Article citation info:
Stopa W., Wróbel B., Paszkiewicz-Jasińska A., Zielewicz W. 2022. The Effect of the Timing of Harvesting the First Regrowth of the Sward on Relative Feed Value. *Journal of Research and Applications in Agricultural Engineering* 67 (2): 39–44. https://doi.org/10.53502/JRGN9663

Łukasiewicz Poznań Institute of Technology

Journal of Research and Applications in Agricultural Engineering

Journal website: https://tech-rol.eu/

The Effect of the Timing of Harvesting the First Regrowth of the Sward on Relative Feed Value

Wojciech Stopa[a]* (https://orcid.org/0000-0002-7477-387X)
Barbara Wróbel[a] (https://orcid.org/0000-0003-4713-5968)
Anna Paszkiewicz-Jasińska[a] (https://orcid.org/0000-0002-0650-3093)
Waldemar Zielewicz[b] (https://orcid.org/0000-0003-3663-8826)

[a] Institute of Technology and Life Sciences-National Research Institute, Falenty, Raszyn, Poland
[b] Poznań University of Life Sciences, Department of Grassland and Natural Landscape Sciences, Poznań, Poland

Article info
Received: 6 December 2022
Accepted: 14 December 2022
Published: 30 December 2022

Keywords
ADF
NDF
ADL
dry matter digestibility
dry matter intake
lignification

The timing of harvesting the first regrowth affects the quantity and quality of the harvested forage, including fibre content. Plant fibre is the building block of cell walls, its components are cellulose, hemicellulose, lignin, undecomposed protein, pectin, water and ash. Its properties are influenced by factors such as meteorological conditions in a given season, soil conditions and fertilization, as well as the developmental stage of the plants at the time of harvest. This paper presents the results of a three-year (2014–2016) study conducted on a three-cut permanent hay-meadow located on mineral soil. Mineral fertilization was carried out annually at the following rates: 60 kg·ha^{-1} N, 30 kg·ha^{-1} P and 60 kg·ha^{-1} K. Biomass samples for testing were taken each year on five dates: April 28–30, May 5–7, May 11–14, May 18–21 and May 24–28. The content of ADF (acid detergent fibre), NDF (neutral detergent fibre), ADL (acid detergent lignin) was determined in the collected plant samples. Next, the effect of the date of harvesting the first regrowth of the sward on the degree of lignification, dry matter digestibility (DDM), theoretical dry matter intake (DMI) and the relative feed value of the forage expressed by the RFV index was evaluated. The study found an effect of the timing of harvesting the first regrowth of the sward on the parameters studied. The fibre fraction contents of NDF, ADF and ADL increased each year with the following dates, having an effect on reducing the relative feed value of plants.

DOI: https://doi.org/10.53502/JRGN9663

1. Introduction

Permanent grassland is agricultural land occupied for the cultivation of meadows and pastures, and is used as a source of organic, inexpensive and valuable feed, which is often the only food for herbivores during the summer. This forage can take the form of: forage pasture in the summer season and hay, silage and dried feed in the winter. Its share in the ration depends on the intensity of feeding. On extensive farms, its share can be as much as 100% of the total ration (often being the only source of cheap and readily available food for cattle and sheep), while on high-production farms the share is usually lower. Pasture, or grassland used for grazing, is also a place of enclosure for animals, which is a particularly important element of cattle breeding in organic farming. In Europe, permanent grassland is estimated to occupy more than a third of

* Corresponding author: w.stopa@itp.edu.pl

all agricultural land. In Poland, grassland accounts for 21.7% of the agricultural area, of which 16.9% is permanent grassland. Average annual yields from them amount to 50 dt·ha^{-1}, with the largest share going to the harvest of the first regrowth, mainly for hay production. The yield of permanent grasslands depends for the most part on the intensity of managementand meteorological conditions in a given season [1–4].

