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THE CONTENT OF PHOSPHORUS AND POTASSIUM IN MIXTURES OF FIELD PEA AND SPRING TRITICALE DETERMINE THE QUALITY OF GREEN MASS

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ABSTRACT

Background. The cultivation of mixtures of legume and cereal can bring many benefits to agriculture, among others it can provide good quality roughage for direct feeding in the form of green fodder. The aim of this study was to evaluate the effect of the share of components in the mixture of field pea with spring triticale and the harvest date on the content of phosphorus and potassium in green matter.
Material and methods. The field experiment was conducted in 2016–2018 and two factors were studied: I – the proportion of components in the mixture: field pea – clean sowing, spring triticale – clean sowing, field pea 75% + spring triticale 25%, field pea 50% + spring triticale 50%, field pea 25% + spring triticale 75%; II – harvesting date: flowering stage of field pea, flat green pod stage of field pea.
Results. The highest content of phosphorus and potassium was found in field pea, while among the mixtures, in the one with 75% of field pea and 25% of spring triticale. A higher content of the mineral elements in question was found in mixtures harvested at the field pea flowering stage compared with mixtures harvested at the stage of the flat green pod of field pea.
Conclusion. The most favourable concentration of phosphorus and potassium in green matter is provided by a mixture with 75% of field pea and 25% of spring triticale harvested at flowering stage of field pea.

Key words: field pea, harvest date, mixtures, phosphorus, potassium, spring triticale

INTRODUCTION

Green fodder grown on arable land is used primarily for feeding ruminant animals, primarily cattle. Forage management in farms focused on livestock production is one of the main factors determining its efficiency and thus the level of agricultural income. According to many authors (Stein *et al.*, 2004; Aufrere *et al.*, 2008; Brzóska and Śliwiński, 2011), the factor determining the usefulness of fodder, apart from high yield, is also its nutritive value. High-quality roughage is possible to obtain from legume – cereal mixtures, provided that the proper proportion of components, harvest date, and appropriate selection of plant varieties are used (Makarewicz *et al.*, 2015). Legume – cereal mixtures can be used for direct feeding in the form of green fodder or as silage raw material (Księżak and Staniak, 2009). In animal nutrition it is important to observe the content of mineral components in the produced fodder, which ensure the proper course of physiological functions in animals (Jankowska-Huflejt and Wróbel, 2008). Failure to provide sufficient mineral nutrients

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negatively affects the development of young animals and additionally decreases the productivity of adult animals (Jankowska-Huflejt *et al.*, 2009). Phosphorus is the second most common mineral in animals after calcium, and is responsible, together with calcium, for the ossification process and plays an important role in energy metabolism (Radwińska and Żarczyńska, 2014). According to Dittmer and Thompson (2010), cattle are more sensitive to phosphorus deficiencies in feed than sheep. Potassium, like sodium, has many important functions in the body, including regulating intracellular osmotic pressure, regulating water balance, and affecting muscle contractility and tone. Potassium deficiencies are manifested by muscle weakness, decreased feed intake and reduced performance (Radwińska and Żarczyńska, 2014). Therefore, an important element of feed management is the control and evaluation of the quality of supplied feed for ruminants. The aim of this study was to evaluate the effect of the share of components in the mixture of field pea with spring triticale and the harvest date on the content of phosphorus and potassium in green matter. It was hypothesised that the share of components in the mixture and the harvest date of mixtures of field pea and spring triticale have a significant effect on the content of phosphorus and potassium in the biomass obtained. This will allow to evaluate the difference and to choose the mixture with the highest content of phosphorus and potassium.

MATERIAL AND METHODS

The field experiment was conducted in 2016–2018 at the Agricultural Experimental Station in Zawady belonging to the University of Natural Sciences and Humanities in Siedlce. The terrain was flat, water erosion did not occur. In terms of agricultural usefulness, the soils were classified as very good rye complex, IVb class, with slightly acidic to neutral pH. The content of available mineral elements in the soil was: P 8.1 $mg \cdot 100g^{-1}$, K 12.2 $mg \cdot 100g^{-1}$, Mg 5.2 $mg \cdot 100g^{-1}$. The humus content was 1.39%. The experiment was set up in split-block design in three replications. Two factors were studied in the experiment: I – the proportion of components in the mixture: field pea – pure sowing, spring triticale – pure sowing, field pea 75% + spring triticale 25%, field pea 50% + spring triticale 50%, field pea 25% + spring triticale 75%; II – harvesting date: flowering stage of field pea (BBCH 65), flat green pod stage of field pea (BBCH 79). The detailed list of mixtures and their sowing rates is presented in Table 1.

