

Quantitative and qualitative changes in the green mass protein of white lupin during the growing season

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Citation: Straková E., Suchý P. (2025): Quantitative and qualitative changes in the green mass protein of white lupin during the growing season. *Plant Soil Environ.*, 71: 820–828.

Abstract: The aim of the study was to assess the quantitative and qualitative changes in crude protein of the white lupin (*Lupinus albus* L.) green mass during the growing season in stands of three cultivars of white lupin (ZULIKA, AMIGA, DIETA), intended for feeding purposes as protein roughage, when grown under the same soil and climatic conditions in the Czech Republic. Changes in the crude protein and amino acid content were monitored during the growing season from the 9th to the 18th week of stand age. Changes in the crop dry weight were characterised by a statistically significant ($P \leq 0.05$) decrease in crude protein from the 9th to the 15th week of stand age (ZULIKA 203.50–176.82 g/kg, AMIGA 190.58–161.59 g/kg, DIETA 201.41–175.84 g/kg). In the following period, during the maturation of lupin pods, from the 15th to the 18th week, the change in the crude protein content of the green matter was not statistically significant (ZULIKA 176.82–162.12 g/kg, AMIGA 161.59–150.95 g/kg, DIETA 175.84–175.24 g/kg). For most of the amino acids studied, a decrease in their content in the dry weight of the green matter was demonstrated from the 9th to the 15th week, with a subsequent statistically significant ($P \leq 0.05$) increase from the 15th to the 18th week of stand age. Interesting differences were observed in the arginine content, which showed a statistically significant increase ($P \leq 0.05$) during the growing season (ZULIKA 7.93–16.03 g/kg, AMIGA 6.88–13.04 g/kg, DIETA 7.56–17.45 g/kg). Changes in the dry weight of the crop in the crude protein and amino acid content can be considered characteristic of lupin crops because of the identical evidence in all three white lupin cultivars studied.

Keywords: Fabaceae; annual forage; vegetation phase; green mass production; nutrition

Currently, the European Union is focusing on exploring new sources of protein feed, which has sparked renewed interest in growing legumes for both animal and human consumption. The Czech Republic supports activities that contribute to strengthening plant protein production and developing the protein crop sector at the European and national levels. This support has led to the adoption of the so-called "Protein Strategy of the Czech Republic", for which a thematic task "Options for expanding the cultivation of protein crops in the Czech Republic in the context of European initiatives to support protein crops and reduce protein

deficit" is currently being prepared (MoA CR 2024). Interest in growing crops of the genus *Lupinus* has been suppressed in the past by the import of soybeans and soy products, which have become the dominant source of protein for animal feed. The worldwide trend of rising prices for soy and soy products, along with concerns about GMO soy, has recently led to an increased interest in cultivating local protein sources, particularly legumes such as soy, but also peas, lupin, and others. From an ecological perspective, cultivating the genus *Lupinus* enhances soil fertility by enriching the soil with nitrogen through symbiotic bacteria

Supported by the Project FVHE VETUNI Brno ITA2024 (TA 242061), "Health status and production parameters of selected food animal species and quality of raw materials of animal origin as a consequence of the use of quality feeds or their supplements".

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<https://doi.org/10.17221/334/2025-PSE>

in the root nodules (Tounsi-Hammami et al. 2019, Msaddak et al. 2023), and the seeds are an important protein commodity suitable for feed purposes; in some cultivars, they are nutritionally more valuable than soybean (Straková et al. 2024, 2025). Around the world, lupin seeds and their products have also found significant use in human nutrition (Boukid and Pasqualone 2022).

The primary interest in cultivating cultivars of the genus *Lupinus* is the production of lupin seeds and their nutritional value (Borowska et al. 2015, Pospíšil and Pospíšil 2015). White lupine (*Lupinus albus* L.) can also be used as an annual forage for the production of the green matter, for direct feeding or possible preservation (ensiling), and thus for the production of quality roughage for the nutrition of ruminants and herbivorous animals. Its use as roughage is hindered by ignorance of the production and nutrient composition of lupin crops, which can be comparable to other forages grown on arable land, such as alfalfa or clover. The spread of lupine cultivation in the Czech Republic, as in the EU, is conditioned by suitable varietal composition, site conditions, growing season, and disease resistance.