An important criterion for harvested plant biomass (in addition to its quantity) is its quality. A key element in the forage value is the content of structural carbohydrates (fibres). They are the building blocks of plant cell walls, which include cell walls that are difficult to digest (made up of hemicellulose, cellulose and lignin), and cell contents that can mostly be digested by ruminants (starch and sugars). Fibre is not only a source of energy, but regulates digestive processes and ensures proper motility of the digestive tract. For many years, the estimated nutritional value of feed was calculated based on crude fibre content. This method, due to estimation uncertainties, has been refined and now uses the Peter van Soest method by determining neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). The method was developed to determine: energy value (and appropriate dosage), total nutrient content and relative feed value. These parameters allow farmers to set hay prices, manage forage more favourably, set dates for carrying out meadow sward harvesting, and control forage storage conditions. The fibre fraction content of NDF, ADF and ADL indicates: the maximum amount of forage an animal is able to consume, and determines the animal's ability to digest a given forage [5]. The greatest influence on the content of structural carbohydrates is exerted by: climatic and soil conditions, fertilization, and the developmental stage of the plants at harvest [6–11].

Therefore, it was assumed that variation in the content of structural carbohydrates in successive dates of harvest the first regrowth may have a significant effect on forage quality parameters. The purpose of this study was to evaluate the effect of the timing of harvesting the first regrowth of the sward on the content of the fibre fractions ADF, NDF, ADL, the resulting relative feed value of the forage expressed by the RFV index, and the degree of lignification.

2. Methodology

The research was conducted in 2014–2016 in the Institute of Technology and Life Sciences – National Research Institute in Falenty. The experiment was established on a three-cutpermanent meadow located on a mineral soil classified as leached brown and pseudopodzol soils. Mineral fertilization was carried out annually at the following rates: 60 kg·ha^{-1} N (ammonium nitrate), 30 kg·ha^{-1} P (granulated triple superphosphate 46% P_2O_5) and 60 kg·ha^{-1} K (potassium salt 60% P_2O_5). The meadow sward consisted of grasses, dicotyledonous herbs and weeds. The dominant grass species were: *Dactylis glomerata* L., *Poa pretensis* L. and *Festuca rubra* L., while the dicotyledons and weeds were: *Taraxacum officinale* F.H. Wigg., *Achillea millefolium* L. and *Trifolium pratense* L. In the first two years, the dominance of grasses was 70%, while in the third year of the study it decreased to 62%.

One kilogram biomass samples for the study were taken each year on five dates:

I. April 28–30,
II. May 5–7,
III. May 11–14,
IV. May 18–21,
V. May 24-28,

in order to determine the content of ADF, NDF, ADL, degree of lignification and relative feed value (RVF). The fibre content of ADF, NDF and ADL were determined in dried and milled samples, by NIRS method [12] with a NIRFlex N-500 instrument, using INGOT® ready-made calibrations for meadow hay. Lignin proportion i.e. lignification of cell wall, was calculated as 100 x ADL/NDF.

Based on the content of the ADF and NDF fibre fractions (%), the quality of the harvested biomass was synthesized by calculating dry matter intake (DMI), digestible dry matter (DDM) and relative feed value index (RFV) according to the formula of Linn and Martin [13]:

$$RFV = DDM - DMI / 1.29 \qquad (1)$$

where:
RFV – relative feed value (RFV),
DMI – dry matter intake, % body weight; DMI = 120 NDF,
DDM – digestible dry matter, %; DDM = 88.9 – 0.779 ADF.

Based on the value of the RFV index, feeds were assigned to different quality classes:
I quality class – RFV>150,
II quality class – RFV 125-151,
III quality class – RFV 103-124,
IV quality class – RFV 87-102,
V quality class – RFV 75-86.

2.1. Statistical analyses

Statistical processing of the results was carried out using MS Excel and Statistica 6.0. The significance of the effect of the experimental factors was verified using the Tukey test, along with contrast analysis, at a significance level of α = 0.05.

