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THE SELECTED ELEMENTS OF THE CHEMICAL COMPOSITION OF MIXTURES OF NARROWLEAF LUPIN (*LUPINUS ANGUSTIFOLIUS* L.) WITH SPRING TRITICALE (X *TRITICOSECALE WITTMACK*) GROWN FOR GREEN FODDER

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Abstract. Field studies were conducted in 2016–2018 at the Agricultural Experimental Station in Zawady, which belongs to the Siedlce University of Natural Sciences and Humanities, located near Siedlce in the Mazowieckie Voivodeship. The aim of the conducted research was to evaluate the content of selected nutrients in mixtures of narrowleaf lupin with spring triticale harvested at two developmental stages of narrowleaf lupin. The highest content of total carbohydrates, water-soluble carbohydrates and crude ash, among the mixtures, was revealed in a mixture with 75% narrowleaf lupin and 25% spring triticale. In contrast, the highest crude fat content was found in mixtures with component shares of narrowleaf lupin and spring triticale of 75% + 25% and 50% + 50%, respectively. A higher carbohydrate and crude ash content was determined in mixtures harvested at the flowering stage of narrowleaf lupin, while higher crude fat contents were determined in mixtures harvested at the flat green pod stage of narrowleaf lupin. Among the mixtures to be grown to achieve fodder with a high content of total carbohydrates, water-soluble carbohydrates, crude fat and crude ash a mixture with 75% + 25% components of narrowleaf lupin and spring triticale, respectively, should be recommended and harvested at the narrowleaf lupin flowering stage.

Key words: narrowleaf lupin, spring triticale, mixture, total carbohydrates, water-soluble carbohydrates, crude fat, crude ash.

INTRODUCTION

The development of sustainable agriculture and climate change are driving increasing interest in growing legume-cereal mixtures in European ruminant production systems (Maxin et al. 2017). Growing legume-cereal mixtures allows for increased self-sufficiency in feed supply by farms, and brings environmental, agronomic and economic benefits (Lithourgidis et al. 2011; Pelzer et al. 2012). According to the authors, the agronomic benefits are higher yields of legume-cereal mixtures compared to pure sowing crops, better use of available re-

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sources and reduced incidence of pests and weeds. As environmental benefits, Lithourgidis et al. (2011) cite the possibility of reducing the use of mineral fertilisers and pesticides thereby minimising the environmental impact of agriculture, while at the same time reducing the financial outlay incurred by farmers. According to Soufan and Al-Suhaibani (2021), a major challenge facing agriculture is the provision of feed in sufficient quantity and with acceptable nutritional value. This is mainly due to the increasing human population and the consequent increase in demand for animal products (FAO 2022), and the decreasing area of arable land due to the development of urbanised areas (Ahmada et al. 2007). As reported by Nasar et al. (2019) a mixture of cereals and legumes has been identified as one of the best agricultural practices in organic and low-input farming systems in areas with low water availability. Forage obtained from cereals, despite high and stable yields, is not very suitable for feeding high-yielding ruminants due to its low quality (Piltz and Rodham 2022). Legumes yields high quality forage, but the yields obtained are low, especially in dry years (Piltz et al. 2021). As reported by many authors (Genc-Lermi 2018; Pflueger et al. 2020; Bacchi et al. 2021), the cultivation of legume-cereal mixtures improves crop yields and yields forage of much better quality, including high protein content, compared to monoculture crops. According to Bo et al. (2022a), a significant benefit of feeding forage with high protein content to livestock is an increase in their productivity. The variability in the yield of legume-cereal mixtures and the quality of the forage obtained, in different locations, with different plant mixing ratios (Jacobs and Ward 2012; Blagojević et al. 2017; Genc-Lermi 2018; Pflueger et al. 2020) suggests the need for regional studies. Such studies will allow the selection of the best plant species and varieties and the proportion of their share in the mixture to obtain forage with high protein and carbohydrate content and stable yields. In addition, as reported by Bracey et al. (2022), harvest date affects the nutritional value of the forage due to physiological changes in plant biomass. Therefore, it is important to assess changes in forage quality at different harvest dates. According to (Ciavarella et al. 2000; Oba 2010), increased water-soluble carbohydrate content in forages improves digestibility, intake and palatability of forages which can improve livestock productivity. As reported by Singer et al. (2018) water-soluble carbohydrates provide a source of rapidly available energy in feeds.

