

## POST-HARVEST RESIDUES OF NARROW-LEAVED LUPIN (*Lupinus angustifolius* L.) / SPRING RYE (*Secale cereal* L.) MIXTURES AS A SOURCE OF BIOLOGICAL NITROGEN FOR WINTER TRITICALE (*Triticosecale* Wittm. ex A. Camus)

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**Abstract.** Field research was conducted in 2010-2012 to determine the manuring value of the post-harvest residues of narrow-leaved lupin (*Lupinus angustifolius* L.)/spring rye (*Secale cereal* L.) mixtures. The following two experimental factors were investigated: I. forecrop – mixtures: narrow-leaved lupin – pure stand 100%, spring rye – pure stand 100%, narrow-leaved lupin 75% + spring rye 25%, narrow-leaved lupin 50% + spring rye 50%, narrow-leaved lupin 25% + spring rye 75%; II. forecrop harvest date: narrow-leaved lupin flowering stage, flat green pod stage. It was inferred, based on the obtained results, that the greatest quantity of post-harvest residues was supplied by spring rye as well as narrow-leaved lupin/spring rye mixtures containing 25 + 75% and 50 + 50% of the respective components, harvested at the stage of flat green pod of narrow-leaved lupin, the greatest nitrogen amount being supplied by narrow-leaved lupin harvested at the aforementioned development stage. The highest grain yield was produced by winter triticale (*Triticosecale* Wittm. ex A. Camus) following an incorporation of the post-harvest residues of narrow-leaved lupin/spring rye mixture containing 50 + 50% of the respective components and harvested at the stage of narrow-leaved lupin flat green pod.

**Keywords:** forecrop, 1000 grain weight, yield, total nitrogen content

### Introduction

Legume/cereal mixtures are valuable green fodder crops fed to cattle, their post-harvest residues being a source of biological nitrogen for following crop plants, cereals in particular. Also, they are more environmentally friendly than mineral nitrogen fertilisers (Jensen and Hauggard-Nielsen, 2003; Herridge et al., 2008). Compared to legume post-harvest residues, such biomass has a broader C:N ratio, which results in its mineralisation process being slowed down. As reported by Mayer et al. (2003), Tripolskaja and Šidlauskas (2010) as well as Nemeikšiene et al. (2010), an application of legume post-harvest residues preceding winter wheat results in mineral nitrogen leaching into deeper soil strata during the autumn-winter-spring period, which is caused by rapid mineralization of such biomass. As far as the post-harvest residues of legume/cereal mixtures are concerned, the biological nitrogen is gradually released to be used by the following plant throughout the whole growing season, which prevents its leaching and protects the soil environment (Arlauskiene and Maiksteniene, 2008; Nemeikšiene et al., 2010).

Triticale is a species which has been recently introduced for cultivation purposes. A paucity of literature has been noticed pertaining to the manuring value of legume/cereal post-harvest residues for this crop plant.

It has been assumed that an incorporation of the crop residues of narrow-leaved lupine/spring rye mixtures at the stage of narrow-leaved lupin flowering and flat green pod will make it possible to determine differences in yield performance and amount of nitrogen accumulated in winter triticale grain, and indicate which mixtures have the most beneficial effect on grain yield and amount of nitrogen accumulated in winter triticale grain.

The objective of the study was to determine the manuring value of post-harvest residues of narrow-leaved lupin/spring rye mixtures harvested at the stage of narrow-leaved lupin flowering and flat green pod, expressed in terms of grain yield and amount of biological nitrogen accumulated in winter triticale grain.