2.2. Weather conditions

The variability of weather conditions was high throughout the study period. Meteorological data were collected at the Falenty station located with close proximity to the experimental meadow. Based on the weather data, the hydrothermal coefficient (k) for the growing seasons was calculated according to Selyaninov [14].

$$K = (P10) / \Sigma t \quad (2)$$

where:
P – the total monthly rainfall (mm);
Σt – the monthly total of average daily air temperature >0°C.

Tab. 1. Values of the Selyaninov hydrothermal coefficient (k)

Year	Value in month		
	March	April	May
2014	1.82	1.45	2.35
2015	1.00	1.62	0.94
2016	2.37	1.27	0.65

Explanations: k > 3.00 - extremely humid; k ∈ 2.51–3.0 – very humid, k ∈ 2.01-2.50 - humid, k ∈ 1.61–2.00 - quite humid, k ∈ 1.31–1.60 – optimum, k ∈ 1.01–1.30 – quite dry, k ∈ 0.71–1.00 – dry, k ∈ 0.41–0.70 – very dry, k ≤ 0.40 – extreme dry. Source: own study.

The course of weather conditions during the study period was quite varied. The most favourable year in the study years in terms of precipitation was year 2014, while the following years (2015 and 2016) were drier, May 2016 considered as very dry. Quite humid conditions were in April 2015 and March 2014. March 2016 was very humid due to lower air temperature, on the other hand in March 2015 conditions were dry. Mean air temperature varied each year, lowest observed temperature was 9.2°C in 2015 and highest was 10.4°C in 2014. Highest rainfall was in May 2014 (104.9 mm), compared with May 2015 – 39.4 mm and May 2016 – 32.8 mm.

3. Results and discussion

The results of the study of individual parameters of meadow sward are shown in Tab. 2.

Tab. 2. Meadow sward parameters in years and dates of meadow sward harvesting

Timing of harvest		ADF [% DM]		NDF [% DM]		ADL [% DM]		Lignification [%]		DMI [%body mass]		DDM [%]		RFV	
2014	I	32.21	bc	45.69	a	3.93	b	8.68	b	2.64	c	63.81	bc	131	c
	II	29.11	a	45.82	a	3.48	a	7.61	ab	2.62	c	66.22	d	135	c
	III	30.06	ab	48.00	ab	3.43	a	7.16	a	2.51	bc	65.48	cd	127	bc
	IV	33.56	c	52.44	b	4.05	b	7.74	ab	2.29	ab	62.76	b	112	b
	V	37.25	d	59.88	c	4.71	c	7.87	ab	2.01	a	59.89	a	93	a
Mean		**32.4**	B	**50.3**	B	**3.92**	B	**7.81**	B	**2.42**	A	**63.63**	A	**120**	A
2015	I	23.57	a	38.48	a	2.94	a	7.66	a	3.13	c	70.54	d	171	c
	II	27.88	b	44.09	ab	3.52	b	8.05	a	2.73	b	67.18	c	142	b
	III	29.09	bc	45.49	b	3.67	b	8.14	a	2.65	ab	66.24	bc	136	b
	IV	30.93	cd	49.29	bc	3.89	b	7.93	a	2.45	ab	64.81	ab	123	ab
	V	32.18	d	51.83	c	3.98	b	7.69	a	2.32	a	63.83	a	115	a
Mean		**28.7**	A	**45.8**	A	**3.60**	A	**7.89**	B	**2.66**	B	**66.52**	B	**137**	B
2016	I	24.61	a	44.01	ab	2.59	a	5.89	a	2.73	ab	69.73	c	148	b
	II	25.61	a	42.11	a	3.08	ab	7.39	ab	2.86	c	68.95	c	153	b
	III	29.49	b	48.57	bc	3.62	bc	7.45	ab	2.48	ab	65.92	b	127	a
	IV	30.39	bc	49.74	c	3.66	bc	7.36	ab	2.42	a	65.23	ab	123	a
	V	32.89	c	53.85	c	4.26	c	7.89	b	2.24	a	63.28	a	110	a
Mean		**28.6**	A	**47.6**	A	**3.44**	A	**7.20**	A	**2.54**	B	**66.62**	B	**132**	B

Averages for different years of study marked with different capital letters in the same column are significantly different (p ≤ 0.05). Source: own study.