Schoofs and Entz (2000) highlight the use of Fabaceae crops as a complement to perennial pasture or silage crops, and also discuss the potential application of annual legumes in combination with cereals for integrated weed control through natural plant competition. As reported by McCartney and Fraser (2010), the rising cost of fossil fuels needed to produce mineral fertilisers and pesticides, and greater awareness of the devastating impact of soil erosion and environmental pollution, are leading to a renewed interest in the use of annual legumes in agricultural systems in, for example, Canada and the USA. The appropriate time of sowing, growth, development and yield of white lupin (*Lupinus albus* L.) was discussed by Akil and Okant (2020). The crude protein content of the white lupin green matter (17.0–22.3%) was studied by Gatel (1994).

The aim of the study was to investigate the quantitative and qualitative changes in crude protein during the growing season in three cultivars of white lupin (ZULIKA, AMIGA and DIETA). Information on the optimum growing season in relation to the nutritional value of roughage is important in terms of animal digestive physiology for maximum nutrient availability to ruminant or herbivorous animals and for subsequent optimum digestibility and utilisation of nutrients from roughage.

MATERIAL AND METHODS

The work deals with the nutritional value and protein quality of the green matter of white lupine (*Lupinus albus* L.) during the growing season. Three samplings of the green matter of the white lupine stand were chosen from an area of 1 m² at 9, 15 and 18 weeks of stand age. This is a period in which significant quantitative and qualitative changes occur, affecting both the growth of the stand and its nutritional value. White lupin cvs. ZULIKA, AMIGA, and DIETA were selected; these cultivars are characterised by good growing properties and are adapted to growing in the climatic and soil conditions of the Czech Republic.

All three cultivars were grown in 2024, in the Benešov District, Central Bohemian Region, Czech Republic, within one site at an altitude of 276 m a.s.l. The site is situated in an area with Cambisol soil, characterised by a slightly acidic pH. Before sowing, nutrients were added to the soil by spring fertilisation with NPK fertiliser (N 7%, P 20%, K 28% + inoculant). A total of 56 kg of nitrogen was supplied, which ensured a good start for the crop until sufficient tubers were formed, after which nitrogen was provided mainly through symbiosis with rhizobia. Sowing was carried out in April using certified fungicide-treated seed and a pneumatic sowing machine. Depending on the soil type and condition at the time of sowing, the sowing depth was 4–5 cm. Each cultivar was grown on an area of 10 ha at a sowing rate of 200 kg/ha/cultivar (700 thousand seeds/ha). During the monitored growing season, the average temperature ranged from 24.9 °C to 27.2 °C with total precipitation of 47.5–39.8 mm (weeks 9–15) and an average temperature of 27.2 °C and total precipitation of 39.7 mm until the 18th week of vegetation. At weeks 9, 15, and 18 of stand age, 8 samples per cultivar were obtained from 1 m² of 8 plot locations for nutritional analysis of white lupine stands. A systematic selection method was used to choose eight sample plots, where samples were taken at regular 30-metre intervals across the cultivation area. The average green matter yield was converted to green matter production per ha. The obtained samples were dried and homogenised (the target particle size was 1 millimetre), and basic analysis for dry matter, crude protein, and amino acid content was carried out according to the AOAC methodology (1995). The dry matter content of the samples was first determined (at 60 °C) before drying to analytical

dryness (at 105 °C). For exactness of comparison, the nutritional indices were expressed in g per 1 kg of the dry matter, which was determined by drying the sample at 105 °C under specified gravimetric conditions. An analysis of the crude protein (CP) content was carried out, in which nitrogen was determined by the Kjeldahl method, multiplied by a coefficient of 6.25. Nitrogen determination was performed using a Buchi analyser (Centec automatika, spol. s.r.o., Prague, Czech Republic). Samples were analysed for total amino acid content after acid hydrolysis using an automatic analyser, AAA 400 (INGOS a.s., Prague, Czech Republic), based on the colour-forming reaction of amino acids with ninhydrin as an oxidising agent. From the spectrum of amino acids analysed, attention was focused on Asp, Thre, Ser, Glu, Pro, Gly, Ala, Val, Met, Ile, Leu, Tyr, Phe, His, Lys, Arg.

At the stage of fully developed white lupin vegetation (week 15 of vegetation), the height of the lupin stands was also monitored. Eight plants from each cultivar were measured using a measuring rod, resulting in a total of 24 samples.

