AGRONOMY SCIENCE
wcześniej – formerly
Annales UMCS sectio E Agricultura

VOL. LXXVIII (3) 2023

https://doi.org/10.24326/as.2023.5132

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The proportion of components in field pea and spring triticale mixtures and harvest stage – influence on crude fiber content determined by the NIR method and forage digestibility

Udział komponentów w mieszankach grochu siewnego i pszenżyta jarego oraz faza zbioru – wpływ na zawartość włókna surowego określonego metodą NIR i strawność paszy

Summary. The work presents results of a study conducted in 2016–2018 to determine the effect of component share in the mixture and harvest stage on concentration of crude fibre and its fractions as well as digestibility of field pea/spring triticale mixtures. The following two factors were examined in a field experiment: factor I – component share in a mixture: field pea in pure stand 100%, spring triticale in pure stand 100%, field pea 75% + spring triticale 25%, field pea 50% + spring triticale 50%, field pea 25% + spring triticale 75%; factor II – harvest stage: field pea flowering stage (BBCH 65), field pea flat green pod stage (BBCH 79). The concentration of crude fibre and its fractions (NDF, ADF, ADL) were determined in the dry matter in addition to dry matter digestibility and organic matter digestibility. The lowest content of crude fiber and its fractions, among the mixtures, was revealed in the mixture with the share of components of pea and spring triticale 75% + 25% and 50% + 50%, respectively. Harvesting mixtures at a later stage caused an increase in crude fiber content and its fraction in dry matter. The superior dry matter digestibility and organic matter digestibility were found for field pea and field pea/spring triticale mixtures containing 75% + 25% and 50% + 50% of the respective components and harvested at the stage of field pea flowering.

Key words: crude fiber, digestibility, field pea, spring triticale

Citation: The proportion of components in field pea and spring triticale mixtures and harvest stage – influence on crude fiber content determined by the NIR method and forage digestibility. Agron. Sci. 78(3), 111–122. https://doi.org/10.24326/as.2023.5132

INTRODUCTION

Leguminous plants grown in pure stand are quite unreliable as far as their yield is concerned [Kocer and Albayrak 2012]. The problem can be alleviated by cultivation of legume/cereal mixtures [Soufan and Al-Suhaibani 2021], which seems particularly viable in years characterised by water shortages during the growing season [Nasar et al. 2019]. Cultivation of legume/cereal mixtures is widely presented in literature.

Of leguminous plants recommended for cultivation in mixtures, field pea, faba bean and lupins are the most important crops in terms of animal nutrition [Sońta and Rekiel 2020]. Field pea is recognised as one of the most valuable components because it provides good quality green fodder. The maturation of pea varieties coincides with that of spring cereals, and they have a relatively low transpiration coefficient [Karkanis et al. 2016], low shading of lower parts and good stand stability. Spring triticale is a cereal characterised by a superior yield-formation potential, it is non-demanding as far as soil is concerned, and it is very resistant to diseases [Mergoum et al. 2019]. Thus, examination of this species as a component of mixtures with field pea is justifiable and desirable. Such mixtures may be cultivated on Stagnic Luvisols which are dominant soils in Poland where farmers struggle with shortages of forage for cattle.

In terms of feed intake by and digestibility for ruminants, it is of importance to determine its content of neutral detergent fibre (NDF), and acid detergent fibre (ADF). According to Aufrere et al. [2008] as well as Krämer-Schmid et al. [2016], the feed content of NDF allows determination of feed intake level. Jankowska [2012] claims that ADF content determines feed digestibility. An increase in ADF content is followed by a decline in feed digestibility. Many authors [Papoa et al. 2012, Iqbal et al. 2018, Manoj and Shekara 2020, Salama 2020] believe that fibre amount in the obtained feed is related to the cutting timing, plant development stage, plant morphological structure, share of individual components in the mixture as well as site and thermal conditions. According to Kim et al. [2011], harvesting green forage at the right time is important for obtaining maximum nutritional value of forage. Forage plants when harvested at the vegetative stage have low yields and low fiber content. In contrast, their harvest at the reproductive stage have the highest digestibility of dry matter and nutrient composition [Muck et al. 2015]. According to Bo et al. [2022], the most suitable harvesting phase for legume-cereal mixtures to achieve high biomass production and chemical composition is the flowering phase. Skórko-Sajko et al. [2016] and Salama and Zeid [2016] reported that when harvest stage was delayed from legume budding to full flowering (goat's rue being the leguminous component), there was observed a rapid increase in the concentration of NDF, ADF, ADL and hemicellulose, accompanied by a decline in cellulose content and soluble sugars.