3.1. Acid detergent fibre (ADF)

Determination of the ADF fraction makes it possible to decide the susceptibility to digestion of the forage, and therefore allows precise estimation of the energy value of the forage. The ADF content of biomass depended on the harvest date and increased with each successive date, with the exception of 2014, where higher values were observed during the first harvest date than in the early May dates (second and third). The lowest average contents of this fibre fraction were observed in the drier years (2015 and 2016). This is associated with an increase in digestibility of feed in these years compared to the first year. The average ADF content decreased from 32.44% to 28.60%. The same results were obtained by researchers in [15], where an increase in the ADF fibre fraction (also NDF, ADL) was obtained as the developmental stage of *Trifolium pratense* L. and *Lotus corniculatus* L. progressed.

3.2. Neutral detergent fibre (NDF)

NDF values are a very important feed parameter reflecting how much forage an animal can consume. It consists of hemicellulose, cellulose, lignin and lignin-bound nitrogen. NDF gives the forage its preferred structure and provides a source of energy for rumen microorganisms. During the study, an annual increase in the value of the parameter was observed at each successive date. The average values of NDF were the highest in the first year of the study, as in the case of ADF, while the dynamics of its increase were significantly higher. In 2014, the percentage of NDF increased from 45.69% on the first surveyed date to 59.88% on the last date, and in the same year ADF values increased from 32.21% on the first date to 37.25% on the last date. The effect of harvesting time was also shown in [16] on *Festulolium braunii* (cultivar 'Felopa'). In the study, the amount of NDF was influenced by the harvest date. It was also observed, no significant variation in ADF fibre content for harvest date and years of study as well as fertilizer factors.

3.3. Acid detergent lignin (ADL)

ADL is an acid detergent lignin parameter and represents the fraction of lignin in ADF. Along with cellulose and hemicellulose, it is one of the main building blocks of plant cell walls. Its percentage of dry matter content varied on average between 3.44% in 2016 and 3.92% in 2014. In 2015 (in May), there was a non-significant increase in values at around 8% lignin content occurring for the last four dates studied.

3.4. Lignification

Lignification is a biological process of cell wall encrustation, namely the deposition of lignin on its surface. It causes a reduction in water content and a strong hardening of the cells, resulting in an increase in the plant's resistance to mechanical damage. Lignification in all three years showed little variation throughout the study period. Significant changes were observed in 2014 and 2016, while no significant shifts were obtained in 2015. The lowest degree of lignification was found in the first term of 2014, while the lowest in the first term of 2016.

3.5. Dry matter digestible(DDM) and dry matter intake (DMI)

DDM and DMI values are calculated based on NDF and ADF parameters. DDM represents the theoretical digestibility of the forage. In order to achieve adequate forage properties, the value of this parameter should be at least 65% according to [17]. DMI, on the other hand, is the dry matter intake. Both of these values allow to calculate the relative feed value of RFV (formula 1). The resulting percentage of DDM is appropriate for 2015 and 2016, while the average for 2014 is about 64%. This is lower than the recommended value. Inadequate percentages were calculated for harvests I – 63.81%; IV – 62.76% and V – 59.89% (characterized by the lowest value of all years). The last term of 2014 is the only one in which values of less than 60% were observed. In the remaining years, a more pronounced downward trend in DDM content is observed with each successive term. In a study [17] conducted on permanent grasslands, annual variability in DDM content was also detected. The average annual values were about 61–62%, and with no significant effect of NPK fertilization on the changes in their content was observed.

DMI, or feed intake, is a very important factor especially for cows with high milk yields, which require the provision of sufficient amounts of energy and other nutrients. According to Barteczko J., Bielański P., Borowiec F., et. al. [18], depending on the body weight of dairy cows and their performance, a minimum of 2.3% of body weight is required for normal digestion (for dry cows, this may be 1.7-2.0% of body weight). In the study, averages above 2.4% were observed for each year. As for DDM, the lowest values are observed for year one (2014), higher for the following years.