Table 1. The detailed list of mixtures, their sowing rates and sowing density

Proportion of components in the mixture, %		Sowing rates of the mixture components, $kg \cdot ha^{-1}$		Number of sown seeds/grains per 1 m^2	
field pea	spring triticale	field pea	spring triticale	field pea	spring triticale
100	–	240	–	126	–
75	25	180	55	95	141
50	50	120	110	63	282
25	75	60	165	32	423
–	100	–	220	–	564

In autumn phosphorus and potassium fertilizers were applied in doses depending on the soil chemical composition, i.e. 34.8 $kg \cdot ha^{-1}$ P in the form of 46% triple superphosphate and 99.2 $kg \cdot ha^{-1}$ K in the form of 60% potassium salt. In spring, nitrogen fertilizers in the form of ammonium nitrate 34% were applied before sowing seeds. On all treatments, with the exception of field pea grown in pure sowing, 30 kg N·ha^{-1} was applied. At the stalk shooting stage, an additional 50 kg·ha^{-1} N was applied for spring triticale and 30 kg·ha^{-1} N for mixtures of field pea with spring triticale. The seeds of field pea (Roch cultivar) and spring triticale (Milewo cultivar) were sown in the 1st decade of April according to the first experimental factor. The plants were harvested according to the second factor of the experiment: field pea flowering stage (3rd decade of June) and field pea flat green pod stage (1st decade of July). During the harvest of mixtures, fresh weight samples were collected from each plot for chemical analyses. In the collected plant material, phosphorus and potassium contents in dry matter were determined by the inductively coupled plasma excitation-optical detector (ICP-OES) emission method using a Perkin Elmer Optima 8300 emission spectrometer.

Each of the studied characteristics was subjected to analysis of variance according to the split-block design scheme. In case of significant sources of variability, detailed comparison of means was made with the use of Tukey's Test.

Thermal and precipitation conditions in the years of the study were varied (Table 2).

Table 2. Weather conditions during the growing season of field pea/spring triticale mixtures according to the Zawady Meteorological Station

Years	Month				Means
	April	May	June	July	
	Temperature, °C				
2016	9.1	15.1	18.4	19.1	15.4
2017	6.9	13.9	17.8	16.9	13.9
2018	13.1	17.0	18.3	20.4	17.2
Long-term mean 1990–2008	8.2	14.2	17.6	19.7	14.9
	Precipitation, mm				Total
2016	28.7	54.8	36.9	35.2	155.6
2017	59.6	49.5	57.9	23.6	190.6
2018	34.5	27.3	31.5	67.1	160.4
Long-term mean sums 1990–2008	37.4	47.1	48.1	65.5	198.1

In the period from April to July 2016 an average temperature of 0.5°C higher than the multi-year average was recorded. During the entire period, precipitation was more than 40 mm lower compared to the multi-year total. In the period from April to July 2017, the average temperature in this period was 1°C lower than the multi-year average, in turn, the precipitation total was slightly lower than the multi-year total. The average temperature recorded during the analysed period in 2018 was more than 2°C higher than the multi-year average. In contrast, total precipitation was 35 mm lower than the multi-year average.

RESULTS AND DISCUSION

Phosphorus content in mixtures of field pea with spring triticale was significantly differentiated by weather conditions, share of components in the mixture, harvest date and their interaction. The highest phosphorus content was recorded in mixtures of field pea with spring triticale harvested in 2018, when the average temperature during the growing season was the highest and the rainfall was significantly below the multi-year average (Table 3).

Table 3. Phosphorus content in field pea/spring triticale mixtures according to component share in the mixture in 2016–2018, $g \cdot kg^{-1}$ d.m.

