YIELD AND CHEMICAL COMPOSITION OF FIELD PEA/OAT (*PISUM SATIVUM* L./*AVENA SATIVA* L.) MIXTURES GROWN FOR GREEN MATTER

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(Received 28th Jan 2019; accepted 6th Mar 2019)

Abstract. The paper presents results of a research conducted between 2010 and 2012 to determine the effect of the proportion of components in a mixture and harvest date on yield and chemical composition of field pea/oat (*Pisum sativum* L., *Avena sativa* L.*)* mixtures. Two factors were examined in the study: factor I − proportion of components in a mixture: field pea 100%, oat 100%, field pea 75% + oat 25%, field pea 50% + oat 50%, field pea 25% + oat 75%; factor II − harvest date: the stage of field pea flowering and the stage of flat green pod of field pea. The following characteristics were examined: green matter yield of field pea/oat mixtures, nutrient content, NDF and ADF content. The results were statistically analysed. The highest fresh matter yield was produced by the 50% + 50% mixture of field pea and oat. Field pea/oat mixtures harvested at the stage of field pea flowering contained more total protein, crude ash and digestible nitrogen-free extracts. The mixtures harvested at the stage of flat green pod of field pea were higher in crude fibre, fibre fractions (NDF, ADF) and crude fat.
Keywords: *nutrient content, crude fibre, total protein, crude ash, fresh matter*

Introduction

Crop plants cultivated in mixtures usually produce higher yields compared to pure stands (Księżak and Staniak, 2013). It is the result of better utilisation of habitat conditions, including minerals and water from soil reserves. Spring cereals use roots to penetrate the surface soil layer whereas legumes reach the deeper layer. Also, plant species have different periods of critical demand for water and nutrients (Rutkowska and Pikuła, 2016).

Pisum sativum L. is a valuable component of legume/cereal mixtures. As the species includes various morphological forms (short or long stem, leafed and narrow-leafed), its potential to be mixed with spring cereals varies. Leafed cultivars seem to be the most suited to cultivation for green matter (Blagojevic et al., 2017). Oat may be a component mixed with field pea and sown on soils representing the rye good complex. One of its advantages is lower soil requirements compared with other cereal species (Shoaib et al., 2013).

A major issue which needs to be considered when cultivating legume/cereal mixtures is selection of an optimal harvest date which, paired with plant growth stage, makes it possible to rationally use the obtained yield. Also, when cultivating mixtures, one has to pay attention to nutrient content which determines the quality of harvested livestock feed. Feed digestibility is limited by plant cell wall components called fractions of neutral detergent fibre (NDF) and acid detergent fibre (ADF). Many authors (Rodrigues et al., 2008; Belanger et al., 2013; Stejskalova et al., 2013; Truba et al., 2017) believe

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1705_1026710276
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that modern livestock feeding systems (of cows in particular), take into account neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents instead of or in addition to crude fibre. There are few works which assess the nutritive value of *Pisum sativum* L./*Avena sativa* L. mixtures in terms of the content of NDF and ADF fractions. The present paper is an attempt to at least partially fill this gap. The objective of the work is to determine the effect of the proportion of components in a mixture and harvest date on yielding and chemical composition of *Pisum sativum* L./*Avena sativa* L.

Materials and methods

Field research was conducted between 2010 and 2012 at the Zawady Experimental Farm (52°03' 39" N, 22° 33' 80" E) which belongs to Siedlce University of Natural Sciences and Humanities. The experimental soil was Albic Luvisol (Arenic), its reaction was neutral and it had average available phosphorus, potassium and magnesium contents. Humus content was 1.37%. The experimental design was a split-plot arrangement with three replicates. Two factors were examined in the study: factor I − proportion of components in a mixture: field pea 100%, oat 100%, field pea 75% + oat 25%, field pea 50% + oat 50%, field pea 25% + oat 75%; factor II − harvest date: the stage of field pea flowering, the stage of flat green pod of field pea. A detailed description of the mixtures and their sowing rates is as follows: field pea 170 kg$\circ$ha^{-1}, oat 180 kg$\circ$ha^{-1}, field pea 128 kg$\circ$ha^{-1} + oat 45 kg$\circ$ha^{-1}, field pea 85 kg$\circ$ha^{-1} + oat 90 kg$\circ$ha^{-1}, field pea 43 kg$\circ$ha^{-1} + oat 135 kg$\circ$ha^{-1}.