High concentrations of water-soluble carbohydrates in feeds improve livestock gain and milk production (Lee et al. 2001; Miller et al. 2001; Tas et al. 2006). According to Kleefisch et al. (2018), providing livestock with adequate water-soluble carbohydrate is important for energy requirements and better utilisation of nitrogen in feed, which would otherwise be removed in urine or milk. On the other hand, according to Bertilsson et al. (2017), feeding feeds high in water-soluble carbohydrates does not increase the risk of rumen acidosis, mainly due to their positive effect on rumen pH (Klevenhusen and Zebeli 2021). According to Humer et al. (2018) rumen acidosis can cause metabolic disorders, so it is important to feed livestock feeds that do not increase the risk of this condition. The crude fat content is also an important quality characteristic of green fodder, as it affects the gross energy value. According to Idris et al. (2019), fat yields more than 9 kcal/g, while proteins and carbohydrates yield about 5 kcal/g. As reported by Quirino et al. (2022), the determination of the crude ash content of animal feed plays an important role in the nutritional interpretation of animal feed, allowing an indirect estimate of total organic matter, which includes all potential energy-producing compounds. Despite numerous studies on the forage value of legume-cereal mixtures, there are few studies assessing the suitability of spring triticale for growing in mixtures with legumes for green fodder. Spring triticale is a cereal that has been relatively recently introduced into cultivation in Poland and needs to be tested in mixtures with legumes grown for green fodder. This provided the inspiration for the field experiment presented here.

The aim of this study was to evaluate the effect of the components in the mixture of narrowleaf lupin with spring triticale and the harvest date of the mixtures on the content of selected nutrients in the green fodder.

MATERIAL AND METHODS

The experiment was conducted at the Agricultural Experimental Station in Zawady belonging to the University of Natural Sciences and Humanities in Siedlce in 2016–2018. The field experiment was established on soil of class IVb of the very good rye complex – according to the Polish soil classification, with a slightly acidic to neutral pH. According to the World Reference Base for Soil Resources (WRB) classification, the experimental soil was Stagnic Luvisols. Before the experiment was set up, the soil had a high abundance of P – 8.1 mg·100 g^{-1} and Mg 5,2 mg·100 g^{-1} and an average abundance of K 12.2 mg·100 g^{-1}, humus content was 1.39%. In all years of the study, the forecrop for the mixtures was oat. The experiment was conducted in a split-block design, in three replications. Two factors were tested in the experiment: A) the share of components in the mixture: narrowleaf lupin – pure sowing, spring triticale – pure sowing, narrowleaf lupin 75% + spring triticale 25%, narrowleaf lupin 50% + spring triticale 50%, narrowleaf lupin 25% + spring triticale 75%; B) Harvest date: flowering stage of narrowleaf lupin (BBCH 65), flat green pod stage of narrowleaf lupin (BBCH 79). The number of seeds sown per 1 m^2 at each experimental site was as follows: narrowleaf lupin – 120, spring triticale – 600, narrowleaf lupin 90 + spring triticale 150, narrowleaf lupin 60 + spring triticale 300, narrowleaf lupin 30 + spring triticale 450. Mixtures were sown at the appropriate percentage of monoculture sowing. In the third decade of October, phosphorus and potassium fertilisers were applied at doses of: 34.8 kg·ha^{-1} P, in the form of triple superphosphate 46% and 99.2 kg·ha^{-1} K, in the form of 60% potassium salt. In the first decade of April, nitrogen fertilisers in the form of ammonium nitrate 34% were applied before sowing the seeds. On all objects, with the exception of narrowleaf lupin grown in pure sowing, 30 kg N·ha^{-1} was applied. At the stem elongation spring triticale, an additional 50 kg N·ha^{-1} was applied to spring triticale and 30 kg N·ha^{-1} to mixtures of narrowleaf lupin with spring triticale. Seeds of narrowleaf lupin of the Neptun variety with germination capacity 83% and means of thousand-seed weight 158 g and spring triticale of the Milewo variety with germination capacity 95% and means of thousand-seed weight 47 g were sown in the first decade of April according to the first factor of the experiment. Mixtures were sown at two passes of the Mazur 5 type S052/C grain drill. The first passing was performed to sow spring triticale at the depth of 4 cm, and the second passing to seed narrowleaf lupin at the depth of 4 cm. The row spacing was 20 cm. The plants were harvested according to the second factor of the experiment: narrowleaf lupin flowering stage (3rd decade of June) and narrowleaf lupin flat green pod stage (1st decade of July). Harvesting the green fodder for chemical analysis was done manually using electric shears. During harvest of mixtures, fresh matter samples were collected from 1 m^2 in each plot. The representative sample from a 1 kg plot canopy was shredded and dried in the room with free air flow of ambient temperature. After drying total carbohydrates, water-soluble carbohydrates, crude fat and crude ash were determined in the dry matter (DM) by near-infrared spectrometry (NIRS) using a NIRFlex N-500 spectrometer. The method is described in the Polish Standard called PN-EN ISO 12099:2017-10 and in the literature (Burns et al. 2010).

