applied sciences

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Effects of Slurry Applied with Soil Conditioners and Mineral Fertilizers on Fiber Fraction Content in *Festulolium braunii* (K. Richt.) A. Camus

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Received: 4 July 2020; Accepted: 17 September 2020; Published: 19 September 2020

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Abstract: This paper deals with the effects of slurry, soil conditioners, and mineral fertilizers on *Festulolium braunii* fiber content. The field studies with three replications and a completely randomized design lasted two years (2016–2017). The effects of slurry applied on its own or in combination with mineral fertilizers and with two products improving soil properties was tested on the Sulino cultivar of *F. braunii*, a forage grass species. The results of the studies demonstrated that crude fiber content of *F. braunii* significantly varied across harvests. The treatment also significantly affected neutral detergent fiber (NDF) fraction content in the biomass. Due to an interaction effect, its amounts in grass treated with the combination of slurry and UGmax, a product improving soil properties, increased by 10% when compared to plants treated with slurry only, and the addition of Humus Active, another product improving soil properties, increased it by 7%, while the addition of mineral fertilizers did so by only 4%. The amounts of acid detergent fiber (ADF) in *F. braunii* significantly varied across growing seasons. However, none of the research factors significantly affected the amounts of acid detergent lignin (ADL).

Keywords: fiber; natural fertilizer; forage grasses

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1. Introduction

Structural carbohydrates, also referred to as crude fiber, are sugars including cellulose, hemicellulose, lignin, and pectinic substances [1]. They have a significant impact on the amounts of nutrients in forage and, consequently, on livestock productivity [2]. Crude fiber content of the biomass varies across the harvests of the same growing season, and it depends mainly on the plant species, its cultivar, and age [3], as well as on fertilizer treatment, or the volume of atmospheric precipitation [4,5]. Łuczak and Rogalski [1] report that minimum crude fiber content in dry matter is 10–15%. For maintaining proper digestibility and high energy value of nutrients, it should not be higher than 28–30%.

There are three fiber fractions: neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL). NDF contains cellulose, hemicelluloses, and lignin, ADF contains cellulose and lignin without tannins, and ADL contains lignin, cutin, and ash. Increased NDF content in the forage reduces its intake [6–10], while the amount of the ADF fraction is negatively correlated with its digestibility [10]; its low content increases net energy concentration [11].

An important species of fodder grasses is *Festulolium braunii*, a cross between *Festuca pratensis* and *Lolium multiflorum*. This grass produces higher yields of better quality than the species from which it originates [12]. In addition, it is drought resistant and grows very well when planted on its own in arable fields [13].

The purpose of this study was to assess the proportions of crude fiber fractions in *Festulolium braunii* treated with slurry on its own and combined with soil conditioners or mineral fertilizers.

When conducting the studies, the following research hypotheses were adopted:

(1) Slurry supplemented with soil conditioners as well as slurry supplemented with mineral NPK fertilizers will have a more beneficial effect on the content of raw fiber and its fractions in *Festulolium braunii* than slurry applied on its own.
(2) Slurry supplemented with soil conditioners will have a more positive effect on the content of fiber fractions in *Festulolium braunii* than slurry used in combination with NPK mineral fertilizers.

2. Material and Methods

The two year (2016–2017) research was set up in the experimental field of University of Natural Sciences and Humanities in Siedlce, Poland (52°10′ N, 22°17′ E). The Sulino cultivar of *Festulolium braunii*, a forage grass, was used to study the effect of the research variables. The experiment started in the autumn of 2015, when the plants were sown at a recommended rate of 18 kg ha^{-1}.

2.1. Experimental Design

The experiment, with 4.5 m^2 (1.5 × 3.0 m) plots, was replicated three times, with a completely randomized design. The main variable was slurry used on its own and together with soil conditioners (UGmax and Humus Active), or mineral fertilizers (NPK), with the following combinations: (O) control plot (no treatment); (S) slurry; (S + UGmax) slurry + UGmax; (S + HA) slurry + Humus Active; and (S + NPK) slurry + NPK.

2.2. Soil and Treatments

The experiment was conducted on loamy sand soil, which, according to Polish Soil Classification, was of the anthropogenic order, culture earth type, and hortisole subtype [14]. With pH of 6.7 and its C:N ratio of 10.6:1, the soil contained 14.50 g kg^{-1}DM of organic carbon, 1.36 g kg^{-1}DM of total nitrogen, 170.00 mg kg^{-1}DM of available phosphorus, 84.00 mg kg^{-1}DM of magnesium, and 114.00 mg kg^{-1}DM of potassium.