3.6. Relative feed value

The RFV index, which combines feed intake (DMI) and digestibility (DDM), determines the relative feed value, or total forage quality. The highest value (171) was observed in the first term of 2015. The lowest value that year was 115, and considering all years, it was 93 (occurring in the last term of 2014). The average RFV index was lowest in the first year of the study (120), while in 2015 and 2016, it was respectively: 137 and 132. The analysis shows that with each successive harvest, the relative feed value of the forage decreases. Knowing this indicator, we can assign forages to different quality classes. Dried plant biomass from the first three harvest dates can be classified as II quality class. It can be used as feed for dairy cows, young heifers selected for covering. The first quality class was achieved in the first term of 2015 and the second term of 2016, while the lowest class (IV) was characterized in the last term of 2014, this forage is unsuitable for feeding fattening or dried dairy cows.

The differences in the contents of the various fractions may be due to the higher average temperature during the growing season, it may have contributed to an increase in the rate of development and affected the ratio of leaves to stems in plants. In 2015 and 2016, meteorological conditions were less favourable than in 2014. This is evident from the hydrothermal Selyaninov coefficient (Tab. 1), where we observe that very good moisture conditions for plant development were in May 2014 (2.35), while the worst occurred in May 2015 and 2016 (0.94 and 0.65). Moderate water stress can delay maturation while maintaining forage quality at a higher level. This is particularly evident in 2015 and 2016, where there were worse moisture conditions. The results of the study are in line with those of other researchers [19, 20], who also observed the effect of biomass harvesting date on plant chemical composition.

4. Summary

The study observed the effect of the date of harvesting the first regrowth on biomass quality. Changes in cellulose, hemicellulose, lignin and lignification contents were studied. The proposed dates reflect, those used in agricultural practice. During plant growth and development, a number of physical and chemical transformations take place. The highest growth rate is usually observed just at the beginning of the growing season, and by the end of April it is almost completely stopped. The early meadow sward consists of young leaves containing large amounts of total protein, sugars and minerals, with the passage of time, lignification of cell tissues increases, leading to a decrease in the proportion of nutrients and water. This process has a negative impact on digestibility and feed intake, and consequently on relative feed value, which begins to decline. In agricultural practice, haying is often done at dates later than those at which the highest forage nutritive value has been studied. This is often dictated by higher yields at later dates, resulting in greater forage weight and volume. The obtained results can be used in management practices of hay meadows used at different system intensities to increase the nutritive value of harvested forage, especially to reduce the fiber fraction.

References

[1] Jankowska-Huflejt H., Domański P. 2008. Present and possible directions of utilising permanent grasslands in Poland. *Water-Environment-Rural Areas* 8: 31–49.

[2] Jankowska-Huflejt H., Wróbel B. 2008. Evaluation of usefulness of forages from grasslands in livestock production in examined organic farms. *Journal of Research and Applications in Agricultural Engineering* 53(8): 103–108.

[3] Wróbel B., Paszkiewicz-Jasińska A., Zielewicz W., Spychalski B. 2022. Wpływ terminu koszenia łąk na plon oraz względną wartość pokarmową runi łąkowej. *Technika Rolnicza, Ogrodnicza, Leśna* 1: 15–22.

[4] Niedbała G., Wróbel B., Piekutowska M., Zielewicz W., Paszkiewicz-Jasińska A., Wojciechowski T., Mohsen N. 2022. Application of artificial neural networks sensitivity analysis for the pre-identification of highly significant factors influencing the yield and digestibility of grassland sward in the climatic conditions of Central Poland. *Agronomy* 12: 1133. DOI: https://www.mdpi.com/2073-4395/12/5/1133

[5] *Oznaczanie włókna w paszach dla zwierząt. Włókno surowe, neutralno-detergentowe oraz kwaśno-detergentowe – normy i możliwości automatyzacji.* 2018. https://www.fossanalytics.com/-/media/files/documents/papers/laboratories-segment/ebook-fibre-analysis-of-animal-feed-pl.pdf, access on 25.11.2022.