Each trait tested was subjected to an analysis of variance according to a split-block design scheme. In the case of significant sources of variation, a detailed comparison of means was made using the Tukey Test. Statistical calculations were performed using in-house algorithms in MS Excel v. 12.0.

Thermal and precipitation conditions varied during the years of the study (Table 1).

Table 1. Weather conditions during the growing season of narrowleaf lupin/spring triticale mixtures according to the Zawady Meteorological Station

Years	Month				Means
	IV	V	VI	VII	
	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
1990–2008	8.2	14.2	17.6	19.7	14.9
	precipitation [mm]				sum
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
1990–2008	37.4	47.1	48.1	65.5	198.1

The year 2017 was the most favourable for the cultivation of mixtures of narrow-leafed lupin with spring triticale, as it had the highest total precipitation and the lowest air temperature. In the analysed period the means temperature was 1°C lower than the multi-year means, in turn, the sum precipitation was 8.1 mm lower than the multi-year sum. In the analysed period 2016 an means temperature of 0.5°C higher than the multi-year means was recorded. During the entire period, precipitation sum was lower compared to the multi-year sum by 42.5 mm. The means of temperature recorded during the analysed period in 2018 was 2.3°C higher than the multi-year means. In contrast, sum precipitation was 37.7 mm lower than the multi-year sum.

RESULTS AND DISCUSSION

The share of components in the mixture of narrowleaf lupin with spring triticale, weather conditions during cultivation and their interaction significantly differentiated the content of total carbohydrates and water-soluble carbohydrates in the biomass obtained (Table 2).

Table 2. Total carbohydrates and water-soluble carbohydrates content in narrowleaf lupin/spring triticale mixtures according to component share in the mixture in 2016–2018, g·kg^{-1} DM

Component share in the mixture % (A)		Total carbohydrates				Water-soluble carbohydrates			
		years (Y)			means	years (Y)			means
narrowleaf lupine	spring triticale	2016	2017	2018		2016	2017	2018	
100	0	262.1	248.8	283.8	264.9	162.5	156.5	173.7	164.2
75	25	192.0	171.4	214.9	192.7	118.5	104.0	135.5	119.3
50	50	164.2	154.4	180.9	166.5	108.5	94.5	119.6	107.5
25	75	127.6	112.8	148.5	129.6	86.2	71.4	98.8	85.5
0	100	84.1	82.9	88.3	85.1	68.0	62.7	77.0	69.2
Means		166.0	154.0	183.2	–	108.7	97.8	120.9	–
$HSD_{0.05}$									
Y		5.3				4.7			
A		8.1				7.1			
Y × A		14.0				12.4			