Statistical analysis. A total of 72 samples were analysed in the study. In each time period (week 9, 15, 18 of the plant age), three cultivars of white lupin (ZULIKA, AMIGA, DIETA) were monitored. Eight samples were observed for each cultivar. Each reported average value was based on eight individual measurements. We performed data acquisition, mathematical analysis, and statistical inference. The results were evaluated by mathematical and statistical procedures using UNISTAT version 6.5 (Unistat Ltd, London, UK). Among the basic descriptive statistical indicators, the mean ($\bar{x}$) and $\pm$ standard deviation (SD) were chosen. ANOVA analysis was used, and the Tukey-*HSD* test was used to determine specific differences between the groups studied subsequently.

Differences between mean values were evaluated at a significance level of $P \leq 0.05$ as statistically significant differences and are indexed in the tables using lowercase letters in the range a–c. The statistical significance of the average values of plant height was tested in week 15 of vegetation among the cultivars. The statistical significance of the average values of green mass production, crude protein, and amino acids was tested across the growth stages.

RESULTS AND DISCUSSION

Green matter production. Significant quantitative and qualitative changes were observed in the white lupine stand during the growing season, especially from the 9th to the 18th week of its age, which were related to the growth of the stand and its nutritional value. The key period of stand growth was weeks 9–15, during which intensive green biomass production occurred. By the 15th week of vegetation, most of the green pods of white lupine were fully developed, and the stand did not increase further in green mass. The period from the 15th to the 18th week of stand age was characterised by a decrease in green biomass production, leaf area drop, the development and maturation of lupine pods (seeds), and the accumulation of storage substances in the generative organs. During the period of a fully developed white lupine stand (week 15), the height of the lupin plants was monitored as an indicator, which closely corresponded with the production of green biomass of the crop. The cv. DIETA had the tallest plants on average, measuring 72.3 cm, while the cv. AMIGA had a slightly lower average height of 71.2 cm, and the cv. ZULIKA had the shortest average height at 68.1 cm (Table 1). Statistically significant differences ($P \leq 0.05$) were observed between the plant heights of white

Table 1. The height of the lupin and green matter production of ZULIKA, AMIGA, and DIETA white lupin cultivars ($n = 8$)

		$\bar{x} \pm \text{SD}$		
		ZULIKA	AMIGA	DIETA
The height of the lupin (cm)	week 15	68.10 ^b $\pm$ 2.998	71.20 ^{ab} $\pm$ 4.131	72.30 ^a $\pm$ 1.418
	week 9	6.95 ^c $\pm$ 1.870	6.32 ^c $\pm$ 1.585	7.14 ^c $\pm$ 1.232
In the original mass (t/ha)	week 15	54.30 ^a $\pm$ 6.610	49.53 ^a $\pm$ 4.889	50.19 ^a $\pm$ 4.250
	week 18	17.31 ^b $\pm$ 1.533	21.02 ^b $\pm$ 2.140	27.83 ^b $\pm$ 3.735
In dry matter (t/ha)	week 9	0.93 ^b $\pm$ 0.240	0.91 ^c $\pm$ 0.223	0.98 ^c $\pm$ 0.133
	week 15	8.92 ^a $\pm$ 1.323	7.43 ^b $\pm$ 0.629	7.43 ^b $\pm$ 0.884
	week 18	7.91 ^a $\pm$ 0.519	8.69 ^a $\pm$ 0.625	8.86 ^a $\pm$ 0.650

$\bar{x}$ – arithmetic mean $\pm$ SD – standard deviation, ^{a–c}indices express the statistical difference at the significance level ($P \leq 0.05$) between weeks of monitoring for each cultivar

<https://doi.org/10.17221/334/2025-PSE>

lupin cultivars ZULIKA and DIETA (Table 1). The heights we recorded for the observed white lupin cultivars are lower compared to those reported by Hýbl et al. (2011), who measured plant heights of 75–100 cm without specifying the growth stage. Tadele and Berhanu (2024) reported plant heights for three lupin cultivars: 78.9 cm (VITABOR), 79.7 cm (LOCAL), and 86.0 cm (SANABOR). Lower plant heights for the SANABOR and VITABOR cultivars were reported by Friehiwot et al. (2019). Rudloff (2011) listed an average plant height of 82 cm for different lupin cultivars. McCartney and Fraser (2010) reported white lupin plant heights ranging from 20 to 150 cm.