Each study years, the mixtures were preceded by winter triticale. In autumn, phosphorus and potassium fertilisers were applied at the rates of pure element dependent on the soil chemical composition, i.e.: 35.2 kg$\circ$ha^{-1} P and 99.6 kg$\circ$ha^{-1} K. In spring, nitrogen fertiliser, at the rate of 30 kg$\circ$ha^{-1} N, was applied to all the units (excluding pure stand field pea) prior to seed sowing. An additional N rate, 50 and 30 kg$\circ$ha^{-1}, was applied to oat and field pea/oat mixtures, respectively, at the stage of stem elongation. Seeds of field pea cv. Roch and oat cv. Zuch were sown in early April. Harvest was performed in late June (the stage of field pea flowering) and early July (the stage of flat green pod of field pea). During harvest, fresh matter yield was determined in each plot, and average fresh matter samples were collected to perform chemical analyses. The following characteristics were determined in the dry matter of the plant material sampled: total protein, crude ash, crude fibre and contents of fractions of neutral detergent fibre and acid detergent fibre (by near-infrared reflectance spectrometry NIRS using a NIRFlex N-500 spectrometer) as well as crude fat (by Soxlet method). Based on the determined nutrient contents, digestible nitrogen-free extracts were calculated as a difference between four components and the sum 1000.

Each characteristic studied was subjected to variance analysis appropriate for the split-block design. Tukey test was used to separate means when significant sources of variation had been found.

Results

The fresh matter yield content of field pea/oat mixtures

The fresh matter yield of field/oat was significantly affected by the experimental factors and their interaction (*Table 1*). The highest fresh matter yield was produced by

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the 50% + 50% mixture of field pea and oat. Yields of the remaining mixtures were significantly lower. The yield of oat fresh matter was significantly higher compared with the 75% + 25% mixture. The highest fresh matter yield was produced by field pea grown in pure stand. Harvest date had a significant effect on fresh matter yield, it being higher for field pea/oat mixtures harvested at the stage of flat green pod of field pea compared with mixtures harvested at the stage of field pea flowering. An interaction was confirmed indicating that the highest fresh matter yield was produced by the 50% + 50% mixture of field pea and oat harvested at the stage of flat green pod of field pea, it being the lowest for pure stand field pea harvested at the flowering stage.

Table 1. *Fresh matter yield of field pea/oat mixtures (means across 2010-2012), t∘ha^{-1}*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	58.2a	70.9a	64.6a
0	100	64.5c	76.8c	70.7c
75	25	62.1b	72.8b	67.5b
50	50	69.5e	80.9d	75.2d
25	75	66.7d	75.3c	71.0c
Means		64.2A	75.3B	-

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The total protein content of field pea/oat mixtures

Statistical analysis revealed a significant influence of the experimental factors and their interaction on total protein content in field pea/oat mixtures (*Table 2*). The highest concentration of total protein was recorded in field pea cultivated in pure stand. Mixtures had a lower total protein content; of these the 75% + 25% mixture had the highest content of this component. An increase in the proportion of oat in the mixture was followed by a decline in total protein content, it being the lowest in pure stand oat. Harvest date had a significant effect on total protein content in mixtures. Field pea/oat mixtures harvested at the stage of field pea flowering had a higher concentration of total protein than mixtures harvested at the stage of flat green pod. An interaction was detected which indicated that pure stand field pea harvested at the flowering stage had the highest total protein content, it being the lowest in pure stand oat and field pea/oat mixtures with the component proportion of 50% + 50% and 25% + 75% harvested at the stage of flat green pod of field pea.