## Materials and Methods

Field research was conducted in 2010-2012 at the Zawady Experimental Farm (52°03'39"N, 22°33'80"E) of Siedlce University of Natural Sciences and Humanities in Poland. The soil on which the experiment was set up was Stagnic Luvisol, its reaction was neutral and it contained average amounts of available phosphorus, potassium and magnesium. Humus content was 1.40%. The experiment was a split-block arrangement with three replicates. The following two factors were examined: I. forecrop – mixtures: narrow-leaved lupin, pure stand 100%, spring rye, pure stand 100%, narrow-leaved lupin 75% + spring rye 25%, narrow-leaved lupin 50% + spring rye 50%, narrow-leaved lupin 25% + spring rye 75%; II. harvest date: the stage of narrow-leaved lupin flowering, the stage of narrow-leaved lupin flat green pod. The following seeding rates were used: narrow-leaved lupin 260 seeds m<sup>-2</sup>, spring rye 217 grains m<sup>-2</sup>, narrow-leaved lupin 195 seeds m<sup>-2</sup> + spring rye 54 grains m<sup>-2</sup>, narrow-leaved lupin 130 seeds m<sup>-2</sup> + spring rye 109 grains m<sup>-2</sup>, narrow-leaved lupin 65 seeds m<sup>-2</sup> + spring rye 163 grains m<sup>-2</sup>. In all the study years, the mixtures were preceded by oats. The agrotechnics of mixtures narrow-leaved lupin + spring rye are presented in the *Table 1*. Narrow-leaved lupin (cv. Zeus) and spring rye (cv. Bojko) seeds were planted in early April as described for factor I. The plants were harvested in late June (stage of narrow-leaved lupin flowering) and early July (stage of narrow-leaved lupin flat green pod). Following forecrop harvest, post-harvest residues of narrow-leaved lupin/oat mixtures were collected from an area of 1 m<sup>2</sup> and to the depth of 30 cm in each plot in order to determine their dry matter yield. The residue dry matter was used to determine total nitrogen content (by means of Kjeldahl method).

Winter triticale cv. Borwo was sown in mid-September at the rate of 239 grains m<sup>-2</sup>. Pre-plant phosphorus and potassium applications were made at the rates adjusted to soil availability, that is 70 kg ha<sup>-1</sup> P and 99 kg ha<sup>-1</sup> K. Nitrogen fertiliser was split into two rates of 40 and 60 kg ha<sup>-1</sup> applied, respectively, after the cereal resumed growth in the spring, and at the stage of stem elongation. Winter triticale was harvested in late July. Grain yield was determined in each plot and its average samples were taken to determine total nitrogen by Kjeldahl method (AOAC, 2006). Additionally, 1000 grain weight was recorded.

Analysis of variance (split-block) was performed on the data for each experimental characteristic. Means were compared using Tukey's test, at the significance level of P ≤ 0.05, when significant sources of variation had been confirmed. All the statistical calculations were performed using the authors' algorithms in MS Excel 7.0.

**Table 1.** The agrotechnics of mixtures narrow-leaved lupin + spring rye in experiment 2010-2012

Forecrop – mixtures	Fertilization			Plant protection
	Before sowing		BBCH 31-32	
	in autumn	in spring		
Narrow-leaved lupine – pure stand 100%	35.2 kg⊙ha <sup>-1</sup> P 99.6 kg⊙ha <sup>-1</sup> K	-	-	mechanical weed control (harrow)
Spring rye – pure stand 100%	35.2 kg⊙ha <sup>-1</sup> P 99.6 kg⊙ha <sup>-1</sup> K	30 kg⊙ha <sup>-1</sup> N	50 kg⊙ha <sup>-1</sup> N	mechanical weed control (harrow)
Narrow-leaved lupine 75% + spring rye 25%	35.2 kg⊙ha <sup>-1</sup> P 99.6 kg⊙ha <sup>-1</sup> K	30 kg⊙ha <sup>-1</sup> N	30 kg⊙ha <sup>-1</sup> N	mechanical weed control (harrow)
Narrow-leaved lupine 50% + spring rye 50%	35.2 kg⊙ha <sup>-1</sup> P 99.6 kg⊙ha <sup>-1</sup> K	30 kg⊙ha <sup>-1</sup> N	30 kg⊙ha <sup>-1</sup> N	mechanical weed control (harrow)
Narrow-leaved lupine 25% + spring rye 75%	35.2 kg⊙ha <sup>-1</sup> P 99.6 kg⊙ha <sup>-1</sup> K	30 kg⊙ha <sup>-1</sup> N	30 kg⊙ha <sup>-1</sup> N	mechanical weed control (harrow)

## Results

### *Dry matter yield of the post-harvest residues of narrow-leaved lupin/spring rye mixtures*

The dry matter yield of the post-harvest residues of narrow-leaved lupin/spring rye mixtures was significantly affected by the experimental factors and their interaction (Table 2).

