.96 [b]	3.52 [c]	3.55 [c]
60	17.2 [b]	18.8 [b]	16.3 [a]	15.1 [a]	18.4 [b]	18.1 [b]	1.46 [b]	1.38 [a]	2.74 [ab]	2.94 [ab]	3.35 [b]	3.46 [b]
80	17.4 [b]	18.7 [b]	18.4 [b]	18.0 [b]	19.5 [c]	19.1 [c]	1.32 [a]	1.30 [a]	2.65 [a]	2.74 [a]	3.19 [a]	3.29 [a]

* See Tab. 1.

Tab. 17 Concentrations of fat and ash in mixture seeds depending on pea cultivar and its percentage in the mixture (%).

Pea percentage (%)	Fat						Ash					
	2011		2012		2013		2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	2.37* [a]	2.49 [b]	2.27 [a]	2.64 [b]	2.50 [b]	2.42 [a]	2.04 [a]	2.33 [a]	2.02 [a]	2.01 [a]	2.71 [a]	2.92 [a]
60	2.42 [ab]	2.40 [ab]	2.30 [a]	2.63 [b]	2.44 [a]	2.45 [a]	2.32 [b]	2.52 [b]	2.13 [b]	2.15 [b]	2.92 [b]	3.21 [b]
80	2.44 [a]	2.43 [a]	2.34 [b]	2.51 [a]	2.81 [c]	2.50 [b]	2.39 [b]	2.82 [c]	2.32 [c]	2.39 [c]	3.13 [c]	3.27 [b]

* See Tab. 1.

Tab. 18 Concentrations of micronutrients (P and K) in mixture seeds depending on pea cultivar and its percentage in the mixture (%).

Pea percentage (%)	P				K			
	2011		2012		2013		2012	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Tarchalska'	'Wiato'
40	0.38* [a]	0.41 [a]	0.39 [a]	0.38 [a]	0.44 [a]	0.47 [a]	0.57 [a]	0.81 [a]
60	0.41 [b]	0.44 [b]	0.38 [a]	0.38 [a]	0.45 [a]	0.47 [a]	0.66 [a]	0.86 [b]
80	0.42 [b]	0.42 [b]	0.37 [a]	0.41 [b]	0.48 [b]	0.49 [b]	0.82 [ab]	0.95 [c]

Pea percentage (%)	K					
	2011		2012		2013	
	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'	'Wiato'	'Tarchalska'
40	0.51 [a]	0.60 [a]	0.60 [a]	0.57 [a]	0.81 [a]	0.83 [a]
60	0.61 [b]	0.82 [ab]	0.65 [a]	0.66 [a]	0.86 [b]	0.95 [b]
80	0.63 [b]	0.98 [bc]	0.76 [b]	0.82 [ab]	0.95 [c]	0.98 [c]

* See Tab. 1.

Discussion

The weather conditions during the growing season had a significant impact on the growth, development, and yield of the cereal–legume mixtures. Michalska [13] found that pea seed yield is significantly affected by weather conditions in April and the largest demand for water in developing pea plants occurs about two weeks before flowering. In young growing pea plants, water stress causes growth inhibition, a weaker growth of leaves and stems as well as a reduction in the assimilation surface of the leaves [14]. The result is a reduction in the number of flower buds set, number of pods set per plant, number of seeds per pod, and thousand seed weight [15]. Księżak and Magnuszewska [16] observed high sensitivity of pea grown in mixtures with spring cereals to a small amount of rainfall in June. Under these conditions, pea plants had a shorter flowering period and a small number of pods. Additionally, there was a significant acceleration of plant maturation, which negatively affected the proper formation of pea seeds and cereal grains. These authors [16] indicated that the obtained results showed high sensitivity of peas to a smaller amount of rainfall during the growing season. At the same time, they confirmed that under reduced soil moisture growing legume–cereal mixtures provide greater stability and a higher level of yields than the cultivation of these plants in pure stands.

Increasing the percentage of pea in the weight of sown seeds caused an increase in its percentage in the mixture yields, but only in the third year with favorable weather conditions. Siuta [17] stated that under the conditions of organic farming increasing the percentage of legumes decreased the yield of mixtures. According to this author, the yields of pea–wheat mixtures or mixtures with barley, regardless of their composition, were similar to the yields of those species in pure stands. According to Księżak [18] and Staniak et al. [11], increasing the percentage of pea seeds in the weight of sown seeds under the conditions of significant rainfall in June increases the mixture yield, regardless of the pea cultivar. Księżak [18] found that the yields of a mixture of barley with the pea varieties 'Set' and 'Terno' were very similar, while it was higher for a mixture with the semi-leafless variety 'Ramrod'. Rudnicki [19] pointed out the importance of the pea variety in determining the level of yields of mixtures with cereals. According to many authors, mixtures fertilized with mineral fertilizers yield best when pea seeds account from 30 to 50% in the mixture composition [20,21]. Księżak [22] obtained significantly higher yields of mixtures of pea with spring wheat with a 30% share of legume seeds at sowing. They decreased with increasing the percentage of pea up to 40 and 50%. Księżak and Magnuszewska [16], however, did not record any effect of increasing the percentage of pea at sowing on the seed yield of pea–wheat mixtures grown conventionally.