The crude fibre content of field pea/oat mixtures

Crude fibre content in field pea/oat mixtures was significantly affected by the experimental factors and their interaction (*Table 3*). The lowest crude fibre content was determined in pure stand field pea, it being the highest in oat. The presence of oat in mixtures with field pea contributed to an increase in crude fibre content. Of the test mixtures, the highest crude fibre content was recorded in the 75 + 25% and 50 + 50% mixtures. Also, harvest date had a significant effect on crude fibre content in mixtures

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which was higher in mixtures harvested at the stage of flat green pod of field pea than the stage of field pea flowering. An interaction between the experimental factors was confirmed. It indicated that the lowest crude protein content was characteristic of pure stand field pea and the 75 + 25% mixture, both harvested at the stage of field pea flowering, it being the highest in oat cultivated in pure stand and harvested at the stage of flat green pod of field pea.

Table 2. *Total protein content in field pea/oat mixtures (means across 2010-2012), g⊙kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage field of pea	
100	0	146c	140c	143c
0	100	128a	118a	123a
75	25	134b	126b	130b
50	50	130a	122a	126a
25	75	128a	121a	125a
Means		133B	125A	-

Values in columns followed by the same small letter and values in rows followed by the same capital letter do not differ significantly at $P < 0.05$

Table 3. *Crude fibre content in field pea/oat mixtures (means across 2010-2012), g⊙kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	234a	259a	247a
0	100	276c	306d	291d
75	25	243a	263a	253a
50	50	252b	275b	264b
25	75	268c	287c	278c
Means		255A	278B	-

Values in columns followed by the same small letter and values in rows followed by the same capital letter do not differ significantly at $P < 0.05$

The neutral detergent fibre (NDF) content of field pea/oat mixtures

Statistical analysis revealed a significant influence of the experimental factors and their interaction on the content of neutral detergent fraction (NDF) in field pea/oat mixtures (*Table 4*). The lowest NDF content was recorded in field pea cultivated in pure stand, it being the highest in oat. As the proportion of field pea in mixture was reduced and oat proportion increased, an increase in the NDF content was observed. Of the test mixtures, the lowest NDF content was determined in the 75 + 25% mixture. Harvest date had a significant effect on NDF content in field pea/oat mixtures. The content was lower in mixtures harvested at the field pea flowering stage than at the stage of flat

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DOI: http://dx.doi.org/10.15666/aeer/1705_1026710276
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green pod. There was observed an interaction between the experimental factors which indicated that the lowest NDF content was recorded in pure stand field pea and harvested at the flowering stage, it being the highest in oat harvested at the stage of flat green pod of field pea.

Table 4. *Neutral detergent fibre (NDF) content in field pea/oat mixtures (means across 2010-2012), g⊙kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	400a	486a	443a
0	100	519e	629e	574e
75	25	431b	511b	471b
50	50	456c	548c	502c
25	75	479d	582d	531d
Means		457A	551B	-

Values in columns followed by the same small letter and values in rows followed by the same capital letter do not differ significantly at $P < 0.05$

The acid detergent fibre (ADF) content of field pea/oat mixtures

The content of acid detergent fibre (ADF) was significantly influenced by the experimental factors and their interaction (*Table 5*). The lowest ADF content was recorded in field pea cultivated in pure stand and the highest in oat. The more oat was added to the mixture, the higher the ADF content. Of the test mixtures, the lowest ADF content was recorded in the 75 + 25% mixture of field pea and oat. A interaction was detected indicating that the lowest ADF content was characteristic of pure stand field pea harvested at the flowering stage, it being the highest in oat harvested at the stage of flat green pod of field pea.

Table 5. *Acid detergent fibre (ADF) content in field pea/oat mixtures (means across 2010-2012), g⊙kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	303a	334a	319a
0	100	359d	387d	373e
75	25	318b	340a	329b
50	50	326b	354b	340c
25	75	341c	369c	355d
Means		329A	357B	-

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The crude fat content of field pea/oat mixtures

Statistical analysis demonstrated a significant effect of the experimental factors and their interaction on crude fat content in field pea/oat mixtures (*Table 6*). The highest crude fat content was determined in pure stand oat, it being the lowest in field pea. An addition of oat to mixtures with field pea contributed to an increase in crude fat content. Of the test mixtures, the highest crude fat content was recorded in the 25 + 75% mixture. Harvest date had a significant effect on crude fat content in mixtures. More crude fat was determined in mixtures harvested at the stage of flat green pod of field pea compared with the flowering stage. An interaction was found: the highest crude fat content was determined in oat cultivated in pure stand and harvested at the stage of flat green pod of field pea, it being the lowest in field pea harvested at the flowering stage.

