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DRY MATTER AND PROTEIN YIELD IN MIXTURES OF PEA WITH OAT GROWN FOR GREEN FORAGE

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ABSTRACT

Background. Legume-cereal mixtures grown for green forage are a valuable source of high protein feed for ruminants. This paper presents the results of a study from 2009-2011 aimed at determining the effect of the proportion of components in a mixture and the time of harvest on dry matter yield as well as on the content and yield of total protein of field pea mixtures with oat grown for green forage.

Material and methods. Two factors were considered in the experiment: (I) the proportion of components in the mixture: field pea – pure sowing 100%, oat – pure sowing 100%, field pea 75% + oat 25%, field pea 50% + oat 50%, field pea 25% + oat 75% and (II) the time of harvesting: field pea flowering stage, field pea flat green pod stage. During harvesting the mixtures, the yield was determined and mean fresh matter samples were taken from each plot for chemical analyses. In the collected plant material, the content of dry matter and total protein was determined.

Results. The dry matter yield, the content and yield of total protein of field pea and oat mixtures were significantly differentiated by the weather conditions, experimental factors and their interaction. The highest yields of dry matter and total protein were obtained from the pea and oat mixture with the proportion of components 50% + 50% harvested at the field pea flat green pod stage.

Conclusion. Field pea grown in pure sowing harvested at the flowering stage was characterized by the highest total protein content. The field pea and oat mixtures contained less total protein. Among them, the mixture of field pea with oats with the proportion of components 75% + 25% was characterized by the highest content of total protein.

Key words: proportion of components in mixture, time of harvesting, yield, total protein content, protein yield, pea developmental stage

INTRODUCTION

Legume-cereal mixtures grown for green forage are a valuable source of high protein feed for ruminants (Borowiecki and Księżak, 1998, 2001; Ceglarek *et al*., 1997; Carr *et al*., 2004; Płaza *et al*., 2014). The quantity of yield and the total protein content are determined by the species composition of the mixture, the proportion of components in the mixture and the date of harvesting (Borowiecki and Księżak, 2000; Buraczyńska *et al*., 2004; Lithourgidis *et al*., 2006). Among the Fabaceae plants, pea is distinguished by a high biomass yield. However, this is a species with slender stems, therefore it should be grown with cereal plants that act as supporting plants (Ceglarek *et al*., 1994a; Chen *et al*., 2004). Of cereals, oat is recommended for cultivation in light soils (Buraczyńska and Ceglarek, 2009). Such mixtures are distinguished by favourable qualities. The introduction of a crop fixing free nitrogen from the atmosphere into

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cultivation allows for reducing nitrogen fertilization. The expenditures related to crop protection are also limited as compared with pure cereal sowing or even leguminous plants. The short growing period of mixtures contributes to achieving a good site for winter crops, such as oilseed rape or triticale. A very advantageous feature of growing such mixtures are their productive and agrotechnical values (Borowiecki and Księżak, 2000, 2001).

The research hypothesis assumes that the proportion of components in the pea and oat mixture and the date of harvesting have a significant effect on the yield of dry matter and total protein, and their appropriate combination will allow for obtaining green forage with the optimal content and yield of total protein.

The aim of this study was to determine the effect of the proportion of components in the mixture and the date of harvesting on dry matter yield and the content and yield of total protein in mixtures of pea with oat grown for green forage.

MATERIAL AND METHODS

The field experiment was carried out in 2009-2011 at the Agricultural Experimental Station in Zawady (50°20' N; 22°30' E), belonging to the University of Natural Sciences and Humanities in Siedlce. The study was carried out in podzolic soil, with the neutral pH and a medium content of available phosphorus, potassium and magnesium. The content of humus was 1.38%. The experiment was established in the split-block design with three replications. Two factors were investigated:

I – the proportion of components in the mixture: field pea – pure sowing 100%, oat – pure sowing 100%, field pea 75% + oat 25%, field pea 50% + oat 50%, field pea 25% + oat 75% and

II – the time of harvesting: field pea flowering stage, field pea flat green pod stage.

The following sowing rates were used: field pea 170 kg·ha^{-1}, oat 180 kg·ha^{-1}, field pea 128 kg·ha^{-1} + oat 45 kg·ha^{-1}, field pea 85 kg·ha^{-1} + oat 90 kg·ha^{-1}, field pea 43 kg·ha^{-1} + oat 135 kg·ha^{-1}.