Composition of mixture, % (A)		Years (Y)			Means
field pea	spring triticale	2016	2017	2018	
100	0	4.83	4.78	5.05	4.89
75	25	4.45	4.39	4.70	4.51
50	50	3.85	3.79	4.10	3.91
25	75	3.26	3.20	3.51	3.32
0	100	2.53	2.47	2.78	2.59
Means		3.78	3.72	4.03	–
$LSD_{0.05}$ for:					
Years (Y)					0.07
Composition of mixture (A)					0.10
Interaction (Y × A)					0.18

2016 with lower average temperature and similar precipitation, and 2017 with lower average temperature and much higher precipitation revealed significantly lower phosphorus contents compared to the 2018 growing season. The increase in phosphorus content in legume – cereal mixtures in years with higher average temperature and lower total precipitation is also confirmed by studies by Staniak *et al.* (2012) and Księżak and Staniak (2013). In our study, we found significantly the highest phosphorus concentration in field pea, while it was lower in spring triticale. This results from the fact that legume plants, compared to cereals, are characterized by a higher content of macronutrients, at each developmental stage. Comparison of research results obtained by other authors (Woźniak and Makarski, 2013; Woźniak *et al.*, 2014; Jarecki and Bobrecka-Jamro, 2015; Schoebitz *et al.*, 2020; Sammama *et al.*, 2021) confirm that legume plants accumulate more phosphorus, compared to cereals. In the present experiment, among the analyzed mixtures the highest content of phosphorus was found in the mixture in which field pea constituted 75% of the components in the mixture and spring triticale 25%. It was found that the addition of field pea to the mixture with spring triticale caused a significant increase in the phosphorus content in the biomass obtained. A similar relationship in their studies on various legume – cereal mixtures was obtained by other authors (Buraczyńska and Ceglarek, 2011; Kotecki, 2014; Gill and Omokanye, 2018). In our study, the interaction of weather conditions and the share of components in the mixture was demonstrated. Significantly the highest phosphorus content was characterized by field pea in 2018, while the lowest by spring triticale in 2016–2017. Among the mixtures, significantly the highest phosphorus concentration was recorded in 2018 in the mixture with a share of 75% field pea and 25% spring triticale.

Thermal and moisture conditions significantly differentiated the phosphorus concentration in mixtures of field pea and spring triticale at the harvest dates studied (Fig. 1).

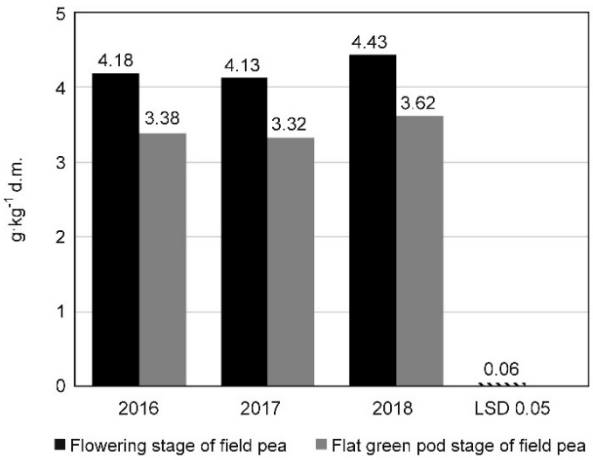

Fig. 1. Phosphorus content in field pea/spring triticale mixtures according to harvest date in the research years 2016-2018, g kg^{-1} d.m.

The highest content of this mineral component was revealed in mixtures harvested at the flowering stage of field pea in 2018, while mixtures harvested at the flat green pod stage of field pea in 2017 were significantly characterized by the lowest content.

Phosphorus content in mixtures of field pea with spring triticale was significantly modified by the harvest date (Table 4).

Analogously to the studies conducted by other authors (Wanic and Michalska, 2009; Płaza *et al.*, 2017; 2019; Peprah *et al.*, 2021), higher phosphorus content was recorded in the green matter of legume – cereal mixtures harvested at an earlier developmental stage of the legume plant. Mixtures harvested at the flowering stage of field pea plants had significantly higher phosphorus concentrations compared to those harvested at the flat green pod stage of field pea plants. An interaction was found in which field pea at flowering concentrated the most phosphorus, while the lowest content of this macroelement was observed in spring triticale harvested at the stage of flat green field pea pod. Among the mixtures, the significantly highest content of phosphorus was found in the mixture with 75% of field pea component and 25% of spring triticale harvested at the flowering stage of field pea.

Statistical analysis revealed a significant effect of growing season conditions, the experimental factors studied and their interactions on potassium content in mixtures of field pea and spring triticale. Significantly highest potassium concentration was revealed in mixtures harvested in 2018, which recorded the highest average air temperature, and precipitation sum significantly below the multi-year average (Table 5).