The highest total carbohydrate content was revealed in the mixtures harvested in 2018. This year was characterised by the highest means of temperature among the years analysed and a shortage of rainfall during the growing season of the mixtures. The lower average temperature in 2016 compared to 2018 caused a significant reduction in total carbohydrate content of ca. 9.5%. In contrast, 2017, which had the highest precipitation sum, yielded the significantly lowest total carbohydrate content, ca. 16% lower compared to 2018. Also, for the content of water-soluble carbohydrates, thermal and rainfall conditions significantly influenced their content in the narrowleaf lupin/spring triticale mixture. The highest content was found in the mixtures harvested in 2018, which experienced a rainfall deficit and high average temperature. In 2016, a significantly lower water-soluble carbohydrate content of ca. 10% was recorded compared to 2018, while the significantly lowest content, lower by ca. 19% was recorded in 2017. The higher content of total carbohydrates and water-soluble carbohydrates in the biomass of mixtures in years with low rainfall and high temperature may be due to an increase in nutrient concentration as a result of water deficit for the plants. Additionally, according to Piltz et al. (2021) plants are less able to convert non-structural carbohydrates into structural carbohydrates as a result of severe water stress. Also, studies by other authors have shown higher carbohydrate concentrations in legume-cereal mixtures and legume-cereal monoculture in years with lower total rainfall and higher average temperature (Gill and Omokanye 2018; Piltz et al. 2021; Bo et al. 2022b). In our study, also the proportion of components in the mixture significantly differentiated the content of total carbohydrates and water-soluble carbohydrates. The highest total carbohydrate content was found in the narrowleaf lupin and the lowest in spring triticale. The difference between the legume and cereal monoculture crop was 179.8 $g \cdot kg^{-1}$ DM. The higher carbohydrate content of legume biomass compared to cereal crops was also shown in their studies by (Salawu et al. 2001; Jilani et al. 2018; Akbağ 2022; Ibrahim and El-Sawah 2022; O'Kiely et al. 2022). In our study, the highest content of total carbohydrates and water-soluble carbohydrates among the mixtures was found in the mixture with 75% narrowleaf lupin and 25% spring triticale. In the experiment carried out, the addition of spring triticale to the mixture with narrowleaf lupin resulted in a significant reduction in carbohydrate content. A ca.13% reduction in total carbohydrate content was revealed in the mixture with an equal share of both components, while a ca. 33% reduction in total carbohydrate content was revealed in the mixture with 25% + 75% components of narrowleaf lupin and spring triticale, respectively, compared to the mixture with the highest share of narrowleaf lupin. In the case of water-soluble carbohydrate content, there was a ca. 10% reduction in the mixture with an equal share of both components and a ca. 28% reduction in the mixture with a predominance of spring triticale compared to the mixture with 75% share of narrowleaf lupin and 25% spring triticale. The obtained relationship is also confirmed by studies conducted by other authors on different legume-cereal mixtures (Brown et al. 2018; Jilani et al. 2018; Rad et al. 2020). In our study, there was an interaction of the share of components in the mixture and the years of the study revealed that the highest content of total carbohydrates and water-soluble carbohydrates in all years of the study was found in narrowleaf lupin, while the lowest in spring triticale. Among the mixtures, the highest content of total carbohydrates, in all years of the experiment, was revealed in the mixture with 75% share of narrowleaf lupin. In the case of water-soluble carbohydrates, no significant differences were found between the mixture with 75% share of narrowleaf lupin and 25% of spring triticale and the mixture with equal share of components in 2016 and 2017. A significant difference between these mixtures was observed in the year 2018. The highest means of temperature and sum precipitation lower by ca. 38 mm than the multi-year sum were recorded in this year.

In the experiment conducted, the harvesting phase of the narrowleaf lupin/spring triticale mixtures significantly differentiated the content of total carbohydrates and water-soluble carbohydrates in the biomass (Table 3).

Table 3. Total carbohydrates and water-soluble carbohydrates content in narrowleaf lupin/spring triticale mixtures (means across 2016–2018), g·kg^{-1} DM

Component share in the mixture % (A)		Total carbohydrates harvest date (B)		Water-soluble carbohydrates harvest date (B)	
narrowleaf lupin	spring triticale	I	II	I	II
100	0	263.5	266.3	196.9	131.5
75	25	201.3	184.2	137.4	101.3
50	50	171.6	161.3	127.0	88.0
25	75	139.2	120.0	96.0	75.0
0	100	90.8	79.3	77.4	61.1
Means		173.3	162.2	126.9	91.4
$HSD_{0.05}$					
B		2.8		3.2	
A × B		7.5		7.4	

I – flowering stage of narrowleaf lupin; II – flat green pod stage of narrowleaf lupin.