According to Fernández-Núñez et al. [2012], digestibility of produced biomass is determined by crop species and variety, applied fertiliser, development stage at harvest and prospective conservation. According to Eskandari et al. [2009], legumes contain less cellulose and hemicellulose than cereals. Thus, according to a study conducted by Pourali et al. [2023] on growing sorghum with clover, increasing the proportion of sorghum in the mixture crop increased the ADF and NDF content of the resulting forage. According to Bakhtiyari et al. [2020], a high content of ADF and NDF decreases forage digestibility. An analysis by Riaz et al. [2014] shows that cattle digest NDF and ADF better compared to sheep. The ability of cattle to better digest low-quality feeds is linked by the authors to the fact that they retain feed in the rumen longer, which may result in higher digestive efficiency compared to sheep. Riaz et al. [2014] also suggest that goats are considered more resistant to digesting low-quality feeds with high fiber concentrations. According to Ma et al. [2019], higher NDF and ADF content in feed results in reduced degradability. Higher degradation rates of NDF and ADF, on the other hand, are beneficial for rumen fermentation and can lead to higher concentrations of volatile fatty acids, which can provide cattle with more energy. Genc-Lermi [2018] claim that an increase in the share of leguminous plant in the sward enhances digestibility of the resulting biomass.

Climate change causing increasingly frequent periods of prolonged drought is prompting field research into crops that can provide high-quality fodder for livestock despite weather conditions. In addition, the cultivation of legumes and their mixtures with cereals increases crop biodiversity and reduces the need for mineral fertilizers. Therefore, the cultivation of legume-cereal mixtures seems to be an appropriate approach to sustainable agriculture. The objective of the study was to determine the effect of component share in a mixture and its harvest stage on crude fibre content and fractions, and digestibility of field pea/spring triticale mixtures.

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 experimental soil was Stagnic Luvisol, of very good rye complex, of valuation class of IVb soil. The content of available mineral elements in the soil was: P 81.0 mg kg^{-1}, K 122.0 mg kg^{-1}, Mg 52.0 mg kg^{-1}. The humus content was 13.9 g kg^{-1}. The experiment was set up in split – block design in three replications in each year. The original plot size was 20 m^2 (5 m × 4 m). 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 stage: flowering stage of field pea (BBCH 65), flat green pod stage of field pea (BBCH 79). The sowing rates were as follows: field pea 240 kg ha^{-1}, spring triticale 220 kg ha^{-1}, field pea 180 kg ha^{-1} + spring triticale 55 kg ha^{-1}, field pea 120 kg ha^{-1} + spring triticale 110 kg ha^{-1}, field pea 60 kg ha^{-1} + spring triticale 165 kg ha^{-1}. In autumn phosphorus and potassium fertilizers were applied in doses depending on the soil chemical composition, i.e. 34.8 kg ha^{-1} P in the form of 46% triple superphosphate and 99.2 kg 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 pea grown in pure sowing, 30 kg N ha^{-1} was applied. At the stalk shooting stage, an additional 50 kg N ha^{-1} was applied for spring triticale and 30 kg N ha^{-1} for mixtures of pea with spring triticale. Field pea (Roch) and spring triticale (Milewo) seeds were planted in early April as described for factor I. Sowing was carried out with a Mazur 5 type S052/C grain drill. The crops were harvested at the stages described for factor II, that is the stage of field pea flowering (late June) and the stage of field pea flat green pod (early July). During the harvest of mixtures, fresh weight samples were collected from each plot for chemical analyses. A total of 30 samples were taken each year: five mixture seeding combinations × two harvesting stages × three replications. The sample was shredded and dried in the room with free air flow of ambient temperature. The samples of field pea and spring triticale mixtures were used to determine crude fibre content, neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignins (ADL), dry matter digestibility and organic matter digestibility. The method used was near infrared spectroscopy provided by a NIRFlex N-500 spectrometer. The analysis was performed using Büchi's N555-503 calibration for feed. The method is described in the Polish Standard called PN-EN ISO 12099:2017-10 and in the literature [Burns et al. 2010].

Each characteristic tested was subjected to analysis of variance suitable for the split-block design. When significant sources of variation were confirmed, their means were separated using Tukey test at a significance level of $P \leq 0.05$. All the calculations were performed in Statistica, version 13.3 (Hamburg, Germany).