**Table 2.** Dry matter quantity of forecrop post-harvest residues (averaged across 2010-2011), t⊙ha<sup>-1</sup>

Forecrop – mixtures (I)	Forecrop harvest date (II)		Means
	Stage of narrow-leaved lupine flowering	Stage of narrow-leaved lupine flat green pod	
Narrow-leaved lupine – pure stand 100%	4.86a*	5.78a	5.32A
Spring rye – pure stand 100%	5.12a	6.84b	5.98B
Narrow-leaved lupine 75% + spring rye 25%	4.93a	5.87a	5.40AB
Narrow-leaved lupine 50% + spring rye 50%	5.03a	6.42ab	5.73AB
Narrow-leaved lupine 25% + spring rye 75%	5.09a	6.69b	5.89AB
<b>Means</b>	5.01A	6.32B	-
<i>ANOVA</i>	P-value		HSD <sub>0.05</sub>
Forecrop – mixtures (I)	<0.001		0.61
Forecrop harvest date (II)	<0.001		0.28
Interaction: IxII	<0.001		0.74

\*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 greatest post-harvest residue biomass was supplied by spring rye cultivated in pure stand and mixed with narrow-leaved lupin. The lowest biomass of post-harvest residues was introduced to the soil by narrow-leaved lupin grown in pure stand. Harvest date had a significant influence on the quantity of dry matter of post-harvest residues of narrow-leaved lupin mixed with spring rye, it being higher for mixtures harvested at the stage of narrow-leaved lupin flat green pod compared with the flowering stage. An interaction of the experimental factors resulted in the highest biomass of post-harvest residues being supplied by spring rye and its mixtures with narrow-leaved lupine when they contained 25 + 75% and 50 + 50% of the respective components.

### ***Nitrogen amount supplied to the soil by incorporating the biomass of post-harvest residues***

Statistical analysis revealed a significant impact of the experimental factors and their interaction on the amount of nitrogen introduced into the soil with the incorporated biomass of the post-harvest residues of narrow-leaved lupin and spring rye (*Table 3*).

**Table 3.** Nitrogen amount introduced into soil with incorporated biomass of post-harvest residues (averaged across 2010-2011), kg ha<sup>-1</sup>

Forecrop – mixtures (I)	Forecrop harvest date (II)		Means
	Stage of narrow-leaved lupine flowering	Stage of narrow-leaved lupine flat green pod	
Narrow-leaved lupine – pure stand 100%	114.7d*	135.2d	124.9D
Spring rye – pure stand 100%	68.4a	79.8a	74.1A
Narrow-leaved lupine 75% + spring rye 25%	98.9c	121.4dc	110.2C
Narrow-leaved lupine 50% + spring rye 50%	92.6b	109.7b	101.2C
Narrow-leaved lupine 25% + spring rye 75%	81.5b	91.6b	86.6B
<b>Means</b>	91.2A	107.6B	-
<i>ANOVA</i>	P-value		HSD <sub>0.05</sub>
Forecrop – mixtures (I)	<0.001		10.2
Forecrop harvest date (II)	<0.001		3.8
Interaction: IxII	<0.001		12.4

\*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 highest nitrogen amount was associated with an incorporation of narrow-leaved lupine post-harvest residues, the quantity of nitrogen accumulated by legume/cereal post-harvest residues being lower. Of the legume/cereal mixtures, the 75 + 25% and 50 + 50% mixtures were the greatest nitrogen contributors. The mixture containing 25 + 75% of narrow-leaved lupin and spring rye, respectively, supplied less nitrogen accumulated in its post-harvest residues, it being the lowest in spring rye-post harvest residues. Forecrop harvest date had a significant effect on nitrogen amount introduced into the soil due to an application of post-harvest residues. More nitrogen was supplied

by the post-harvest residues of narrow-leaved lupin/spring rye mixtures harvested at the stage of narrow-leaved lupin green pod stage, compared with the flowering stage. An interaction between experimental factors was confirmed. Narrow-leaved lupin grown in pure stand and harvested at the flat green pod stage provided more nitrogen in its post-harvest residues. Of the mixtures, the post-harvest residues of narrow-leaved lupin/spring rye mixtures containing 75 + 25% and 50 + 50% of the respective components harvested at the stage of narrow-leaved lupin flat green pod introduced more nitrogen into the soil than the 25 + 75% mixture harvested at the same development stage. The post-harvest residues of spring rye harvested at the stage of narrow-leaved lupin flowering and flat green pod were the poorest nitrogen sources.