Table 4. Phosphorus content in field pea/spring triticale mixtures (means across 2016–2018), g·kg^{-1} d.m.

Composition of mixture, % (A)		Harvest date (B)	
field pea	spring triticale	flowering stage of field pea	flat green pod stage of field pea
100	0	5.29	4.48
75	25	4.92	4.10
50	50	4.31	3.52
25	75	3.71	2.94
0	100	3.00	2.18
Means		4.25	3.44
$LSD_{0.05}$ for:			
Harvest date (B)			0.03
Interaction (A × B)			0.12

Table 5. Potassium content in field pea/spring triticale mixtures according to component share in the mixture in 2016–2018, $g \cdot kg^{-1}$ d.m.

Composition of mixture, % (A)		Years (Y)			Means
field pea	spring triticale	2016	2017	2018	
100	0	36.1	34.6	39.5	36.8
75	25	34.3	33.0	37.9	35.0
50	50	30.6	29.3	34.2	31.3
25	75	27.6	26.3	31.0	28.3
0	100	24.3	23.0	27.9	25.0
Means		30.6	29.2	34.1	–
$LSD_{0.05}$ for:					
Years (Y)					0.4
Composition of mixture (A)					0.6
Interaction (Y × A)					1.0

On the other hand, the lower potassium concentration was recorded in mixtures harvested in 2016, while it was significantly lowest in mixtures harvested in 2017, which was characterized by the highest rainfall sum and the lowest temperature during the crop growing season. Also Księżak and Staniak (2009) in their study found lower potassium concentration in legume and cereal mixtures in years with higher sum of precipitation. Similar results in the case of lupine seeds were obtained by Carvalho (2005), who found significantly higher potassium concentration in plants subjected to water deficits. In our study the share of components in the mixture also significantly differentiated the potassium content. Field pea grown in pure sowing was characterized by the highest concentration of this macro element, spring triticale by the lowest. Also Fordoński *et al.* (2015) and Szpunar-Krok *et al.* (2009) revealed higher potassium concentration of legume plants compared to cereals. In our study, it was shown that increasing the share of the legume component in the mixture resulted in a significant increase in potassium content in the biomass obtained. Similarly Mut *et al.* (2017) and Zaeem *et al.* (2021) observed in their experiment on maize mixtures with legume plants an increase in potassium content in biomass with increasing the share of the legume component in the mixture. Also by other authors (Buyankin and Krasnoperov, 2020; Turan *et al.*, 2020; Arif *et al.*, 2022) in their study revealed an increase in potassium concentration in mixtures with an increase in the share of sown legume plants. In our study the highest concentration of this mineral component was found in the mixture with 75% share of field pea and 25% share of spring triticale. The obtained results also confirm the studies of other authors (Staniak *et al.*, 2012; Księżak *et al.*, 2016). In our own studies, the interaction of weather conditions and the share of components in the mixture was demonstrated. Seed field pea harvested in 2018 concentrated the most potassium. The significantly lowest potassium content was revealed in 2017 in spring triticale grown in pure sowing. Among mixtures, the highest concentration of this macronutrient was revealed with 75% of field pea and 25% of spring triticale in 2018.

Weather conditions significantly modified potassium content in mixtures of field pea and spring triticale at the analyzed harvest dates (Fig. 2).

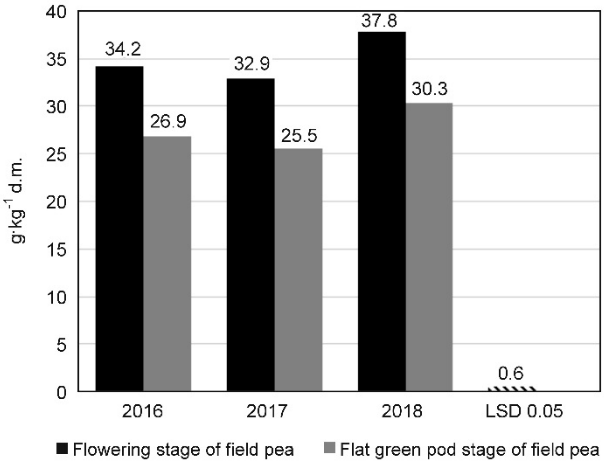

Fig. 2. Potassium content in field pea/spring triticale mixtures according to harvest date in the research years 2016–2018, g kg^{-1} d.m.