The growth of the crop is closely related to the production of green biomass, which was expressed in both the original biomass weight and the dry matter weight (Table 1). Okuyucu et al. (2004) highlight the influence of soil and climatic conditions at the white lupin cultivation site, as well as its genotype, which significantly impact the green matter yield, ranging from 5 to 10 t of dry matter/ha. Our green matter production yields corresponded with those obtained by Okuyucu et al. (2004). Pospíšil et al. (2022) reported different yields of the lupin green mass for the cultivar ENERGY, with 19.9–27.9 t/ha (fresh mass) and 2.9–4.2 t/ha (dry matter) in 2018, and 20.2–26.5 t/ha (fresh mass) and 3.3–4.0 t/ha (dry matter) in 2019, depending on the sowing density for the cv. FEODORA, yields were 16.9–24.0 t/ha (fresh mass) and 2.2–3.1 t/ha (dry matter) in 2018, and 18.4–24.6 t/ha (fresh mass) and 3.1–4.2 t/ha (dry matter) in 2019, depending on sowing density. Tadele and Berhanu (2024) reported lupin biomass yield as fodder with average values ranging from 3.41 to 4.06 t/ha. Yenesew et al. (2015) reached similar conclusions for sweet lupin (4.2 ± 2.91 t/ha). Our results are higher, potentially due to the environmental conditions, sowing density, or the genetic

potential of the selected cultivar. McCartney and Fraser (2010) reported a lupin green mass yield of 8 t/ha in dry matter. As shown in Table 1, statistically significant differences ($P \leq 0.05$) were observed among all growth stages of white lupin (week 9, 15, and 18 of vegetation) for all cultivars monitored (ZULIKA, AMIGA, DIETA).

Crude protein content. As shown in Table 2, there were significant changes in the crude protein content during the vegetation stages monitored (9, 15, and 18 weeks of stand age). These changes were characterised by a statistically significant ($P \leq 0.05$) decrease in crude protein; from the 9th to the 15th week of stand age, a statistically significant ($P \leq 0.05$) decrease in the CP content was observed in the dry weight of green matter for all lupin cultivars studied; in the subsequent period of maturation of lupin pods, from the 15th to the 18th week, the change in the CP content of green matter was not statistically significant. Differences in the CP content between lupin genotypes may be due to variations in the ratio of stem, leaf, and growth stages. CP genotypes that have a high leaf ratio may also have a higher CP content. Tadele and Berhanu (2024) report that the average crude protein content of the lupin green mass ranges from 193.7 to 290.8 g/kg of dry matter. Stødkilde et al. (2019) studied the crude protein content in the green biomass of red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), and alfalfa (*Medicago sativa* L.) as sources of protein for animal nutrition. Plants were harvested at a stubble height of 7 to 10 cm in June, and *Medicago sativa* in July (the 1st harvest). They report an average crude protein content of 213 g/kg of the dry matter for *Trifolium pratense*, 226 g/kg of the dry matter for *Trifolium repens*, and 197 g/kg of the dry matter for *Medicago sativa*. According to Reverter et al. (1999), *Medicago sativa* showed a crude protein value of 174 g/kg of the dry matter, *Trifolium repens* 241 g/kg

Table 2. Differences in the crude protein content in the green matter dry weight of the white lupin green matter (g/kg) during the growing season ($n = 8$)

	$\bar{x} \pm \text{SD}$		
	ZULIKA	AMIGA	DIETA
Week 9	203.50 ^a $\pm$ 21.978	190.58 ^a $\pm$ 16.073	201.41 ^a $\pm$ 16.408
Week 15	176.82 ^b $\pm$ 9.545	161.59 ^b $\pm$ 11.846	175.84 ^b $\pm$ 16.801
Week 18	162.12 ^b $\pm$ 23.446	150.95 ^b $\pm$ 19.945	175.24 ^b $\pm$ 19.386