Soil conditioners, the compositions of which are presented in Table 1, were used every year in early spring at the following doses, according the producer's recommendations: UGmax—0.6 L ha^{-1}; Humus Active—50 L ha^{-1}. Slurry, produced by dairy cows, was applied three times during each growing season at 30 m^3 ha^{-1}. Its C:N ratio of 8:1 was narrow, and it contained 10% of dry matter, N-33.0 g kg $^{-1}$DM, P_2O_5-16.0 g kg^{-1}DM, K_2O-16 g kg^{-1}DM, MgO-10.0 g kg^{-1}DM, and Ca-21.0 g kg^{-1}DM.

Table 1. Soil conditioner composition.

Soil Conditioner	Macronutrients (g kg^{-1})						Micronutrients (mg kg^{-1})				Microorganism and Others
	N	P	K	Ca	Mg	Na	Mn	Fe	Zn	Cu	
UGmax	1.2	0.2	2.9	-	0.1	0.2	0.3	-	-	-	*Azotobacter*, *Pseudomonas*, yeast, actinomycetes, lactic acid bacteria, photosynthetic bacteria,
Humus Active	0.2	1.3	4.6	3.0	0.5	-	15	500	3	1	active humus with beneficial microorganisms

The following amounts of mineral fertilizers were applied each growing season: 100 kg ha^{-1} of ammonium nitrate (NH_4NO_3): 80 kg ha^{-1} of triple granular superphosphate ($Ca(H_2PO_4)_2$); 120 kg ha^{-1} of potassium salt (KCl). The doses of nitrogen and potassium were divided into three parts, applied before each growth cycle, while phosphorus was applied once, before the start of the growing period.

2.3. Weather Conditions

The experiment was established in autumn 2015, and in 2016 the plants were fully developed. The Hydrological and Meteorological Station in Siedlce provided meteorological data, based on which Sielianinov's hydrothermal coefficient (Table 2) was calculated [15] to study temporal variability of the weather and its effects on plant growth and development. To calculate the coefficient (K) the following formula was used [16]:

$$K = P/0.1\ \Sigma t$$

where P—total monthly rainfall; Σt—monthly sum of average daily air temperatures.

Table 2. Sielianinov's hydrothermal coefficient (K).

Year	Month						
	April	May	June	July	August	September	October
2015	1.36 (o)	1.87 (mw)	1.64 (mw)	0.59 (sd)	1.92 (mw)	0.64 (sd)	0.12 (ed)
2016	1.22 (md)	2.63 (sw)	0.87 (d)	1.08 (md)	0.18 (ed)	1.46 (o)	1.94 (mw)
2017	2.88 (sw)	1.15 (md)	1.08 (md)	0.45 (sd)	0.96 (d)	1.92 (mw)	1.90 (mw)

$K \leq 0.4$ extremely dry (ed); $0.4 < K \leq 0.7$ severely dry (sd); $0.7 < K \leq 1.0$ dry (d); $1.0 < K \leq 1.3$ moderately dry (md); $1.3 < K \leq 1.6$ optimal (o); $1.6 < K \leq 2.0$ moderately wet (mw); $2.0 < K \leq 2.5$ wet (w); $2.5 < K \leq 3.0$ severely wet (sw); $K > 3.0$ extremely wet (ew).

During the growing season (2016) the best weather conditions were only in September, while May was severely wet. June, July, and August, all three being very important months for grass growth, were dry, moderately dry, and extremely dry, respectively. During the next growing season (2017) the period from May to August was moderately dry and severely dry, with no optimum conditions recorded.

2.4. Determination Methods

Each growing season the grass was harvested three times. Plant material was collected and appropriately prepared to obtain a representative sample. The fresh matter yield was determined, and a 0.5 kg sample was collected to determine the content of dry matter. At the same time, crude fiber, and fiber fraction (NDF, ADF, and ADL) content was measured by means of near-infrared spectroscopy (the Polish standard PN-EN ISO 12099:2010), marked with the autoanalyzer of the Swiss company Büchi using the LSDFlex N-500 and INGOT forage calibrations for dry grass [17,18].