The highest concentration of potassium was recorded in mixtures harvested at the flowering stage of field pea in 2018, while the lowest concentration was observed in mixtures from 2017 harvested at the flat green pod stage of field pea.

Potassium content in mixtures of field pea and spring triticale was also significantly differentiated by harvest date (Table 6).

The highest potassium content was revealed in mixtures harvested at the flowering stage of field pea. Delaying the harvest date to the flat green pod stage induced a significant decrease in potassium concentration. The obtained relationship is confirmed in the studies of other authors (Wanic and Michalska, 2009; Płaza *et al.*, 2017; 2019) In the present experiment, the interaction of the share of components in the mixture and the harvest date was demonstrated. Indeed, the highest potassium content was recorded in field pea harvested at the flowering stage, while the lowest was revealed in spring triticale harvested at a later stage of the legume plant development, i.e. at the stage of the flat green pod of field pea. Among the mixtures, the highest potassium concentration was revealed for the mixture with the following share of components: 75% field pea and 25% spring triticale harvested at the flowering stage of field pea.

Table 6. Potassium content in field pea/spring triticale mixtures (means across 2016–2018), g·kg^{-1} d.m.

Composition of mixture, % (A)		Harvest date (B)	
field pea	spring triticale	flowering stage of field pea	flat green pod stage of field pea
100	0	41.0	32.6
75	25	39.0	31.1
50	50	35.1	27.6
25	75	31.9	24.7
0	100	28.1	22.0
Means		35.0	27.6
$LSD_{0.05}$ for:			
Harvest date (B)			0.3
Interaction (A × B)			0.5

CONCLUSIONS

The highest content of phosphorus and potassium was found in field pea, while the lowest in spring triticale. Among the mixtures, the highest content of phosphorus and potassium was found in the mixture with 75% of field pea and 25% of spring triticale. A higher content of phosphorus and potassium was found in mixtures harvested at the flowering stage of field pea than in mixtures harvested at the flat green pod stage of field pea. The green matter of field pea-triticale mixtures was characterized by a higher concentration of phosphorus and potassium under conditions with less precipitation during the growing season. The highest content of phosphorus and potassium in green matter is provided by a mixture with 75% of field pea and 25% of spring triticale harvested at the flowering stage of field pea. In order to obtain valuable fodder for livestock with the highest content of phosphorus and potassium, a mixture with 75% of field pea and 25% of spring triticale should be recommended for cultivation. The crop should be collected in the flowering stage of the legume plants.

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ZAWARTOŚĆ FOSFORU I POTASU W MIESZANKACH GROCHU SIEWNEGO Z PSZENŻYTEM JARYM UPRAWIANYCH NA ZIELONĄ MASĘ

Streszczenie

Uprawa mieszanek bobowato-zbożowych może przynieść wiele korzyści rolnictwu, między innymi mogą one stanowić dobrej jakości paszę objętościową do bezpośredniego skarmienia w postaci zielonki. Celem badań była ocena wypływu udziału komponentów w mieszance grochu siewnego z pszenżytem jarym oraz terminu zbioru na zawartość fosforu i potasu w zielonej masie. Doświadczenie polowe przeprowadzono w latach 2016–2018. Badano dwa czynniki: I – udział komponentów w mieszance: groch siewny – siew czysty, pszenżyto jare – siew czysty, groch siewny 75% + pszenżyto jare 25%, groch siewny 50% + pszenżyto jare 50%, groch siewny 25% + pszenżyto jare 75%; II – termin zbioru: faza kwitnienia grochu siewnego, faza płaskiego zielonego strąka grochu siewnego. Najwyższą zawartość fosforu i potasu ujawniono w grochu siewnym, zaś spośród mieszanek – w mieszance o 75% udziale grochu siewnego i 25% udziale pszenżyta jarego. Wyższą zawartość omawianych składników mineralnych wykazywały mieszanki zebrane w fazie kwitnienia grochu siewnego w porównaniu z mieszankami zebranymi w fazie płaskiego zielonego strąka grochu siewnego. Najkorzystniejszą koncentrację fosforu i potasu w zielonej masie zapewnia mieszanka z 75% udziałem grochu siewnego i 25% udziałem pszenżyta jarego, zebrana w fazie kwitnienia grochu siewnego.

Słowa kluczowe: fosfor, groch siewny, mieszanka, potas, pszenżyto jare, termin zbioru