$\bar{x}$ – arithmetic mean $\pm$ SD – standard deviation, ^{a–b}indices express the statistical difference at the significance level ($P \leq 0.05$) between weeks of monitoring for each cultivar

of the dry matter, and *Trifolium pratense* 215 g/kg of the dry matter. Damborg et al. (2020) reported average crude protein values of 267 ± 47 g/kg of the dry matter for *Trifolium repens*, 205 ± 22 g/kg of the dry matter for *Trifolium pratense*, and 217 ± 36 g/kg of the dry matter for *Medicago sativa*. Georgieva et al. (2024) emphasise the significance of the chemical composition of lupin biomass in determining its nutritional value and in effectively utilising lupin as roughage. They report average crude protein values of the lupin green mass ranging from 143.2 to 199.8 g/kg dry matter. Our results for the crude protein content in the green mass of three white lupin cultivars, as a protein-rich roughage, were satisfactory. The highest

average crude protein values were recorded in the 9th week of vegetation with intensive leaf area production of lupin. The subsequent decline in crude protein, depending on the growth stage, may be related to the gradual shedding of leaf area, the formation and ripening of green pods, and the gradual lignification of the lupin crop, where the proportion of structural carbohydrates in plants increases from a general nutritional perspective.

Essential amino acids. The results show that there are differences in the content of individual essential amino acids (eAAs) in the green matter of lupins during the growing season (Table 3). For most of the eAAs (Thre, Ile, Leu, Lys) studied, a decrease in their

Table 3. Differences in the average values of essential amino acids in the dry weight of the white lupin green matter during the observed growing season ($n = 8$)

		$\bar{x} \pm \text{SD}$		
		ZULIKA	AMIGA	DIETA
Thre (g/kg)	week 9	$8.26^a \pm 0.536$	$6.78^a \pm 0.916$	$6.86^a \pm 0.535$
	week 15	$4.37^c \pm 0.379$	$4.24^b \pm 0.393$	$4.80^c \pm 0.407$
	week 18	$5.80^b \pm 0.545$	$5.13^b \pm 1.102$	$5.82^b \pm 0.691$
Val (g/kg)	week 9	$8.75^a \pm 1.781$	$8.50^a \pm 1.171$	$8.05^a \pm 0.998$
	week 15	$6.51^b \pm 0.486$	$5.92^b \pm 0.754$	$6.10^b \pm 0.614$
	week 18	$6.49^b \pm 0.640$	$5.76^b \pm 1.246$	$7.01^b \pm 0.674$
Met (g/kg)	week 9	$0.84^a \pm 0.434$	$0.76^a \pm 0.043$	$0.80^a \pm 0.047$
	week 15	$0.52^{ab} \pm 0.272$	$0.60^b \pm 0.282$	$0.33^b \pm 0.268$
	week 18	$0.39^b \pm 0.217$	$0.33^b \pm 0.263$	$0.10^b \pm 0.252$
Ile (g/kg)	week 9	$7.51^a \pm 1.889$	$7.18^a \pm 1.182$	$6.73^a \pm 1.243$
	week 15	$5.53^b \pm 0.349$	$5.18^{ab} \pm 0.561$	$5.34^b \pm 0.518$
	week 18	$7.05^{ab} \pm 0.880$	$5.90^b \pm 1.251$	$7.39^a \pm 0.806$
Leu (g/kg)	week 9	$12.20^a \pm 3.665$	$11.62^a \pm 1.770$	$11.70^a \pm 1.209$
	week 15	$7.73^b \pm 1.061$	$7.26^b \pm 0.640$	$8.62^b \pm 1.180$
	week 18	$11.61^a \pm 1.064$	$10.01^a \pm 2.024$	$12.83^a \pm 1.213$
Phe (g/kg)	week 9	$5.45^a \pm 1.665$	$4.31^{ab} \pm 1.160$	$1.80^c \pm 0.719$
	week 15	$6.66^a \pm 1.052$	$4.04^b \pm 0.688$	$3.71^b \pm 0.500$
	week 18	$5.74^a \pm 0.909$	$5.49^a \pm 1.346$	$5.82^a \pm 1.286$
His (g/kg)	week 9	$4.40^a \pm 1.850$	$3.16^a \pm 0.600$	$3.67^a \pm 0.490$
	week 15	$3.39^a \pm 0.274$	$3.30^a \pm 0.264$	$3.79^a \pm 0.447$
	week 18	$4.14^a \pm 0.526$	$3.61^a \pm 0.819$	$4.22^a \pm 0.883$
Lys (g/kg)	week 9	$10.62^a \pm 3.036$	$9.36^a \pm 0.798$	$9.74^a \pm 1.043$
	week 15	$6.15^b \pm 0.404$	$5.56^c \pm 0.471$	$6.71^b \pm 0.952$
	week 18	$8.90^a \pm 0.771$	$7.92^b \pm 1.665$	$9.18^a \pm 0.884$
Arg (g/kg)	week 9	$7.93^b \pm 2.136$	$6.88^b \pm 1.269$	$7.56^c \pm 0.636$
	week 15	$6.01^b \pm 1.467$	$8.63^b \pm 2.063$	$10.67^b \pm 3.279$
	week 18	$16.03^a \pm 2.096$	$13.04^a \pm 2.970$	$17.45^a \pm 1.703$