Table 6. *Crude fat content in field pea/oat mixtures (means across 2010-2012), g◎kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	24.0a	25.5a	24.8a
0	100	29.6e	30.6e	30.1e
75	25	25.7b	27.0b	26.4b
50	50	27.1c	28.3c	27.7c
25	75	28.5d	29.4d	29.0d
Means		27.0A	28.2B	-

Values in columns followed by the same small letter and values in rows followed by the same capital letter do not differ significantly at $P < 0.05$

The crude ash content of field pea/oat mixtures

Crude ash content in field pea/oat mixtures was significantly affected by the proportion of components in a mixture, harvest date and their interaction (*Table 7*). Pure stand field pea and the 75 + 25% mixture had the highest crude ash content, it being the lowest in pure stand oat. In the remaining mixtures, crude ash content was lower than in field pea, and it differed insignificantly from oat content. Harvest date had a significant effect on crude ash content in mixtures. A higher concentration of crude ash was recorded in field pea/oat mixtures harvested at the stage of field pea flowering compared with the stage of flat green pod of field pea. There was found an interaction between the experimental factors which indicated that the highest crude ash content was determined in field pea cultivated in pure stand as well as mixed with oat at the following proportions: 75 + 25% and 50 + 50% and harvested at the flowering stage, it being the lowest in oat and the 50 + 50% and 25 + 75% mixtures of field pea and oat harvested at the stage of flat green pod of field pea.

The digestible nitrogen-free extracts of field pea/oat mixtures

Statistical analysis demonstrated a significant influence of the experimental factors and their interaction on digestible nitrogen-free extracts in field pea/oat mixtures (*Table 8*). The highest content of digestible nitrogen-free extracts was determined in the 75 + 25% and 50 + 50% mixtures of field pea and oat, it being the lowest in pure stand

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DOI: http://dx.doi.org/10.15666/aeer/1705_1026710276
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oat and the 25 + 75% mixture. Harvest date had a significant effect on digestible nitrogen-free extracts in field pea/oat mixtures.

Table 7. *Crude ash content in field pea/oat mixtures (means across 2010-2012), g⊙kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	84.2b	73.8b	79.0b
0	100	79.2a	68.3a	73.8a
75	25	82.9b	72.1b	77.5b
50	50	81.0a	70.7a	75.9a
25	75	80.3a	69.0a	74.7a
Means		81.5B	70.8A	-

Values in columns followed by the same small letter and values in rows followed by the same capital letter do not differ significantly at $P < 0.05$

Table 8. *Digestible nitrogen-free extracts in field pea/oat mixtures (means across 2010-2012), g⊙kg^{-1} d.m.*

Proportion of components in the mixture, % (I)		Harvest date (II)		Means
Pea	Oat	Flowering stage of field pea	Flat green pod stage of field pea	
100	0	512b	502b	507b
0	100	529c	477a	503b
75	25	514b	512c	513c
50	50	510b	504c	507b
25	75	495a	494b	495a
Means		512B	498A	-

Values in columns followed by the same small letter and values in rows followed by the same capital letter do not differ significantly at $P < 0.05$

Their concentration was higher in mixtures harvested at the stage of field pea flowering compared with the stage of flat green pod of field pea. There was found an interaction between the experimental factors indicating that the highest content of digestible nitrogen-free extracts was determined in pure stand oat harvested at the stage of field pea flowering, and the lowest in pure stand oat harvested at the stage of flat green pod of field pea.