[6] Poetsch E., Resch R., Krautzer B. 2016. Variability of yield and forage quality between three heading groups of english ryegrass *Lolium perenne* L. during the first growth. *Die Bondenkultur: Journal of Land Menagement, Food and Environment* 67(2): 69–75. DOI: https://sciendo.com/article/10.1515/boku-2016-0007

[7] Wiśniewska-Kadżajan B., Jankowski K. 2019. Changes in the content of structural carbohydrates and lignin in the biomass od *Loliumm ultiflorum* (Lam.) after applying slurry with biopreparations and with NPK. *Acta Scientiarum Polonorum, Agricultura* 18(4): 171–179. DOI: 10.37660/aspagr.2019.18.4.3

[8] Truba M., Wiśniewska-Kadżajan B., Sosnowski J., Malinowska E., Jankowski K., Makarewicz A. 2017. The effect of soil conditioners on cellulose, hemicellulose, and the ADL fibre fraction concentration in *Dactylis glomerata* and *Lolium perenne*. *Journal of Ecological Engineering* 18(1): 107–112. DOI: https://doi.org/10.12911/22998993/66249

[9] Kozłowski S., Golińska B., Swędrzyński A., Goliński P. 1996. Szybkość lignifikacji traw. *Zeszyty Problemowe Postępów Nauk Rolniczych* 442: 257–268.

[10] Andueza D., Rodrigues A. M., Picard M., Rossignol N., Baumont R., Cecato U., Farruggia A. 2015. Relationship between botanical composition, yield and forage quality of permanent grassland over the first growth cycle. *Grass and Forage Science* 71(3): 366–378. DOI: https://onlinelibrary.wiley.com/doi/10.1111/gfs.12189

[11] Grzelak M. 2012. Roughages from ecological grassland. *Journal of Research and Applications in Agricultural Engineering* 57(3): 133–136.

[12] PN-EN ISO 12099:2010.: Pasze ziarno zbóż i produkty przemiału – Wytyczne stosowania spektrometrii bliskiej podczerwieni, 2013.

[13] Linn J.G., Martin N.P. 1989. Forage quality test and interpretation. St. Paul. University of Minnesota Extension Service Publ. AG-FO-2637: 1–5.

[14] Selyaninov G.T.: Methods of agricultural climatology. Agricultural Meteorology, 1930, 22.

[15] Wróbel A., Zielewicz W. 2019. Nutritional value of red clover (*Trifolium pratense* L.) and birds trefoil (*Lotus corniculatus* L.) harvested in different maturity stages. *Journal of Research and Applications in Agricultural Engineering* 64(4): 14–19.

[16] Sosnowski J., Jankowski K. 2013. Względna wartość pokarmowa mieszanek *Festulolium braunii* z lucerną mieszańcową uprawianych w warunkach zróżnicowanego nawożenia azotem. *Folia Pomer. Univ. Technol. Stetin. Agric. Aliment., Pisc., Zootech.* 307(28): 99–106.

[17] Mendra M. 2017. Relative feed value of sward from permanent dry meadow before and after renovation at different fertilization. *Journal of Research and Application in Agricultural Engineering* 62(4): 13–17.

[18] Barteczko J., Bielański P., Borowiec F., et. al. 2015. *Żywienie zwierząt i paszoznawstwo. Podstawy szczegółowego żywienia zwierząt. Vol. 2.* Wydawnictwo Naukowe PWN.

[19] Boob M., Elsasser M., Thumm U., Kartung J., Lewandowski I. 2019. Harvest time determines quality and usability of biomass from lowland hay meadows. *Agriculture* 9(9): 198. DOI: https://doi.org/10.3390/agriculture9090198

[20] Karayilanli E., Ayhan V. 2016. Investigation of feed value of alfalfa (*Medicago sativa* L.) harvested at different maturity stages. *Legume Research* 39: 237–247. DOI: https://arccjournals.com/journal/legume-research-an-international-journal/LR-248