### **Winter triticale grain yield**

Winter wheat grain yield was significantly affected by the experimental factors and their interaction (Table 4).

**Table 4.** Winter triticale grain yield (averaged across 2011-2012),  $t\circ\text{ha}^{-1}$

Forecrop – mixtures (I)	Forecrop harvest date (II)		Means
	Stage of narrow-leaved lupine flowering	Stage of narrow-leaved lupine flat green pod	
Narrow-leaved lupine – pure stand 100%	9.02cd*	9.83c	9.43CD
Spring rye – pure stand 100%	6.37a	7.08a	6.73A
Narrow-leaved lupine 75% + spring rye 25%	8.78c	9.74c	9.26C
Narrow-leaved lupine 50% + spring rye 50%	9.47d	10.18c	9.83D
Narrow-leaved lupine 25% + spring rye 75%	7.19b	8.76b	7.98B
<b>Means</b>	8.17A	9.12B	-
<i>ANOVA</i>	P-value		HSD <sub>0.05</sub>
Forecrop – mixtures (I)	<0.001		0.48
Forecrop harvest date (II)	<0.001		0.24
Interaction: IxII	<0.001		0.55

\*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 highest winter triticale grain yield was obtained following an incorporation of the pos-harvest residues of narrow-leaved lupin grown in pure stand and mixed with spring rye, the respective components being 50 + 50%. In the remaining plots, grain yield was significantly lower, it being the lowest following an incorporation of spring rye post-harvest residues. Harvest date significantly affected winter triticale grain yield. The yield was higher when narrow-leaved lupin/spring rye mixtures had been harvested at the stage of narrow-leaved lupin flat green pod rather than the flowering stage. An interaction between the experimental factors was confirmed. The highest winter triticale grain yield was produced after the cereal followed an incorporation of the post-harvest residues of narrow-leaved lupin/spring rye mixture harvested at the stage of narrow-

leafed lupin flat green pod, and pure-stand narrow-leaved lupin harvested at the aforementioned stage. The lowest yield was produced by cereal following the post-harvest residues of spring rye harvested at the stage of narrow-leaved lupin flowering.

### ***1000 grain weight of winter triticale***

1000 grain weight of winter triticale was significantly affected by the experimental factors and their interaction (*Table 5*).

**Table 5.** Winter triticale 1000 grain weight (averaged across 2011-2012), g

Forecrop – mixtures (I)	Forecrop harvest date (II)		Means
	Stage of narrow-leaved lupine flowering	Stage of narrow-leaved lupine flat green pod	
Narrow-leaved lupine – pure stand 100%	46.7c*	47.9c	47.3C
Spring rye – pure stand 100%	43.5a	44.9a	44.2A
Narrow-leaved lupine 75% + spring rye 25%	46.8cd	47.2c	47.0C
Narrow-leaved lupine 50% + spring rye 50%	47.5d	48.9d	48.2D
Narrow-leaved lupine 25% + spring rye 75%	45.3b	46.0b	45.7B
<b>Means</b>	46.0A	47.0B	-
<i>ANOVA</i>	P-value		HSD <sub>0.05</sub>
Forecrop – mixtures (I)	<0.001		0.5
Forecrop harvest date (II)	<0.001		0.2
Interaction: IxII	<0.001		0.7

\*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 highest 1000 grain weight was recorded for winter triticale following an incorporation of the post-harvest residues of narrow-leaved lupin/spring rye mixture containing 50 + 50% of the respective components. 1000 weight of winter triticale following an incorporation of the post-harvest residues of 75 + 25% mixture of narrow-leaved lupine and spring rye was similar but lower than the value recorded for the best experimental unit. In the remaining plots, significantly lower values were recorded, in particular after an incorporation of spring rye post-harvest residues. Harvest date had a significant influence on 1000 grain weight, it being higher after winter triticale followed narrow-leaved lupin/spring rye mixtures harvested at the stage of narrow-leaved lupine flat green pod stage rather than the legume flowering stage. An interaction was confirmed: the highest 1000 grain weight of winter triticale was recorded after an incorporation of the post-harvest residues of the 50 + 50% mixture of narrow-leaved lupine and spring rye harvested at the stage of narrow-leaved lupine flat green pod. 1000 grain weight of winter triticale following an incorporation of the post-harvest residues of narrow-leaved lupin grown in pure stand and the 75 + 25% mixture of narrow-leaved lupin and spring rye harvested at the stage of narrow-leaved lupin flat

green pod, although significantly lower, remained at a beneficial level. The lowest 1000 grain weight of winter triticale was recorded after an incorporation of the post-harvest residues of spring rye, regardless of the harvest date.