2.5. Statistical Analysis

The following research variables were considered in the experiment: (A)—treatments (5 levels), (B)—growing seasons (2 levels), and (C)—grass growth cycles (3 levels). One factor analysis of variance for replicates in the experiment did not show any significant differences between them.

The results were statistically processed using a three-factor analysis of variance according to the mathematical model [19]:

$$y_{ijlp} = \mathrm{m} + a_i + g_j + e_{ij}^{/1/} + b_l + ab_{il} + e_{ijl}^{/2/} + c_p + ac_{ip} + bc_{lp} + \mathrm{AA} + e_{ijlp}^{/3/}$$

where y_{ijlp}—the value of the variable for the i-th level of factor A and p-th level of factor C for the j-th replicate; m—the mean of research; a_i, b_l, c_p—the effects of factors; g_j—the effect of the j-th replicate; ab_{il}, ac_{ip}, bc_{lp}—the effects of the interaction of two factors; abc_{ilp}—the effect of the interaction of three factors; $e_{ij}^{/1/}$, $e_{ijl}^{/2/}$, $e_{ijlp}^{/3/}$—the effect of random factor; i = 1, 2, ... , a, a—the number of levels of factor A; j = 1, 2, ... , n, n—the number of replicates; l = 1, 2, ... , b, b—the number of levels of factor B; and p = 1, 2, ... ,c, c—the number of levels of factor C.

All calculations were carried out using Statistica 6.0–2001 [20]. In order to compare means, Tukey's test at 0.05 probability level was used.

3. Results

On average, across growing seasons, crude fiber content in plants on plots where slurry was applied together with the UGmax and Humus Active soil conditioners was slightly smaller (approximately 1.6 and 3.4%, respectively) than in plants treated with slurry on its own. The biomass from plots treated with slurry with the addition of mineral fertilizers contained more than 3% of crude fiber compared to the plants treated with slurry only. Crude fiber content in *Festulolium braunii* (Table 3) significantly varied only across harvests.

There was a 2–5% decrease, average of growing seasons, in crude fiber content in plants from the first harvest on plots treated with slurry combined with soil conditioners and slurry supplemented with mineral fertilizers. A different response to the same treatment was observed in the second harvest. The combination of slurry with soil conditioners slightly increased fiber content, but when used together with mineral fertilizers it increased the content by 7% compared to plots where slurry was used on its own. Slurry supplemented with the UGmax and Humus Active soil conditioners reduced raw fiber content by 4.5 and 6.5% (average of the experiment), respectively, compared to slurry used together with mineral fertilizers.

On average the highest crude fiber content was in the grass of the second harvest and the smallest in the first. The content was higher (by 4%) in the first year than in the second.

The content of neutral detergent fiber in *Festulolium braunii* significantly varied depending on the treatment (Table 4). At the same time, according to statistical analysis, the interaction between treatments and growing seasons had a significant impact on this content.

The largest NDF content, average of growing seasons, was in plants treated with slurry combined with UGmax, about 10% higher than on plots with slurry alone. The combined application of the Humus Active soil conditioner resulted in approximately 7% higher content of NDF in *Festulolium braunii* than when it was treated with slurry only. Plants treated with slurry supplemented with mineral fertilizers contained 4% of NDF more than those treated with slurry only. The interaction of slurry with UGmax and Humus Active soil conditioners also increased NDF content by 2.6 and 5.2%, respectively, compared to the effect of slurry supplemented with mineral fertilizers.

In individual harvests, the most NDF fraction was also recorded in the biomass from plots treated with slurry supplemented with the UGmax soil conditioner. In the second harvest in the biomass from the same plots a 12% increase in comparison to the plants treated with slurry only was reported. On average, the largest content was found in the second harvest, the smallest in the third. NDF content was higher in the first year than in second.

The amounts of ADF in *Festulolium braunii* were significantly different in both growing seasons, higher in the second one than in the first (Table 5). In addition, there was a significant interaction between treatments and growing seasons, affecting the content of this fiber fraction.

Across treatments, the largest ADF content was found in the plants treated with slurry only, however combining slurry with soil conditioners resulted in its reduction (for UGmax by 8%, for Humus Active by 12.0%). NPK fertilizers reduced it by 9.0% compared to plants treated with slurry; the analysis of harvests across the growing seasons showed a similar dependence. There were no significant differences between ADF fiber content in *Festulolium braunii* treated with slurry combined with soil conditioners and in plants treated with slurry supplemented with NPK mineral fertilizers.