The highest content of total carbohydrates was revealed in mixtures harvested at the flowering stage of narrowleaf lupin. Delaying the harvesting phase of the mixtures to the flat green pod stage of narrowleaf lupin resulted in a ca. 6% reduction in total carbohydrate content. An analogous relationship was found for water-soluble carbohydrate content. Mixtures harvested at the flowering stage of narrowleaf lupin were characterised by a significantly higher content compared to mixtures harvested at the flat green pod stage of narrowleaf lupin. Delaying the harvest date resulted in a ca. 28% reduction in water-soluble carbohydrate content. Also, other authors found a reduction in the carbohydrate content of legume-cereal mixtures with delayed harvest date (Marković et al. 2020; Bo et al. 2022b). According to Piltz et al. (2021), the water-soluble carbohydrate content in plants decreases with grain development. In our study, the interaction between the share of components in the mixture and the harvest date was demonstrated, which shows that delaying the harvest date of mixtures of narrowleaf lupin with spring triticale and spring triticale in pure sowing causes a significant reduction in the content of total carbohydrates in the biomass obtained. In the case of narrowleaf lupin cultivation, harvesting at the later of the development phases analysed has no effect on the total carbohydrate content. The revealed interaction also showed that the harvesting of mixtures of narrowleaf lupin with spring triticale and of crops in pure sowing of narrowleaf lupin and spring triticale at the later of the analysed development phases of narrowleaf lupin causes a significant reduction in the content of water-soluble carbohydrates. In contrast, as reported by O'Kiely et al. (2022) on faba bean harvested at three dates, the water-soluble carbohydrate content initially increased, while a decrease was revealed at the latest harvest date. Angeletti et al. (2022) in their study on barley and faba bean mixtures found a smaller decrease in carbohydrate content with successive development phases in legumes compared to cereals.

The study revealed an interaction of the harvest date of the narrowleaf lupin/spring triticale mixtures during the study years (Fig. 1).

From the interaction shown, significantly higher contents of total carbohydrates and water-soluble carbohydrates were found in mixtures of narrowleaf lupin with spring triticale harvested at the flowering stage of narrowleaf lupin compared to mixtures harvested at the flat green pod stage of narrowleaf lupin regardless of weather conditions during the growing season of the mixtures.

Klevenhusen and Zebeli (2021) report on the need to provide feeds with water-soluble carbohydrate content of up to 250 g·kg^{-1} DM to high-milking cattle in early lactation in order to overcome negative energy balance after parturition. Outside this period, a sufficient content of water-soluble carbohydrates is 150–200 g·kg^{-1} DM. The green fodder obtained from narrowleaf lupin and a mixture with 75% + 25% of narrowleaf lupin and spring triticale components, respectively, harvested at the flowering stage, is at a similar level and should be useful for feeding high-yielding cattle, while during lactation, the feed should be supplemented with concentrate supplements or concentrate feed.