### **Total nitrogen amount accumulated in winter triticale grain**

Statistical analysis demonstrated a significant effect of the experimental factors and their interaction of the total nitrogen amount accumulated in winter triticale grain (Table 6).

**Table 6.** Total nitrogen amount accumulated in winter triticale grain (averaged across 2011-2012), kg ha<sup>-1</sup>

Forecrop – mixtures (I)	Forecrop harvest date (II)		Means
	Stage of narrow-leaved lupine flowering	Stage of narrow-leaved lupine flat green pod	
Narrow-leaved lupine – pure stand 100%	168.6c*	181.7bc	175.2B
Spring rye – pure stand 100%	128.9a	139.5a	134.2A
Narrow-leaved lupine 75% + spring rye 25%	169.5c	179.3b	174.4B
Narrow-leaved lupine 50% + spring rye 50%	180.6c	196.7c	188.7B
Narrow-leaved lupine 25% + spring rye 75%	142.4b	148.1a	145.3A
<b>Means</b>	158.0A	169.1B	-
<i>ANOVA</i>	P-value		HSD <sub>0.05</sub>
Forecrop – mixtures (I)	<0.001		14.5
Forecrop harvest date (II)	<0.001		9.0
Interaction: IxII	<0.001		16.2

\*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 highest total nitrogen amount was accumulated in the grain of winter triticale following the post-harvest residues of narrow-leaved lupin/spring rye mixture containing 50 + 50% of the respective components, and narrow-leaved lupin grown in pure stand. In the remaining units, total nitrogen amount accumulated in winter triticale grain was significantly lower after an incorporation of the post-harvest residues of narrow-leaved lupin/spring rye mixtures, it being the lowest following an incorporation of spring rye post-harvest residues. Harvest date had a significant impact on the amount of total nitrogen accumulated in winter triticale grain. More nitrogen was accumulated in the grain of winter triticale grown after an incorporation of the post-harvest residues of narrow-leaved lupin mixed with spring rye harvested at the stage of narrow-leaved lupin flat green pod rather than the flowering stage. An interaction of the experimental factors was confirmed it indicating that total nitrogen accumulation in grain was the highest when winter triticale was cultivated after the ploughing down of the post-harvest residues of 50 + 50% mixture of narrow-leaved lupin and spring rye, and pure-stand narrow-leaved lupin harvested at the stage of flat green pod. The lowest total nitrogen

amount was accumulated in the grain of winter triticale following an incorporation of the post-harvest residues of spring rye harvested at the stage of narrow-leaved lupin flowering and flat green pod.

## Discussion

The research reported in this work demonstrated that the post-harvest residues of narrow-leaved lupin and its mixtures with spring rye are a valuable source of biological nitrogen for winter triticale. Modern agriculture strives for reducing mineral nitrogen application and replacing it with biological nitrogen which does not pose a threat to the environment (Bergvist, 2003; Hauggard-Nielsen et al., 2012). Also Thorsed et al. (2006) and Arlauskienė and Maikstienė (2008) reported that, following biological transformation, incorporated biomass becomes a source of nitrogen for the crop plants in the subsequent year. In the experiment reported here, the highest amount of post-harvest residues was supplied by spring rye and narrow-leaved lupin/spring rye mixtures containing 25 + 75% and 50 + 50% of the respective components. Buraczyńska et al. (2011), who cultivated field pea, spring wheat and their mixtures for seed production purposes, found that highest amounts of post-harvest residues were supplied by spring triticale grown in pure stand and mixed with field pea, the respective components being 25 + 75%. High biomass production by grasses and cereals was also confirmed by Watson et al. (2002), Arlauskienė and Maikstienė (2008), Nemeikšienė et al. (2010) and Sarunaite et al. (2013). In the present study, the post-harvest residues of narrow-leaved lupin grown in pure stand introduced the lowest biomass amount into the soil. Also research by Bergvist (2003) and Panagiotis (2015) confirmed that, compared with cereals or grasses, leguminous plants supply less biomass, which is due to the fact that their rooting system is not as well developed as that of grasses although narrow-leaved lupin forms a tap root system. In the present experiment, harvest date had a significant effect on the amount of dry matter supplied by the post-harvest residues of narrow-leaved lupin/spring rye mixtures. A significantly higher amount of post-harvest biomass was supplied by the legume/cereal mixtures harvested at the stage of narrow-leaved lupine flat green pod compared with the flowering stage. It can be explained by the fact that plants harvested at a more advanced growth stage develop more root matter, which translates into a higher amount of biomass supplied with post-harvest residues.