The greatest amount of the ADF fraction in *Festulolium braunii* was in the third harvest of 2017, but, on average, over growing seasons its lowest amounts were in the plants of the third one, with the largest in the second. The content of acid detergent lignin in the plants did not significantly vary across experimental factors (Table 6).

Table 3. The effect of treatments on mean crude fiber content in *Festulolium braunii* dry matter across grass growth cycles and growing seasons (g·kg^{-1}).

Growing Season (B)	Grass Growth Cycle (C)	Treatments (A)					Means	Significance
		* O	* S	* S + UGmax	* S + HA	* S + NPK		
2016	I	273.5	284.6	269.2	256.5	272.7	271.3	↕ C/B = NS **
	II	311.5	313.5	310.5	299.4	324.5	311.9	
	III	315.1	318.7	312.8	278.5	319.0	308.8	
	Means Significance * ↔ A/B = NS ↓ B/A = NS**	300.0	305.6	297.5	278.1	305.4	297.3	**↓ B = NS**
2017	I	276.5	265.2	255.2	280.4	268.5	269.2	
	II	300.1	288.3	297.6	312.8	321.3	304.0	**↕ C/B = NS**
	III	235.7	295.9	293.5	276.8	315.7	283.5	
	Means Significance ↔ A/B = NS ↑ B/A = NS	270.8	283.1	282.1	290.0	301.8	285.5	**↑ B = NS**
Means across growing seasons Significance A = NS		285.4	294.5	289.8	284.5	303.6	291.4	
Means across grass growth cycles								
	I	275.0	274.9	262.2	268.5	270.6	270.2b ****	
	II	305.8	300.9	304.1	306.1	322.9	307.9a	**↕ C = 18.3**
	III	275.4	307.3	289.8	277.7	317.4	293.5a	
Significance ↔ A/C = NS ↕ C/A = NS								

(A)—treatments; (B)—growing season; (C)—grass growth cycle; * O—control treatment (without fertilization); S—slurry; S + UGmax–slurry + UGmax soil conditioner; S + HA—slurry + Humus Active soil conditioner; S + NPK—slurry + mineral NPK fertilizers; ** NS—not significant; *** ↕ ↔ ↓ ↑—the direction of comparisons; **** means marked with the same letters do not differ significantly.

Table 4. The effect of treatments on mean neutral detergent fiber (NDF) content in *Festulolium braunii* dry matter across grass growth cycles and growing seasons (g·kg^{-1}).

Growing Season (B)	Grass Growth Cycle (C)	Treatments (A)					Means	Significance
		* O	* S	* S + UGmax	* S + HA	* S + NPK		
2016	I	499.6	506.5	573.5	515.3	553.2	529.6	
	II	498.7	521.3	586.3	523.4	543.6	534.7	↕ C/B = NS **
	III	503.4	536.4	566.3	542.6	538.7	537.5	
	Means **Significance *** ↔ A/B = 48.3** **↓ B/A = 32.2**	500.6 b **** a	521.4 b a	575.4 a a	527.1 ab b	545.2 a a	533.9	**↓ B = NS**
2017	I	499.8	512.0	545.5	589.5	504.9	530.3	
	II	503.7	498.8	555.7	566.4	522.7	529.5	**↕ C/B = NS**
	III	455.5	481.1	524.4	526.2	513.9	500.2	
	Means **Significance ↔ A/B = 48.3** **↑ B/A = 32.2**	486.3 b a	497.3 b a	541.9 a b	560.7 a a	513.8 ab a	520.0	**↑ B = NS**
Means across growing seasons **Significance ↔ A = 37.1**		493.5 b	509.4 b	558.7 a	543.9 a	529.5 ab	526.9	
Means across grass growth cycles								
I		499.7	509.3	559.5	552.4	529.1	529.9	
II		501.2	510.1	571.0	544.9	533.2	532.1	**↕ C = NS**
III		479.5	508.8	545.4	534.4	526.3	518.9	
Significance ↔ A/C = NS **↕ C/A = NS**								

(A)—treatments; (B)—growing season; (C)—grass growth cycle; * O—control treatment without fertilization); S—slurry; S + UGmax—slurry + UGmax soil conditioner; S + HA—slurry + Humus Active soil conditioner; S + NPK—slurry + mineral NPK fertilizers; ** NS—not significant; *** ↕ ↔ ↓ ↑—the direction of comparisons; **** means marked with the same letters do not differ significantly.