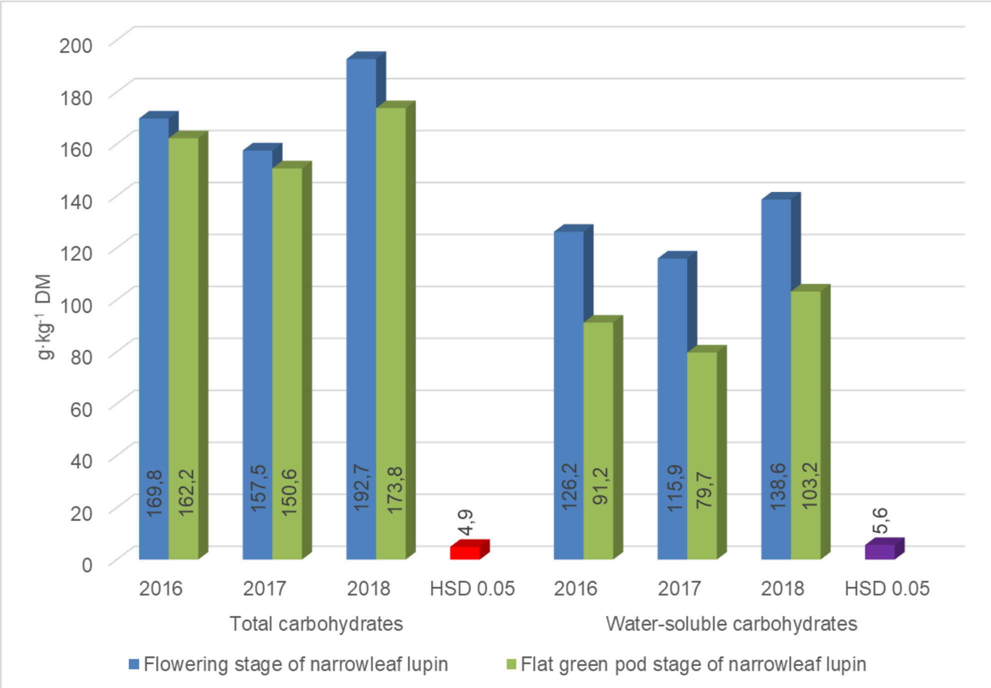

Fig. 1. Total carbohydrates and water-soluble carbohydrates content in narrowleaf lupin/spring triticale mixtures according to harvest date in the research years 2016–2018, g·kg^{-1} DM

In our study, the share of components in the mixture of narrowleaf lupin with spring triticale and weather conditions during the plant growing period significantly differentiated the content of crude fat and crude ash in the green fodder obtained (Table 4).

Table 4. Crude fat and crude ash content in narrowleaf lupin/spring triticale mixtures according to component share in the mixture in 2016–2018, g·kg^{-1} DM

Component share in the mixture % (A)		Crude fat				Crude ash			
		years (Y)			means	years (Y)			means
narrowleaf lupin	spring triticale	2016	2017	2018		2016	2017	2018	
100	0	25.9	25.1	27.6	26.2	82.2	76.7	84.1	81.0
75	25	25.3	24.5	27.0	25.6	80.9	75.5	81.2	79.2
50	50	24.5	23.7	26.2	24.8	78.8	73.3	79.2	77.1
25	75	23.1	22.3	24.8	23.4	76.4	70.9	76.8	74.7
0	100	22.5	21.7	24.2	22.8	74.5	69.0	75.1	72.8
Means		24.2	23.4	25.9	–	78.5	73.1	79.2	–
$HSD_{0.05}$									
Y		0.5				0.7			
A		0.7				0.9			
Y × A		ns				1.7			

ns – non-significant.

The highest content of crude fat and crude ash was found in the green fodder of mixtures of narrowleaf lupin with spring triticale harvested in 2018, which was characterised by the highest means of temperature during plant vegetation and a sum of precipitation lower by 37.7 mm compared to the multi-year sum. The year 2016, which had a lower means of temperature from April to July and a similar sum of precipitation compared to 2018, revealed a reduction in crude fat content of ca. 7% and crude ash content of ca. 1% compared to 2018. In the case of crude ash, however, the reduction in content was not statistically significant. Indeed, the lowest crude fat and crude ash contents were revealed in the green fodder of mixtures harvested in 2017, which had the highest rainfall among the years analysed. In relation to 2018, 2017 showed a decrease in crude fat content of ca. 10% and crude ash content of ca. 8%. A reduction in crude fat and crude ash content in years with higher sum precipitation and lower means of temperature during the growing season was also revealed by other authors in studies carried out on legume-cereal mixtures (Księżak et al. 2016; Bo et al. 2022a; Giannoulis et al. 2022). This is to be explained by the fact that when there is a higher sum precipitation during the growing season of the plants, the dry matter content decreases, including crude fat and crude ash which are part of it. In our study, the highest crude fat content was revealed in the green fodder of narrowleaf lupin and in the mixture with 75% share of narrowleaf lupin and 25% of spring triticale. On the other hand, the significantly lowest content was found in the spring triticale crop and the mixture with 25% + 75% share of narrowleaf lupin and spring triticale components, respectively. The higher crude fat content in legumes compared to cereals is also confirmed by studies conducted by other authors (Pozdíšek et al. 2011; Hamad et al. 2020). In the conducted studies, increasing the share of narrowleaf lupin in the sowing of mixtures resulted in a significant increase in the crude fat content in the obtained green fodder. This is due to the higher concentration of crude fat in legumes compared to cereals. An analogous relationship in studies conducted on other legume-cereal mixtures was also revealed by Księżak et al. (2016), Makarewicz et al. (2015) and İleri et al. (2020). In our own study, the highest crude ash content was found in the green fodder of narrowleaf lupin, while the lowest was found in spring triticale. Also Singh et al. (2019) and Bracey et al. (2022) showed higher ash content in legumes compared to cereals in their experiment. Among the mixtures, the highest content was revealed in the mixture with 75% share of narrowleaf lupin and 25% share of spring triticale. Increasing the share of spring triticale in the sown mixture resulted in a significant decrease in the crude ash content of the green fodder obtained. Also Angeletti et al. (2022) found an increase in crude ash content in faba bean-barley mixtures with an increase in the share of legume in the sowing. In our own study revealed an interaction from which the highest crude ash content in 2016 and 2018 was characterised by narrowleaf lupin. The lowest ash content in 2016 was found in the spring triticale crop. In 2018, the lowest content was revealed in spring triticale green fodder and in a mixture with 25% narrowleaf lupin and 75% spring triticale. In 2017, the year with the highest sum of precipitation, the highest crude ash content, which was not significantly different, was found in the green fodder of narrowleaf lupin and in a mixture with 75% of narrowleaf lupin and 25% of spring triticale.