Post-harvest residues of leguminous plants and their mixtures with cereals are a valuable source of biological nitrogen for the following crops (Buraczyńska et al., 2011). In the present study, the highest nitrogen quantity was supplied to the soil with the post-harvest residues of narrow-leaved lupin, which corresponds with findings reported by Bergvist (2003), Thorsed et al. (2006), Sarunaite et al. (2013) and Panagiotis (2015). It should be stressed that the post-harvest residues of legume/cereal mixtures supply large nitrogen amounts for the following crop (Lemola et al., 2000; Känkänen and Eriksson, 2007; Kramberger et al., 2009; Buraczyńska et al., 2011). In the study discussed here, the highest nitrogen supply was associated with the 75 + 25% and 50 + 50% mixtures of narrow-leaved lupin and spring rye, it being the lowest for spring rye crop residues, which is due to the fact that non-legumes contain less nitrogen and, as a result, are poorer sources of this element for the following plant. The research by Känkänen and Eriksson (2007) confirms this finding as the authors demonstrated that grasses provided less nitrogen for the crop that followed. In the study reported here, harvest date had a significant influence on the amount of nitrogen introduced into the



soil with post-harvest residues. More nitrogen was supplied by residues of narrow-leaved lupin mixed with spring rye and harvested at the stage of narrow-leaved lupin flat green pod compared with the flowering stage, which can be explained by the fact that plants harvested at an earlier development stage contained more nitrogen but their supply of this element is lower because they develop less biomass in the form of post-harvest residues than plants harvested later in the season, the finding corresponding with results reported by Mechri et al. (2016).

Studies by Smagacz (2004), Piekarczyk (2010), Prusiński et al. (2016) and Faligowska et al. (2019) demonstrated that the grain yield of winter cereals following leguminous crops was higher compared with cereal forecrops. Triticale is a species which has been recently introduced for cultivation. As a result, there is a paucity of research into the effect of agrotechnological factors, including forecrop, on triticale yield (Noworolnik and Jaśkiewicz, 2018). In the present study, the highest grain yield of winter triticale was recorded after the cereal followed the narrow-leaved lupin/spring rye mixture containing 50 + 50% of the respective components, and after pure-stand narrow-leaved lupin. High grain yield was also recorded after an incorporation of the 75 + 25% mixture of narrow-leaved lupin and spring rye harvested at the stage of narrow-leaved lupin flat green pod. Research by Buraczyńska et al. (2011) revealed that the highest winter wheat grain yield was associated with an incorporation of the post-harvest residues and straw of spring triticale/field pea mixture containing 25 + 75% of the respective components, as well as field pea post-harvest residues and straw. Also Pszczołkowska et al. (2018) reported a high increase in spring wheat grain yield following leguminous plants. In turn, Känkänen et al. (2001), Känkänen and Erikssen (2007) as well as Nemeikšien et al. (2010) reported that undersown legumes positively affected cereal grain yield. In the experiment reported here, winter triticale grain yield was the lowest following an incorporation of spring rye post-harvest residues. Piekarczyk (2010) and Buraczyńska et al. (2011) demonstrated that post-harvest residues of cereals grown for grain contributed to a decline in cereal grain yield compared with leguminous residues. Känkänen and Erikssen (2007) as well as Nemeikšien et al. (2010) reported a decline in grain yield when cereal had followed undersown grasses. It may have been due to the fact that leguminous plants and their mixtures with cereals or grasses have a narrower C:N ratio compared with cereals or grasses. It contributed to a more rapid decomposition of the incorporated biomass and release of more nitrogen to be used by the following crop which was able to produce a higher yield. In the present study, harvest date of narrow-leaved lupin/spring rye mixtures significantly affected winter triticale grain yield. The yield was higher following an incorporation of the post-harvest residues of narrow-leaved lupine mixed with spring rye and harvested at the stage of flat green pod compared with the flowering stage. This finding can be explained by the fact that post-harvest residues of narrow-leaved lupin/spring rye mixtures ploughed down at an earlier development stage undergo more rapid mineralization, and the following crop cannot fully utilize the nitrogen provided in this way. The element is leached into deeper soil layers and pollutes the soil environment. Better results may be obtained after an incorporation of post-harvest residues of narrow-leaved lupin/spring rye mixtures at a later development stage, that is the stage of narrow-leaved lupine flat green pod.