In all the years of research, the previous crop for mixtures was winter triticale. After the harvest of the previous crop, complete after-harvest soil treatment was performed. In the autumn, phosphorus-potassium fertilizers were applied at rates dependent on the chemical composition of the soil, i.e. 35.2 kg·ha^{-1} P and 99.6 kg·ha^{-1} K. In the spring before sowing the seeds, nitrogen fertilizers were applied at a rate of 30 kg·ha^{-1} N, on all treatments except for field pea grown in pure sowing. During the shooting stage, an additional 50 kg·ha^{-1} N under oat and 30 kg·ha^{-1} N under the pea and oat mixtures were applied. The seeds of field pea (the cultivar Roch) and oat (the cultivar Zuch) were sown on the first ten days of April. Field pea and oat were sown separately, and plant harvesting was performed between the 21st and the 30th June (pea flowering stage) and between the 1st and the 10th of July (pea flat green pod stage). During the harvest of mixtures, the yield of fresh matter was determined on each plot and mean samples were collected to perform chemical analyses. In the collected plant material, the content of dry matter was determined by the oven-drying method and the total protein content by the Kjeldahl method. The dry matter yield was calculated by multiplying the fresh matter yield by the dry matter content, and the total protein yield by multiplying the dry matter yield by the total protein content.

Each of the studied traits was analysed by variance analysis according to the split-block design diagram. For significant sources of variability, a detailed comparison of the treatment means was made using Tuckey's test. For statistical calculations, the author's own algorithms written in MS Excel 7.0 were used.

The years of the study were characterized by a significant variation in the weather conditions (Table 1). During the growing period of 2009, the mean monthly temperature in April was higher than the long-term mean, and in May and June it was lower than the mean. A significant shortage of rainfall was recorded in April. However, heavy rainfall occurred in May and June. In 2010, mean air temperatures during the growing period fluctuated around the mean long-term temperatures. The precipitation totals, except for April, were higher than the mean long-term total precipitation. This year should be regarded as favorable for cultivation of mixtures of field peas with oat. In 2011, the mean monthly air temperatures slightly differed from the

mean long-term temperatures. However, the rainfall totals were lower than the mean long-term totals, except for July, where the recorded precipitation was 120.2 mm. For this reason, this year was disadvantageous for the cultivation of pea and oat mixtures.

Table 1. Pluvio-thermal conditions in the growing season of pea and oat mixtures in 2009–2011 acc. to the Meteorological Station in RSD Zawady

Year	Month				Mean
	April	May	June	July	
			Temperature, °C		
2009	10.3	12.9	15.7	19.4	14.6
2010	8.9	14.0	17.4	21.6	15.5
2011	10.1	13.4	18.1	18.3	15.0
Long-term mean 1990-2005	8.2	14.2	17.6	19.7	14.9
			Precipitation, mm		
2009	8.1	68.9	145.2	26.4	248.6
2010	10.7	93.2	62.6	77.0	243.5
2011	31.0	36.1	39.1	120.2	226.4
Long-term mean 1990-2005	37.4	47.1	48.1	65.5	198.1

RESULTS

The dry matter yield of pea and oat mixtures was significantly differentiated by the weather conditions, experimental factors and their interactions.

In 2009-2010 a higher dry matter yield was obtained than in the unfavourable, dry 2011 (Table 2). The yields of pea and oat mixtures varied and also depended on the proportion of components. All the mixtures gave better yields than field pea grown in pure sowing. Of them, the highest dry matter yield was obtained from the mixture of pea and oat with the participation of components 50% + 50%, and significantly lower from the other mixtures. Oat grown in pure sowing gave lower yields than mixtures, while the lowest – field pea grown in pure sowing. Interaction of the years with the proportion of components in the mixture has been demonstrated, which shows that the highest dry matter yield was obtained in 2009 and 2010 from the mixture of field pea with oat with the proportion of components 50% + 50%. In 2011, the dry matter yield of mixtures with 50% and 25% proportions of field pea was at a similar level. The lowest dry matter yield, however, was obtained in 2011 from oat grown in pure sowing.

The dry matter yield of field pea and oat mixtures harvested at the field pea flat green pod stage was significantly higher than the yield of mixtures harvested at the pea flowering stage (Table 3). An interaction has been demonstrated showing that at the flowering stage of field pea, the yields of mixtures with 50% and 25% proportions of this plant were the highest. However, at the flat green pod stage of field pea, the highest dry matter yield was obtained only from the mixture with a 50% proportion of field pea. The lowest dry matter yield was obtained from pea and oat grown in pure sowing harvested during the flowering stage of field pea.

Statistical analysis showed that the content of total protein in pea and oat mixtures was significantly modified by the weather conditions, the studied experimental factors and their interaction.