$\bar{x}$ – arithmetic mean $\pm$ SD – standard deviation; ^{a-c}indices express the statistical difference at the significance level ($P \leq 0.05$) between weeks of monitoring for each cultivar

<https://doi.org/10.17221/334/2025-PSE>

content in the dry weight of the green matter was demonstrated from week 9 to week 15, followed by a significant increase from week 15 to week 18 of stand age. In Val, a decrease in its content was only demonstrated from the 9th to the 15th week, and its change was not statistically significant until the 18th week. For Phe (excluding DIETA), the change in its content in the dry weight of the green crop was not statistically significant ($P \leq 0.05$) from week 9 to week 15, and its increase was statistically significant ($P \leq 0.05$) from week 15 to week 18 (excluding ZULIKA). In Met, a gradual decline was shown during the growing season until week 18. For His, there were no statistically significant differences in its content in the dry weight of the green matter during the growing season. The differences in the Arg content were interesting, with values increasing significantly over the growing season. Reverter et al. (1999) and Stødkilde et al. (2019) studied essential amino acids in *Trifolium pratense*, *Trifolium repens*, and *Medicago sativa*. These authors reported slightly different values for the monitored essential amino acids compared to our results, which may be attributed to differences in plant species, cultivation practices, harvest times, or methods of amino acid analysis. Although there were slight differences in amino acid values, their results were most similar to those from week 15 of white lupin vegetation, where the lupin crop was well-leaved with developed green pods. Consistent with our results, the lowest values in the cited sources were observed for Met.

Non-essential amino acids. For most of the non-essential amino acids (nAAs) (Ser, Glu, Pro, Gly) studied, a decrease in their content in the dry weight of the green matter was demonstrated from week 9 to week 15, followed by a statistically significant ($P \leq 0.05$) increase from week 15 to week 18 of stand age (Table 4). The opposite trend was shown for Asp, which showed a statistically significant ($P \leq 0.05$) increase in its content by week 15, followed by a significant ($P \leq 0.05$) decrease by week 18 of stand age. In Ala, a gradual decrease was found during the growing season. In contrast, in Tyr, an increase in its content in the dry weight of the green matter during the growing season was statistically significant ($P \leq 0.05$). From the average values of non-essential amino acids in *Trifolium pratense*, *Trifolium repens*, and *Medicago sativa* published by Reverter et al. (1999) and Stødkilde et al. (2019), the highest values were recorded for aspartic acid (Asp) and glutamic acid (Glu), consistent with our results. The values of non-

essential amino acids most closely corresponded with our results in weeks 15 or 18 of white lupin vegetation. In week 9 of white lupin vegetation, the average values of non-essential amino acids we recorded in the lupin green mass were significantly higher than those reported by the cited authors.

Total amino acid content. Changes in the content of total amino acid (AA) in the dry weight of the lupin green matter over the growing season are characterised in Table 5, which shows that their content in the dry weight of the lupin green matter changed only minimally over the growing season. For the cvs. ZULIKA and AMIGA: a certain tendency of a slight decrease in mean Σ AA values can be observed in the 15th and 18th weeks, for the cv. DIETA, on the contrary, shows a tendency for an insignificant increase in mean Σ AA values. From the changes in the total content of essential amino acids in the dry weight of the lupin green matter during the growing season (Table 5), it is evident that from the 9th to the 15th week of stand age, there was a decrease in the content of Σ eAA with a subsequent increase in their content from the 15th to the 18th week. These are characteristic changes that correspond to the changes we observed during the growing season in the CP content of the dry weight of green stands. In the case of ZULIKA and AMIGA, these changes were evaluated as statistically significant ($P \leq 0.05$). From the changes in the total content of non-essential amino acids in the dry matter of lupin green matter during the growing season (Table 5), it is clear that their content in the dry weight of the lupin green matter changed only minimally during the growing season from the 9th to the 18th week of stand age. Changes in Σ AA in the green matter dry weight over the growing season were consistent with changes in the CP content. Stødkilde et al. (2019) compared the total amino acid content in the green mass of *Trifolium pratense*, *Trifolium repens*, and *Medicago sativa* as a protein source for animal nutrition. They report the lowest total amino acid value for *Medicago sativa* at 164 g/kg of the dry matter, *Trifolium pratense* at 188 g/kg of the dry matter, and *Trifolium repens* at 195 g/kg of the dry matter. Our results for the monitored cultivars of white lupin are lower (Table 5) compared to those of these protein sources for animal nutrition.