In the present study, the highest 1000 grain weight of winter triticale was recorded after the cereal followed the 50 + 50% mixture of narrow-leaved lupin and spring rye. Good results were also obtained for winter triticale grown after an incorporation of the

narrow-leaved lupin/spring mixture containing 75 + 25% of the respective components. Also research by Buraczyńska et al. (2011) demonstrated that the highest 1000 grain weight of winter wheat, in addition to the greatest grain yield, was produced when the crop had followed a spring triticale/field pea mixture containing 25 + 75% of the respective components. It may be explained by the fact that winter cereal growing in good, biological nitrogen-rich soil performs well in terms of grain yield and fill.

In the experiment reported here, winter triticale grain accumulated different amounts of total nitrogen depending on the forecrop. The highest total nitrogen quantity was determined in the grain of winter triticale following the narrow-leaved lupin/spring rye mixture containing 50 + 50% of the respective components as well as narrow-leaved lupin grown in pure stand, which corresponds with findings reported by Buraczyńska et al. (2011). These authors obtained the highest nitrogen amounts in the grain of winter wheat following field pea grown for grain, and after spring triticale/field pea mixture containing 25 + 75% of the respective components. A positive effect of leguminous plants on nitrogen accumulation in cereal grain has also been reported by Känkänen and Eriksson (2007), Herridge et al. (2008), Nemeikšien et al. (2010) and Hauggard-Nielsen et al. (2012), which was due to the fact that the post-harvest residues of legumes leave a large quantity of nitrogen compared with non-legumes, a great share of this nitrogen being available for the following plant after mineralization. The work reported here demonstrated that the narrow-leaved lupin/spring rye mixture containing 75 + 25% of the respective components positively affected nitrogen accumulation in winter triticale grain. The amount of total nitrogen was higher when winter triticale had followed narrow-leaved lupin mixed with spring rye and harvested at the flat green pod stage compared with the flowering stage. The possible explanation is that the post-harvest residues of narrow-leaved lupin/spring rye mixtures accumulated more nitrogen at the legume flat green pod stage than the flowering stage. As a result, the cereal retrieved the nitrogen fixed from the air by legumes thus reducing the risk of nitrogen leaching (Nykänen et al., 2009; Nemeikšienė et al., 2010). Taking the above into account, it seems necessary to continue research on the forecrop effect of post-harvest residues of other legume/cereal mixture combinations in winter cereal production.

Mixture of narrow-leaved lupine with spring rye with 50% + 50% components collected in the flat green pod stage is a good forecrop for winter triticale.

## Conclusions

- 1) The greatest quantity of post-harvest residues was supplied by spring rye and narrow-leaved /spring rye mixtures containing 25 + 75% and 50 + 50% of the respective components harvested at the stage of narrow-leaved lupin flat green pod, the nitrogen supply being the highest for narrow-leaved lupin harvested at the aforementioned development stage.
- 2) The highest grain yield was produced by winter triticale cultivated after an incorporation of the post-harvest residues of narrow-leaved lupin/spring rye mixture containing 50 + 50% of the respective components and harvested at the stage of legume flat green pod.
- 3) Grain of winter triticale following an incorporation of the post-harvest residues of narrow-leaved lupin/spring rye mixtures had the highest 1000 grain weight and the greatest nitrogen accumulation, regardless of the date on which the mixtures were harvested.

- 4) It is recommended to continue research on the subsequent impact of legumes and cereals on the yield of winter cereals or winter oilseed rape.

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