RESULTS AND DISCUSSION

Statistical analysis showed a significant effect of the experimental factors and their interaction on crude fibre content in field pea/spring triticale mixtures (Tab. 1). The component share in a mixture significantly affected crude fibre content in mixtures of field pea and spring triticale. An increase in the share of spring triticale in the mixture was followed by a significant increase in the fodder content of crude fibre. Of the experimental mixes, the lowest concentration of crude fibre was determined in the mixture containing 75% field pea and 25% spring triticale. Similar results of research involving different legume/cereal mixtures were reported by Ibrahim et al. [2012], Haghaninia et al. [2020] and Ashoori et al. [2021]. Results of the present experiment revealed a significantly higher crude fibre content in mixtures harvested at the stage of field pea flat green pod compared with mixtures whose harvest had taken place at the stage of field pea flowering. It is concurrent with reports by Papoa et al. [2012], and Płaza et al. [2018]. According to Qu et al. [2014], the increase in crude fiber content with successive phases of plant growth may be due to increased concentration of cell wall components in the stem and leaves and reduced cell solubility. Carmi et al. [2005] additionally suggest that this may be due to the accumulation and synthesis of lignin during the development of the secondary cell wall. In their study, they found an interaction which showed that at the field pea flowering stage, the lowest crude fiber content was shown by field pea and the mixture with the highest proportion of field pea at sowing. On the other hand, harvesting green forage at the field pea flat green pod stage demonstrated the lowest crude fiber content in field pea, while among the mixtures in the mixtures of field pea and spring triticale with a component share of 75% + 25%, respectively.

The experimental factors and their interactions significantly influenced the concentration of neutral detergent fibre, acid detergent fibre and acid detergent lignins (Tabs 2–4). The component share in a mixture significantly affected the aforementioned contents in the test field pea/spring triticale mixtures. The lowest contents were determined in field pea grown in pure stand. Similarly to results reported by other authors [El-Karamany et al. 2014, Salama and Badry 2015, Çarpici 2017, Šiaudinis et al. 2017, Gill and Omokanye 2018, Ashoori et al. 2021, Kahraryan et al. 2021], in the present work, an increase in the legume share in a field pea/spring triticale mixture resulted in a decline in the concentration of neutral detergent fibre, acid detergent fibre and acid detergent lignins. In the research reported here, there was observed a significantly lower concentration of neutral detergent fibre, acid detergent fibre and acid detergent lignins in field pea/spring triticale

Table 1. Crude fibre content in field pea/spring triticale mixtures
(means across 2016–2018; g kg^{-1} d.m.)

Component share in mixture	Harvest stage		Means
	BBCH 65	BBCH 79	
I	233 ±9^{a}	261 ±12^{a}	247 ±17^{A}
II	238 ±10^{a}	265 ±12^{b}	252 ±18^{B}
III	245 ±12^{b}	270 ±14^{c}	258 ±16^{C}
IV	254 ±12^{c}	277 ±16^{d}	266 ±18^{D}
V	265 ±14^{d}	286 ±18^{e}	276 ±19^{E}
Means	247 ±16^{A}	272 ±17^{B}	–

I – field pea in pure stand 100%, II – field pea 75% + spring triticale 25%, III – field pea 50% + spring triticale 50%, IV – field pea 25% + spring triticale 75%, V – spring triticale in pure stand 100%
Values in columns for the interaction followed by the same small letter (a, b) do not differ significantly in P < 0.05. Means for the component share in mixture in column followed by the same capital letter (A, B) do not differ significantly. Means for the harvest stage in verse followed by the same capital letter (A, B) do not differ significantly.

Table 2. Neutral detergent fibre (NDF) content in field pea/spring triticale mixtures
(means across 2016–2018; g kg^{-1} d.m.)

Component share in mixture	Harvest stage		Means
	BBCH 65	BBCH 79	
I	373 ±20^{a}	456 ±16^{a}	415 ±45^{A}
II	424 ±21^{b}	485 ±57^{b}	454 ±53^{B}
III	438 ±18^{c}	501 ±58^{c}	469 ±53^{C}
IV	451 ±18^{d}	525 ±54^{d}	488 ±55^{D}
V	507 ±17^{e}	621 ±11^{e}	564 ±59^{E}
Means	438 ±47^{A}	518 ±72^{B}	–

Explanations as in Table 1.

mixtures harvested at the field pea flowering stage compared with mixes harvested at the stage of field pea flat greed pod. Also other workers reported that, in their experiments with different mixtures, delayed harvest resulted in an increase in fibre content [Salama and Zeid 2016, Genet et al. 2017, Molla et al. 2018]. The increase in the content of the fiber fraction with the increase in the share of spring triticale in the sowing, revealed in the conducted experiment, can be explained by the fact that compared to legumes, especially peas with their tender shoots and leaves, cereals contain more fiber and its fraction, so their

Table 3. Acid detergent fibre (ADF) content in field pea/spring triticale mixtures (means across 2016–2018; g kg^{-1} d.m.)