In our own research, the harvest date of mixtures of narrowleaf lupin with spring triticale significantly influenced the content of crude fat and crude ash (Table 5).

The highest content of crude fat was found in mixtures harvested at the stage of the flat green pod of the narrowleaf lupin. Harvesting mixtures at an earlier developmental stage of narrowleaf lupin resulted in a decrease in crude fat content by ca. 8%. Also, studies conducted by other authors (Faligowska et al. 2014; Makarewicz et al. 2015) revealed an increase in crude fat content with delayed harvest date in both legume-cereal mixtures and in pure legume and cereal sowings. In our study, a higher crude ash content was obtained in the green fodder of mixtures of narrowleaf lupin with spring triticale harvested at the flowering stage of narrowleaf lupin.

Table 5. Crude fat and crude ash content in narrowleaf lupin/spring triticale mixtures (means across 2016–2018), g·kg^{-1} DM

Component share in the mixture % (A)		Crude fat		Crude ash	
		harvest date (B)		harvest date (B)	
narrowleaf lupin	spring triticale	I	II	I	II
100	0	25.2	27.1	86.3	75.7
75	25	24.5	26.6	83.7	74.6
50	50	23.7	25.8	80.3	73.9
25	75	22.4	24.3	76.8	72.6
0	100	21.6	23.9	74.4	71.2
Means		23.5	25.5	80.3	73.6
$HSD_{0.05}$					
B		0.2		0.3	
A × B		ns		0.8	

I – flowering stage of narrowleaf lupin; II – flat green pod stage of narrowleaf lupin; ns – non-significant.

Harvesting the mixtures at the later of the analysed harvest dates resulted in a decrease in crude ash content by ca. 8%. The obtained relationship is also confirmed by the results obtained by other authors (Dahmardeh et al. 2009; Bo et al. 2022a; Seydosoglu and Bengisu 2019; Angeletti et al. 2022). According to Molla et al. (2018), crud ash of plants declined during the maturing process due to natural dilution and translocation of nutrients from vegetative part to the root system. In our study, the interaction of the share of components in the mixture of narrowleaf lupin with spring triticale and the harvest date was revealed, which shows that, irrespective of the mixture composition, delaying the harvest date from the flowering stage of narrowleaf lupin to the flat green pod stage of narrowleaf lupin results in a significant reduction in crude ash concentration in green fodder.

In our own research, the interaction of growing season conditions with the harvest date of narrowleaf lupin and spring triticale mixtures on the crude ash content of the green fodder was demonstrated (Fig. 2).