The breeding of cultivars of sweet lupins with firm pods and a low alkaloid content has enabled these species to be used not only as green manure but also for the production of green fodder for both seed and fodder production. Currently, no literature sources can be found that address the production and

<https://doi.org/10.17221/334/2025-PSE>

Table 4. Differences in the average values of non-essential amino acids in the dry matter of white lupin green matter during the observed growing season ($n = 8$)

		$\bar{x} \pm SD$		
		ZULIKA	AMIGA	DIETA
Asp (g/kg)	week 9	22.36 ^b $\pm$ 7.083	20.16 ^b $\pm$ 5.368	18.51 ^b $\pm$ 5.671
	week 15	36.15 ^a $\pm$ 4.415	35.22 ^a $\pm$ 7.838	38.87 ^a $\pm$ 5.399
	week 18	17.21 ^b $\pm$ 2.191	14.00 ^b $\pm$ 2.081	16.75 ^b $\pm$ 2.221
Ser (g/kg)	week 9	8.20 ^a $\pm$ 0.762	7.45 ^a $\pm$ 1.080	6.97 ^b $\pm$ 0.574
	week 15	5.27 ^b $\pm$ 0.438	5.55 ^b $\pm$ 0.781	6.11 ^b $\pm$ 0.842
	week 18	7.95 ^a $\pm$ 0.723	6.73 ^{ab} $\pm$ 1.670	8.36 ^a $\pm$ 0.890
Glu (g/kg)	week 9	20.22 ^b $\pm$ 4.194	18.92 ^b $\pm$ 2.257	19.13 ^b $\pm$ 1.828
	week 15	14.54 ^c $\pm$ 2.437	13.06 ^c $\pm$ 1.765	18.13 ^b $\pm$ 4.082
	week 18	28.80 ^a $\pm$ 3.576	23.16 ^a $\pm$ 3.890	30.20 ^a $\pm$ 2.886
Pro (g/kg)	week 9	10.02 ^a $\pm$ 1.039	9.53 ^a $\pm$ 1.763	8.77 ^a $\pm$ 0.991
	week 15	5.98 ^c $\pm$ 0.267	6.76 ^b $\pm$ 1.683	6.10 ^b $\pm$ 1.204
	week 18	7.80 ^b $\pm$ 0.715	7.27 ^b $\pm$ 1.604	8.15 ^a $\pm$ 0.874
Gly (g/kg)	week 9	9.39 ^a $\pm$ 0.843	8.12 ^a $\pm$ 1.036	7.96 ^a $\pm$ 0.867
	week 15	4.73 ^c $\pm$ 0.305	4.43 ^c $\pm$ 0.514	5.12 ^b $\pm$ 0.633
	week 18	6.49 ^b $\pm$ 0.589	5.77 ^b $\pm$ 1.202	6.86 ^a $\pm$ 0.737
Ala (g/kg)	week 9	11.98 ^a $\pm$ 2.440	10.54 ^a $\pm$ 1.891	10.65 ^a $\pm$ 0.853
	week 15	9.86 ^a $\pm$ 1.618	7.06 ^b $\pm$ 0.660	6.10 ^b $\pm$ 0.614
	week 18	5.65 ^b $\pm$ 0.510	4.97 ^c $\pm$ 0.958	6.20 ^b $\pm$ 0.617
Tyr (g/kg)	week 9	3.35 ^b $\pm$ 3.582	3.50 ^b $\pm$ 1.100	4.04 ^b $\pm$ 1.248
	week 15	4.02 ^{ab} $\pm$ 0.554	4.24 ^{ab} $\pm$ 0.431	4.72 ^b $\pm$ 0.827
	week 18	6.14 ^a $\pm$ 0.686	5.39 ^a $\pm$ 1.184	6.59 ^a $\pm$ 0.65