Component share in mixture	Harvest stage		Means
	BBCH 65	BBCH 79	
I	286 ±13^{a}	327 ±15^{a}	306 ±25^{A}
II	314 ±26^{bc}	337 ±13^{a}	326 ±24^{B}
III	312 ±13^{b}	347 ±14^{b}	329 ±22^{B}
IV	324 ±14^{c}	361 ±14^{c}	343 ±23^{C}
V	347 ±14^{d}	375 ±15^{d}	361 ±20^{D}
Means	317 ±26^{A}	349 ±22^{B}	–

Explanations as in Table 1.

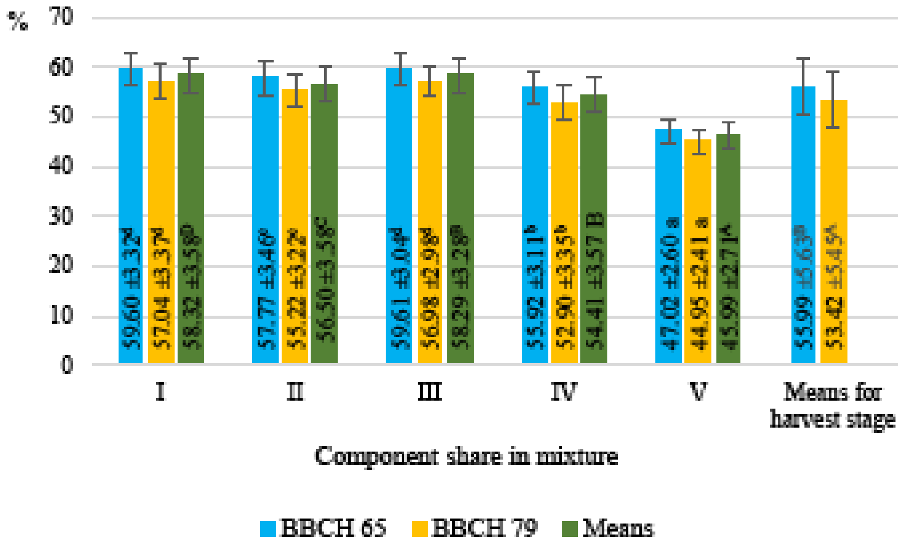
Table 4. Acid detergent lignin (ADL) content in field pea/spring triticale mixtures (means across 2016–2018; g kg^{-1} d.m.)

Component share in mixture	Harvest stage		Means
	BBCH 65	BBCH 79	
I	36.87 ±2.59^{a}	41.88 ±2.67^{a}	39.37 ±3.63^{A}
II	37.65 ±1.57^{a}	42.27 ±3.18^{a}	39.96 ±3.41^{A}
III	38.45 ±1.80^{b}	43.34 ±2.75^{b}	40.90 ±3.37^{B}
IV	40.70 ±2.45^{c}	43.93 ±2.76^{b}	42.31 ±3.07^{C}
V	53.85 ±3.52^{d}	56.93 ±4.68^{c}	55.39 ±4.64^{D}
Means	41.50 ±6.78^{A}	45.67 ±6.95^{B}	–

Explanations as in Table 1.

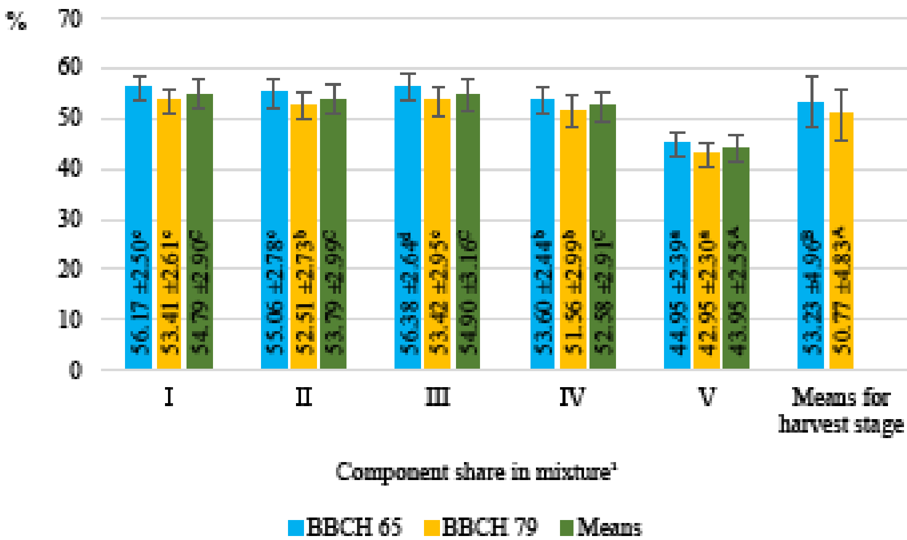
concentration in mixtures is higher, resulting in poorer feed digestibility. The experiment showed an interaction from which it is evident that the lowest content of neutral detergent fiber in both phases of harvesting was characterized by field pea, while the highest was spring triticale. With regard to acid detergent fiber, the lowest content during harvesting at the field pea flowering stage was revealed in field pea, while at a later stage of harvesting it was revealed in field pea and a legume-predominant mixture at sowing. On the other hand, the lowest content of acid detergent lignins at both harvest stages was revealed in field pea and a mixture with a 75% share of field pea.