Table 2. Dry matter yield of pea and oat mixtures in 2009–2011, Mg·ha^{-1}

Proportion of components in the mixture, %	2009	2010	2011	Mean
Field pea 100%	12.24	12.2	9.68	11.41
Oat 100%	14.13	14.14	8.82	12.36
Pea 75% + oat 25%	14.41	14.60	11.20	13.40
Pea 50% + oat 50%	18.52	18.80	12.55	16.62
Pea 25% + oat 75%	17.57	17.77	12.40	15.91
Mean	15.37	15.53	10.93	–
$LSD_{0.05}$ for:				
years	0.322			
proportion of components in the mixture	0.591			
interaction	0.703			

Table 3. Dry matter yield of pea and oat mixtures (means from 2009–2011), Mg·ha^{-1}

Proportion of components in the mixture, %	Time of harvesting	
	field pea flowering stage	field pea flat green pod stage
Field pea 100%	7.56	15.26
Oat 100%	7.42	17.31
Pea 75% + oat 25%	8.92	17.88
Pea 50% + oat 50%	11.09	22.16
Pea 25% + oat 75%	10.72	21.10
Mean	9.14	18.74
$LSD_{0.05}$ for:		
time of harvesting	0.244	
interaction	0.632	

The highest total protein content was recorded in mixtures harvested in the dry 2011, significantly lower in 2010, and the lowest in 2009 (Table 4). The proportion of components in the mixture also significantly modified the total protein content in green forage of field pea with oat. The highest total protein content was recorded in field pea grown in pure sowing. The total protein content in mixtures was significantly lower, but among them, its higher concentration was recorded in mixtures with the proportion of components 75% + 25% and 50% + 50%, than in the mixture with the proportion of components 25% + 75% or in oat grown in pure sowing. The interaction of the years with the proportion of components in the mixture has been demonstrated, which shows that the highest total protein content was recorded in field pea green forage for 2011 and 2010. The highest total protein content was recorded in 2011 in all mixtures, and in 2010 in a mixture of field pea with oat with the proportion of components 75% + 25%. Whereas the lowest concentration of total protein was recorded in 2009 in oat and in pea and oats mixtures with the proportion of components 50% + 50% and 25%

+ 75%. The time of harvest also significantly differentiated the total protein content in pea and oat mixtures (Table 5). Mixtures harvested during the field pea flowering stage contained more total protein than the mixtures harvested at the field pea flat green pod stage. An interaction was demonstrated, which shows that at both times of determinations the highest concentration of total protein was recorded in field pea. The total protein content in its mixtures with oat was significantly lower. The increase in the proportion of oat in the mixture resulted in a decrease in the total protein content, but significant only in the mixture with the proportion of components 25% + 75% harvested during the field pea flowering stage. Its lowest concentration was recorded in oat and in pea and oat mixtures with the proportions of components 25% + 75% and 50% + 50% harvested at the field pea flat green pod stage.

The total protein yield of field pea and oat mixtures was significantly differentiated by the weather conditions during the growing season, the studied experimental factors and their interaction. The highest total protein yield was obtained from pea and oat mixtures harvestsed in 2010, significantly lower in 2009, and the lowest in 2011 (Table 6). The proportion of components in a mixture also significantly modified the total protein yield. The highest total protein yield was obtained from the field pea and oat mixture with 50% of both components. A significantly lower total protein yield was recorded from the other mixtures and their components grown in pure sowing. Interaction of the years with the proportion of components in the mixture was demonstrated, which shows that the highest total protein yield was obtained in 2010 from the field pea and oat mixture with a 50% proportion of both components. Whereas the lowest total protein yield was obtained in 2011 from oat grown in pure sowing. The total protein yield of pea and oat mixtures obtained at the field pea flat green pod stage was significantly higher than the total protein yield obtained from the pea and oat mixtures harvested during the field pea flowering stage (Table 7). The observed interaction of the studied factors showed that the highest total protein yield at the pea flowering stage was obtained from pea and oat mixtures with the proportion of components 50% + 50% and 25% + 75%, and at the flat green pod stage only from the pea and oat mixture with the proportion of components 50% + 50%. However, the lowest yield total protein at the pea flowering stage was obtained from oat grown in pure sowing.

Table 4. Total protein content in pea and oat mixtures in 2009–2011, $g \cdot kg^{-1}$ d.m.