$\bar{x}$ – arithmetic mean $\pm$ SD – standard deviation; ^{a–c}indices express the statistical difference at the significance level ($P \leq 0.05$) between weeks of monitoring for each cultivar

Table 5. The total amino acid content (Σ AA), including essential (Σ eAA) and non-essential amino acids (Σ nAA), in the dry weight of the white lupin green matter (g/kg) of the dry weight ($n = 8$)

		Week 9	Week 15	Week 18
		ZULIKA		
$\bar{x} \pm SD$	Σ eAA	65.85 ^a $\pm$ 15.105	46.85 ^b $\pm$ 2.335	66.16 ^a $\pm$ 5.938
	Σ nAA	85.52 ^a $\pm$ 7.303	80.54 ^a $\pm$ 4.584	80.04 ^a $\pm$ 7.931
	Σ AA	151.37 ^a $\pm$ 19.444	127.39 ^b $\pm$ 5.746	146.20 ^a $\pm$ 13.738
	AMIGA			
	Σ eAA	58.50 ^a $\pm$ 7.997	44.73 ^b $\pm$ 3.271	57.20 ^a $\pm$ 12.151
	Σ nAA	78.22 ^a $\pm$ 10.983	76.31 ^a $\pm$ 10.635	67.28 ^a $\pm$ 12.259
	Σ AA	136.72 ^a $\pm$ 17.340	121.05 ^a $\pm$ 12.408	124.47 ^a $\pm$ 24.350
	DIETA			
	Σ eAA	56.95 ^a $\pm$ 4.522	50.07 ^a $\pm$ 6.106	69.77 ^a $\pm$ 6.945
	Σ nAA	76.03 ^a $\pm$ 8.947	85.15 ^a $\pm$ 5.919	83.12 ^a $\pm$ 7.006
	Σ AA	132.97 ^b $\pm$ 11.434	135.23 ^b $\pm$ 11.212	152.89 ^a $\pm$ 12.514

$\bar{x}$ – arithmetic mean $\pm$ SD – standard deviation; ^{a–b}indices express the statistical difference at the significance level ($P \leq 0.05$) between weeks of monitoring for each cultivar

<https://doi.org/10.17221/334/2025-PSE>

nutritional value of the white lupin green matter as an annual forage crop in relation to its use as roughage, and it is not possible to compare the crude protein content and amino acid spectrum of the white lupin green matter with other authors. In relation to human nutrition, protein quality and digestibility in *Lupinus albus* and *Lupinus angustifolius* have been addressed by Monteiro et al. (2014), who conclude that the lupin cultivars studied are good sources of protein with very good digestibility and are considered a good alternative for human nutrition. The specific requirements of ruminants and herbivores, especially high-producing animals, for the spectrum of nitrogenous substances in their diets can only be met by high-quality roughages. Therefore, it is necessary to deepen knowledge of the nutritional value and production potential of whole lupin plants. This is supported by the work of Warner et al. (1998), which found that grazing lambs on mature stands of lupins and peas resulted in a higher profit per hectare than if the areas had been used for seed production.

Based on the results obtained, the green matter of lupin crops can be considered a promising source of high-quality protein roughage suitable for direct feeding. From the results it can be concluded that several quantitative (crude protein content) and qualitative (amino acid content) changes occurred during the growing season, which were related to the high production of the crop green matter (week 9–15) and the increase in the eAA content (week 15–18), when the protein quality related to the development of generative organs (seed maturation) increased. We can conclude that lupin crops have an excellent nutritional potential, and the green mass of lupins represents a highly valuable rough protein feed. In practical terms, harvesting the green matter must be adapted to the state of the stand, as its development can be influenced by cultivar, soil, and climatic conditions.

Acknowledgement. Supported by the Project FVHE VETUNI Brno ITA2024 (TA 242061) "Health status and production parameters of selected food animal species and quality of raw materials of animal origin as a consequence of the use of quality feeds or their supplements".

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Received: July 28, 2025

Accepted: October 13, 2025

Published online: November 13, 2025