Statistical analysis confirmed a significant impact of the experimental factors and their interaction on dry matter digestibility and organic matter digestibility of field pea/spring triticale mixtures (Figs 1 and 2). Results of the study reported here agree with claims made



Explanation as in Table 1.

Fig. 1. Dry matter digestibility of field pea/spring triticale mixtures (means across 2016–2018)



Explanation as in Table 1.

Fig. 2. Organic matter digestibility of field pea/spring triticale mixtures (means across 2016–2018)

by Fernández-Núñez et al. [2012] as well as Flores Najera et al. [2016] who examined biomass digestibility as affected by crop plant species and its development stage during harvest. The present work revealed similar and significantly highest dry matter digestibility of field pea and the field pea/spring triticale mixture containing 50% + 50% and 75% + 25% of the respective components. Similarly, significantly the highest organic matter digestibility was determined in field pea and field pea/spring triticale mixtures. Both the lowest dry matter digestibility and organic matter digestibility were observed in spring triticale. A higher dry matter digestibility and organic matter digestibility in legumes and legume/cereal mixtures were confirmed in studies conducted by other researchers [Yılmaz et al. 2015, Nakhzari Moghaddam et al. 2016, Salama and Zeid 2016, Genc-Lermi 2018, Seydoşoglu et al. 2020, Kir 2021] who, however, examined different legume and cereal components of mixtures. Under the conditions of the experiment reported here, after harvest of mixtures was delayed from the stage of field pea flowering to field pea flat green pod, there was observed a significant drop in dry matter digestibility and organic matter digestibility, which is concurrent with reports by other authors [Ayub et al. 2008, Seydosoglu and Bengisu 2019, Piltz et al. 2021]. In the current work, an interaction was confirmed, which revealed that the highest dry matter digestibility and organic matter digestibility were for field pea and field pea/spring triticale mixtures containing 75% + 25% and 50% + 50% of the respective components and harvested at both harvest stages.

According to the National Research Council [2001], alfalfa feed provided to cattle should contain a minimum of 19% NDF in dry matter. However, the concentration of NDF in the forage should be higher if the forage is finely chopped. On the other hand, the NRC [2001] recommended ADF content in cattle diets should be a minimum of 17% dry matter. The NDF and ADF contents obtained in our own study are above the minimum values given in NRC [2001]. According to Jankowska-Huflejt and Wróbel [2008], the optimal crude fiber content in feed is 290–330 g kg^{-1} d.m. In our study, the level of crude fiber in all analyzed samples was lower than optimal. According to Andrzejewska et al. [2013], the desirable NDF content in feed for dairy cattle is 400 – 450 g kg^{-1} d.m. In our study, only the NDF content of green pea forage was within the stated limits. A slightly higher content was also obtained in the green forage of a mixture of field pea and spring triticale with a component ratio of 75% + 25%. According to Olszewska and Kobylinski [2016], the digestibility of feed that is fed to cattle should be greater than 65–67%. Thus, the green feed obtained in the presented own research does not meet these requirements..

CONCLUSIONS

The lowest concentrations of crude fibre and its fractions (neutral detergent fibre, acid detergent fibre and acid detergent lignins) were determined in pure stand field pea and the legume/cereal mixture containing 75% field pea and 25% spring triticale. The highest dry matter digestibility and organic matter digestibility were found in field pea grown in pure stand or mixed with spring triticale when the respective component shares were 75% + 25% and 50% + 50%, and harvest was performed at the field pea flowering stage. Obtaining livestock feed from mixtures of field pea with spring triticale can be a valuable feed for farms focused on livestock production, but should not be the only feed fed to livestock.

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The source of funding: Ministry of Education and Science, grant no. 30/20/B.

Received: 3.04.2023
Accepted: 6.11.2023
Published: 22.01.2023