Proportion of components in the mixture, %	2009	2010	2011	Mean
Field pea 100%	132	143	146	140
Oat 100%	112	123	126	120
Pea 75% + oat 25%	119	130	133	127
Pea 50% + oat 50%	115	126	129	123
Pea 25% + oat 75%	114	124	127	122
Mean	118	129	132	–
$LSD_{0.05}$ for:				
years	2.1			
proportion of components in the mixture	4.3			
interaction	6.5			

Table 5. Total protein content in pea and oat mixtures (means from 2009–2011), g·kg^{-1} d.m.

Proportion of component in the mixture, %	Time of harvesting	
	field pea flowering stage	field pea flat green pod stage
Field pea 100%	143	137
Oat 100%	125	115
Pea 75% + oat 25%	131	123
Pea 50% + oat 50%	127	119
Pea 25% + oat 75%	125	118
Mean	130	122
$LSD_{0.05}$ for:		
time of harvesting	1.2	
interaction	5.4	

Table 6. Total protein yield of pea and oat mixtures in 2009–2011, kg·ha^{-1}

Proportion of components in the mixture, %	2009	2010	2011	Mean
Field pea 100%	1614	1758	1412	1595
Oat 100%	1583	1732	1107	1474
Pea 75% + oat 25%	1710	1891	1486	1696
Pea 50% + oat 50%	2124	2359	1615	2033
Pea 25% + oat 75%	1998	2207	1577	1927
Mean	1806	1989	1439	–
$LSD_{0.05}$ for:				
years	59.4			
proportion of components in the mixture	78.1			
interaction	88.3			

Table 7. Total protein yield of pea and oat mixtures (means from 2009-2011), kg·ha^{-1}

Proportion of components in the mixture, %	Time of harvesting	
	field pea flowering stage	field pea flat green pod stage
Field pea 100%	1080	2097
Oat 100%	925	1998
Pea 75% + oat 25%	1167	2201
Pea 50% + oat 50%	1407	2637
Pea 25% + oat 75%	1344	2488
Mean	1185	2284
$LSD_{0.05}$ for:		
time of harvesting	50.4	
interaction	79.1	

DISCUSSION

In the present study, the weather conditions significantly differentiated the dry matter yield of pea and oat mixtures. Also experiments conducted by Ceglarek *et al*. (1994b), Kotecki *et al*. (1997) and Buraczyńska *et al*. (2004) showed that the weather conditions in the growing period significantly modified the yields of mixtures. In the experiment under discussion, analogically to studies by many authors (Borowiecki and Księżak, 2001; Ceglarek *et al*., 1997, 2004; Karadag and Büyükburc, 2003; Lithourgidis *et al*., 2006; Płaza *et al*., 2015), the yields of legume-cereal mixtures were differentiated by the species composition and the proportion of components. In the present study, all mixtures gave higher yields than field pea grown in pure sowing. Of these, the highest dry matter yield was obtained from the pea and oat mixture with the proportion of components 50% + 50%. According to Wasilewski (2006) and Płaza *et al*. (2014), legume-cereal mixtures give more stable yields than their components grown in pure sowing, because they make better use of variable habitat conditions. Also, in a study by Płaza *et al*. (2015), blue lupine grown in pure sowing gave lower yields than that cultivated in a mixture with oat. In the present study, the dry matter yield of pea and oat mixtures harvested at the pea flat green pod stage was significantly higher than the dry matter yield of pea and oat mixtures harvested during the pea flowering stage. A study by Ceglarek *et al*. (1994a) showed that harvesting plants at the milk-dough stage of triticale proved to be the most favourable. Płaza *et al*. (2014) also showed that the harvest of mixtures at the blue lupine flat green pod stage (spring rye in the milk-dough stage) gave the best effect.