Increasing the percentage of pea seeds in the mixture, regardless of foliage type, increased the percentage of its seeds in the yield. Under conditions of reduced rainfall, Księżak [23] recorded a much smaller percentage of pea seeds in the yield of mixtures than the percentage of its seeds in the sowing weight.

The quality of fodder raw material obtained from the mixtures of pea with wheat was largely influenced by the percentage of seeds of the individual mixture components in the yield. Increasing the percentage of pea in the mixture yield positively affected the contents of protein, fat, and ash, but reduced the fiber content.

According to Pisulewska [24], increasing the percentage of legume seeds caused an increase in protein content in mixture seeds, while different percentages of cereals and legumes in the seeding rate did not significantly influence the protein yield. Staniak et al. [11] also found that increasing the proportion of pea seeds in the mixture yield increased the content of protein and fat and reduced the amount of fiber.

Conclusions

The seed yields of the mixtures with the semi-leafless pea 'Tarchalska' were lower than those of the mixtures with 'Wiato' with bipinnate leaves. Increasing the pea percentage in the weight of sown seeds reduced the mixture yield. The percentage of pea seeds (regardless of foliage type) in the mixture yield was significantly lower than that in the weight of sown seeds. The yield of 'Tarchalska' was lower than that of 'Wiato', whose seeds had a larger percentage in the mixture yield. Increasing the percentage of pea seeds from 40 to 80% positively influenced the number of nodes with pods per plant, number of seeds per node, and number of pods and seed weight per plant in both evaluated cultivars. In 'Tarchalska', there was also an increase in thousand seed weight. Small changes occurred in the number of pods per node, number of seeds per pod, height of pea plants, and length of the fruiting parts. Increasing the percentage of pea in the mixture yield positively affected the contents of protein, fat, and ash, but it caused a decrease in the content of fiber. The mixtures with 'Wiato' and 'Tarchalska' contained a similar amount of protein, fiber, and fat, while the mixtures with 'Tarchalska' accumulated more ash. A higher percentage of pea seeds at sowing had a little impact on the content of phosphorus in the seed yield of the mixtures, while the content of potassium slightly increased, regardless of the pea cultivar.

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Plonowanie mieszanek grochu z pszenicą jarą uprawianych ekologicznie

Streszczenie

Celem przeprowadzonych badań było określenie produkcyjności i jakości paszy mieszanek grochu z pszenicą jarą, w zależności od odmiany grochu i jego udziału w masie wysiewanych nasion uprawianych systemie rolnictwa ekologicznego.
Doświadczenie polowe z mieszankami roślin strączkowych ze zbożami jarymi przeprowadzono w Rolniczym Zakładzie Doświadczalnym Grabów (woj. mazowieckie), Polska (21°38′ E, 51°23′ N) w latach 2011–2013 w układzie podbloków losowanych (split-plot), w czterech powtórzeniach. Czynnikiem I rzędu były odmiany grochu: 'Wiato' i 'Tarchalska', a czynnikiem II rzędu udział grochu w mieszance: 40, 60 i 80%.
Oceniano plon nasion mieszanek oraz plon i strukturę plonu poszczególnych komponentów. Oznaczono także zawartość białka, włókna surowego, tłuszczu, popiołu, fosforu i potasu w ziarniakach pszenicy i nasionach grochu.
W badaniach wykazano, że badane czynniki (udział i odmiana grochu w mieszance) oraz przebieg pogody w okresie wegetacji miały znaczący wpływ na wzrost, rozwój i plonowanie grochu i pszenicy uprawianych w mieszance. Plony nasion mieszanek z wąsolistną odmianą 'Tarchalska' były mniejsze niż z odmianą 'Wiato' o tradycyjnym ulistnieniu. Zwiększenie udziału grochu w masie wysiewanych nasion powodowało ograniczenie plonu mieszanek. Udział nasion grochu (niezależnie od formy ulistnienia) w plonie mieszanek był znacznie mniejszy niż w masie wysiewanych nasion. Poziom plonowania wąsolistnej odmiany 'Tarchalska' był mniejszy niż odmiany 'Wiato', której nasiona stanowiły większy udział w plonie mieszanek. Zwiększenie

udziału grochu w plonie mieszanki korzystnie wpływało na zawartość białka i tłuszczu, ale powodowało również zwiększenie ilości popiołu i włókna. Większy udział nasion grochu przy wysiewie miał niewielki wpływ na zawartość fosforu w plonie nasion mieszanek, natomiast nieznacznie zwiększała się zawartość potasu, niezależnie od odmiany grochu.