Discussion

Legume/cereal mixtures are predominantly grown for grain and fodder seed but they can be successfully cultivated for green matter to be used as fodder for cattle. On light soils, which predominate in Poland, field pea and oat may be valuable components used for cultivation in mixtures. In the present study, the highest fresh matter yield was

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produced by the 50 + 50% mixture of field pea and oat. According to Huńady and Hochman (2014), mixtures of field pea (60%) with wheat or spring barley had the highest yields. Also Bedoussac and Justes (2009), Eskandari et al. (2009), Neuman et al. (2009), Kontturi et al. (2011), Księżak and Staniak (2013), Bojarczuk et al. (2014) and Neugschwandtner et al. (2014) demonstrated that mixed stands produce better yields than pure stands as mixtures are better at utilising changeable habitat conditions. In the experiment reported here, the fresh matter yield of the remaining mixtures was significantly lower although still higher than pure stand field pea. Harvest date had a significant effect on the fresh matter yield of field pea/oat mixtures. The yield was higher for mixtures harvested at the stage of flat green pod of field pea. Also studies by Staniak et al. (2012), Bojarczuk et al. (2014) and Rutkowska and Pikuła (2016) revealed that legume/cereal mixtures harvested at a later growth stage produced more biomass.

In the present study, the highest total protein content, crude ash content and digestible nitrogen-free extracts were found in pure stand field pea and in the 75 + 25% mixture of field pea and oat. Also Lithourgidis et al. (2006), Eskandari et al. (2009), Alizahed and Jat (2013), Huńady and Hochman (2014) Neugschwandtner and Kaul (2016) and Blagojevic et al. (2017) reported that leguminous plants grown in pure stand or constituting a high proportion in mixtures with cereals, oat in particular, produced the highest quality green fodder. In the study discussed here, pure stand field pea had the lowest crude fat content as well as the content of neutral detergent fibre (NDF) fraction and acid detergent fibre (ADF) fraction. Also Lithourgidis et al. (2006) found that common vetch cultivated in pure stand and in mixtures with spring triticale or oat had the lowest content of crude fibre and its fractions. In the study reported here, pure stand oat contained the most crude fibre, NDF, ADF and crude fat. According to many authors (Shoaib et al., 2013; Płaza et al., 2017), oat is the cereal that has the highest crude fat content. Also, cereals contain more crude fibre compared with legumes, which makes them less digestible. The factors which limit livestock feed uptake and digestibility include components of plant cell walls which are determined as fractions of neutral detergent fibre (NDA) and acid detergent fibre (ADF) (Belanger et al., 2013; Baert and Van Was, 2014; Truba et al., 2017).

Harvest date is a factor which affects nutrient content and, as a result, livestock feed quality. In the present study, field pea/oat mixtures harvested at the stage of field pea flowering contained more total protein, crude ash and digestible nitrogen-free extracts, which corresponds to findings reported by Lithourgidis et al. (2006), Shoaib et al. (2013), Płaza et al. (2017) and Uzun et al. (2017). In the experiment reported here, green fodder harvested at the earlier growth stage was of better quality, contained less crude fibre and fibre fractions, which made the green fodder more digestible. Research by Lithourgidis et al. (2006), Pires et al. (2006), Rondahl et al. (2006), Rutkowska et al. (2016) and Płaza et al. (2017) demonstrated that legume/cereal mixtures harvested at later development stages were of poorer quality. Primarily, they contained more crude fibre which reduces livestock feed digestibility. However, with fresh matter yield in mind, later harvest of legume/cereal mixtures, that is at the stage of flat green pod of field pea, should be encouraged. The highest fresh matter yield was produced by the 50 + 50% mixture of field pea and oat, and the most favourable chemical composition was determined for the 75 + 25% mixture.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1705_1026710276
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Conclusions

1. The highest fresh matter yield was produced by the 50 + 50% mixture of field pea and oat.

2. Field pea grown in pure stand and mixed with oat at the proportion of 75 + 25% contained the most total protein, crude ash and digestible nitrogen-free extracts.

3. Pure stand oat had the highest crude fibre content, NDF, ADF and crude fat.

4. Field pea/oat mixtures harvested at the stage of field pea flowering contained more total protein, crude ash and digestible nitrogen-free extracts whereas mixtures harvested at the stage of flat green pod of field pea had more crude fibre, NDF, ADF and crude fat.

5. For further research, the selection of other species of legumes and cereals for cultivation in mixtures should be recommended. It will be very important to broaden the research with the features that define the feed value of the mixtures, i.e. the digestibility of the organic matter and the digestibility of the dry matter. The green matter from mixtures of legume and cereal plants can be used for silage used in cattle feeding.

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http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1705_1026710276
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