In the discussed experiment, the weather conditions significantly differentiated the content and yield of total protein of pea and oat mixtures. In experiments by Ceglarek *et al*. (1997), Kotecki *et al*. (1997), Borowiecki and Księżak (2000), Buraczyńska *et al*. (2004), Buraczyńska and Ceglarek (2009), Gałęzowski (2010) and Płaza *et al*. (2015), the shortage of precipitation and higher air temperatures resulted in an increase in the total protein content, whereas the excess of rainfall and lower temperatures caused its decrease. In the present study, the highest content of total protein was recorded in field pea grown in pure sowing. The total protein content in the mixtures was lower, but among them, its higher concentration was noted in mixtures with proportions of components 75% + 25% and 50% + 50% than in the mixture with the proportion of components 25% + 75% or in oat grown in pure sowing. According to Borowiecki and Księżak (2000), Buraczyńska *et al*. (2004), Ceglarek *et al*. (1994a) and Płaza *et al*. (2014), increasing the percentage of cereals in mixtures caused a reduction in the total protein content. The described relationship results from the fact that the increase in the proportion of a cereal component at sowing in a mixture with legumes increases the proportion of a cereal plant in the dry matter of the mixture, and this results in a reduction of the total protein content. In this experiment, similar to Płaza *et al*. (2015), mixtures harvested during the pea flowering stage contained more total protein than those harvested at the pea flat green pod stage. Ceglarek *et al*. (1994b) showed that by delaying the harvesting of mixtures from heading to the milk-dough stage of cereals, the content of total protein in plants is reduced. In the present study, the highest total protein yield was obtained from the pea--oat mixture with 50% of both components. Significantly lower yield of total protein was recorded from the other mixtures and from the components grown in pure sowing. The diversity of total protein yield results from the amount of biomass yield obtained and its total protein content. Also, the results of studies by Ceglarek *et* al. (1994a, 1997), Księżak *et al*. (2014) and Płaza *et al*. (2014) show that leguminous plants in mixtures with cereals increase the total protein yield. Other authors came to similar conclusions (Borowiecki *et al*., 1998; Borowiecki and Księżak, 2001; Buraczyńska and Ceglarek, 2009; Chen *et al*., 2004). The cereal species is a component stabilizing the yield of the mixture, and the legume affects the qualitative values of the obtained feed. In the experiment under discussion, the total protein yield of field pea and oat mixtures obtained at the phase of a green pod of field pea was significantly higher than the total protein yield obtained from the pea and oat mixtures harvested during the flowering stage of field pea. In

addition, in the study by Ceglarek *et al*. (1994a) the highest yield of total protein was obtained by harvesting plants at the milk-dough stage of spring triticale. During this period, the leguminous plant was at the flat green pod stage. This is consistent with the results of studies by Księżak *et al*. (2014) and Płaza *et al*. (2014).

CONCLUSIONS

1. The dry matter yield and total protein yield were significantly differentiated by the conditions of the growing season of field pea and oat mixtures.
2. The highest dry matter and total protein yields were obtained from the mixture of field pea and oat with the proportion of components 50% + 50% harvested at the field pea flat green pod stage.
3. Field pea grown in pure sowing, harvested at the flowering stage, was characterized by the highest content of total protein. The field pea and oat mixtures contained less total protein. Among them, the mixture of field pea with oats with the proportion of components 75% + 25% was characterized by the highest content of total protein.

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PLON SUCHEJ MASY I BIAŁKA MIESZANEK GROCHU SIEWNEGO Z OWSEM UPRAWIANYCH NA ZIELONĄ MASĘ

Streszczenie

Mieszanki bobowato-zbożowe uprawiane na zieloną masę są cennym źródłem paszy bogatej w białko dla zwierząt przeżuwających. W pracy przedstawiono wyniki badań z lat 2009-2011 mające na celu określenie wpływu udziału komponentów w mieszance i terminu zbioru na plon suchej masy oraz zawartość i plon białka ogólnego mieszanek grochu siewnego z owsem uprawianych na zieloną masę. W doświadczeniu uwzględniono dwa czynniki: (I) udział komponentów w mieszance: groch siewny – siew czysty 100%, owies-siew czysty 100%, groch siewny 75% + owies 25%, groch siewny 50% + owies 50%, groch siewny 25% + owies 75% oraz (II) termin zbioru: faza kwitnienia grochu siewnego, faza płaskiego zielonego strąka grochu siewnego. Podczas zbioru mieszanek określono plon oraz z każdego poletka pobrano średnie próby świeżej masy w celu wykonania analiz chemicznych. W pobranym materiale roślinnym oznaczono zawartość suchej masy i białka ogólnego. Plon suchej masy, zawartość i plon białka ogólnego mieszanek grochu siewnego z owsem były istotnie różnicowane przez warunki pogodowe, czynniki doświadczenia i ich współdziałanie. Największy plon suchej masy i białka ogólnego otrzymano z mieszanki grochu siewnego z owsem o udziale komponentów 50% + 50% zebranej w fazie płaskiego zielonego strąka grochu siewnego. Groch siewny uprawiany w siewie czystym zebrany w fazie kwitnienia charakteryzował się najwyższą zawartością białka ogólnego. Mieszanki grochu siewnego z owsem zawierały mniej tego składnika. Spośród nich najwyższą zawartością białka ogólnego wyróżniała się mieszanka grochu siewnego z owsem o udziale komponentów 75% + 25%.

Słowa kluczowe: faza rozwojowa grochu, plon, plon białka, udział komponentów w mieszance, termin zbioru, zawartość białka ogólnego