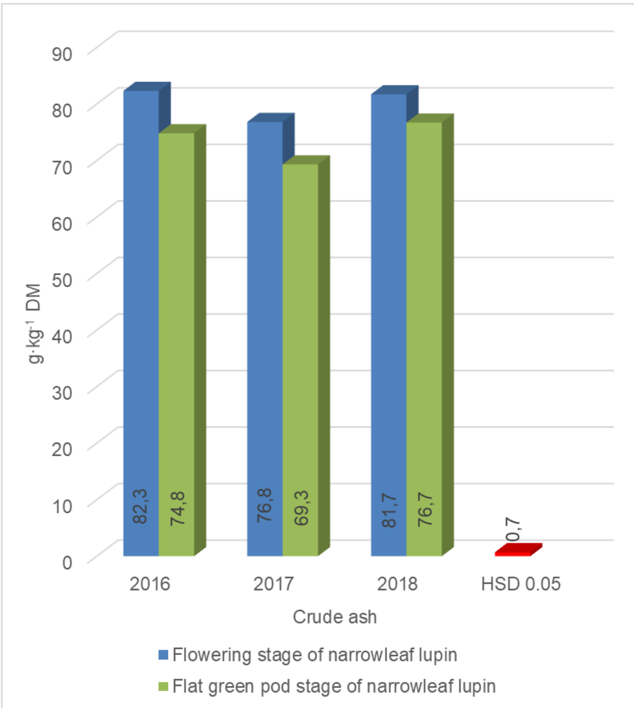

Fig. 2. Crude ash content in narrowleaf lupin/spring triticale mixtures according to harvest date in the research years 2016–2018, g·kg^{-1} DM

In all years of the study, a significantly higher crude ash content was revealed in the green fodder of mixtures harvested at the flowering stage of narrowleaf lupin compared to mixtures harvested at the flat green pod stage of narrowleaf lupin.

CONCLUSIONS

Mixtures of narrowleaf lupin with spring triticale concentrated the highest amount of total carbohydrates, water-soluble carbohydrates, crude fat and crude ash when grown under conditions of low water availability and high average air temperature. Among the mixtures, the mixture with 75% narrowleaf lupin and 25% spring triticale had the highest content of total carbohydrates, water-soluble carbohydrates, crude fat and crude ash. Delaying the harvest of mixtures from the flowering stage to the flat green pod stage of narrowleaf lupin resulted in a significant reduction in total carbohydrate, water-soluble carbohydrate and crud ash content. A higher crude fat content was found in the mixtures harvested at the flat green pod stage of the narrowleaf lupin compared to mixtures harvested at the flowering stage of the narrowleaf lupin. In order to obtain roughage with a high content of total carbohydrates, water-soluble carbohydrates, crude fat and crude ash a mixture with 75% + 25% components of narrowleaf lupin and spring triticale, respectively, should be recommended for cultivation and harvested at the flowering stage of narrowleaf lupin.

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WYBRANE ELEMENTY SKŁADU CHEMICZNEGO MIESZANEK ŁUBINU WĄSKOLISTNEGO (*LUPINUS ANGUSTIFOLIUS* L.) Z PSZENŻYTEM JARYM (X *TRITICOSECALE WITTMACK*) UPRAWIANYCH NA ZIELONĄ MASĘ

Streszczenie. Badania polowe przeprowadzono w latach 2016–2018 w Rolniczej Stacji Doświadczalnej w Zawadach, należącej do Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach i zlokalizowanej w pobliżu Siedlec w województwie mazowieckim. Celem przeprowadzonych badań była ocena zawartości wybranych składników pokarmowych w mieszankach łubinu wąskolistnego z pszenżytem jarym zbieranych w dwóch fazach rozwojowych łubinu wąskolistnego. Najwyższą zawartość węglowodanów ogółem, węglowodanów rozpuszczalnych w wodzie i popiołu surowego spośród mieszanek ujawniono w mieszance o 75-procentowym udziale łubinu wąskolistnego i 25-procentowym udziale pszenżyta jarego. Najwyższą zawartość tłuszczu surowego stwierdzono zaś w mieszankach o udziale komponentów odpowiednio łubinu wąskolistnego i pszenżyta jarego 75% + 25% i 50% + 50%. Wyższą zawartość węglowodanów i popiołu surowego oznaczono w mieszankach zebranych w fazie kwitnienia łubinu wąskolistnego, a wyższą zawartość tłuszczu surowego w mieszankach zebranych w fazie płaskiego zielonego strąka łubinu wąskolistnego. Spośród mieszanek do uprawy w celu osiągnięcia paszy objętościowej o wysokiej zawartości węglowodanów ogółem, węglowodanów rozpuszczalnych w wodzie, tłuszczu surowego i popiołu surowego należy zalecać mieszankę o udziale komponentów 75% + 25% odpowiednio łubinu wąskolistnego i pszenżyta jarego i jej zbiór w fazie kwitnienia łubinu wąskolistnego.

Słowa kluczowe: łubin wąskolistny, pszenżyto jare, mieszanka, węglowodany ogółem, węglowodany rozpuszczalne w wodzie, tłuszcz surowy, popiół surowy.