Table 5. The effect of treatments on mean acid detergent fiber (ADF) content in *Festulolium braunii* dry matter across grass growth cycles and growing seasons (g·kg^{-1}).

Growing Season (B)	Grass Growth Cycle (C)	Treatments (A)					Means	Significance
		* O	* S	* S + UGmax	* S + HA	* S + NPK		
2016	I	346.3	372.3	312.6	299.8	340.6	334.3	
	II	352.4	382.6	345.0	286.7	325.9	338.5	↕ C/B = NS **
	III	355.5	372.6	298.0	298.0	299.6	324.7	
	Means Significance *** ↔ A/B = 42.6 ↑ B/A = 28.2	351.4 ab **** a	375.8 a a	318.5 bc b	294.8 c b	322.0 bc a	332.5b	↓ B = 16.9
2017	I	336.8	351.7	362.5	376.0	337.5	352.9	
	II	334.9	346.8	353.8	361.2	356.4	350.6	↕ C/B = NS
	III	370.5	361.6	358.5	338.1	343.1	354.4	
	Means Significance ↔ A/B = 42.6 ↑ B/A = 28.2	347.4 a a	353.4 a a	358.3 a a	358.4 a a	345.7 a a	352.6a	↑ B = 16.9
Means across growing seasons Significance ↔ A = NS		349.4	364.6	338.4	326.6	333.9	342.6	
Means across grass growth cycles								
I		341.6	362.0	337.6	337.9	339.1	343.6	
II		343.7	364.7	349.4	323.9	341.2	344.6	↕ C = NS
III		363.0	367.1	328.3	318.1	321.4	339.6	
Significance ↔ A/C = NS ↕ C/A = NS								

(A)—treatments; (B)—growing season; (C)—grass growth cycle; * O—control treatment (without fertilization); S—slurry; S +UGmax–slurry + UGmax soil conditioner; S + HA—slurry + Humus Active soil conditioner; S + NPK—slurry + mineral NPK fertilizers; ** NS—not significant; *** ↕ ↔ ↓ ↑—the direction of comparisons, **** means marked with the same letters do not differ significantly.

Table 6. The effect of treatments on mean acid detergent lignin (ADL) content in *Festulolium braunii* dry matter across grass growth cycles and growing seasons (g·kg^{-1}).

Growing Season (B)	Grass Growth Cycle (C)	Treatments (A)					Means	Significance
		* O	* S	* S + UGmax	* S + HA	* S + NPK		
2016	I	39.4	40.1	42.6	42.3	40.6	41.0	
	II	42.3	42.3	43.8	42.8	42.3	42.7	↕ C/B = NS **
	III	42.9	40.6	43.6	43.5	42.6	42.6	
	Means **Significance *** ↔ A/B = NS** **↑ B/A = NS**	41.5	41.0	43.3	42.9	41.8	42.1	↓ B = NS
2017	I	43.6	41.3	37.6	45.2	42.1	41.9	↕ C/B = NS
	II	45.6	42.8	42.7	42.4	43.1	43.3	
	III	45.9	40.7	41.2	38.6	44.6	42.2	
	Mean **Significance ↔ A/B = NS** **↑ B/A = NS**	45.0	41.6	40.5	42.1	43.3	42.5	↑ B = NS
Means across growing seasons **Significance ↔ A = NS**		43.3	41.3	41.9	42.5	42.6	42.3	
Means across grass growth cycles								
	I	41.5	40.7	40.1	43.8	41.4	41.5	
	II	43.9	42.6	43.3	42.6	42.7	43.0	↕ C = NS
	III	44.4	40.7	42.4	41.1	43.6	42.4	
Significance ↔ A/C = NS **↕ C/A = NS**								

(A)—treatments; (B)—growing season; (C)—grass growth cycle; * O—control treatment (without fertilization); S—slurry; S +UGmax–slurry + UGmax soil conditioner; S + HA—slurry + Humus Active soil conditioner; S + NPK—slurry + mineral NPK fertilizers; ** NS—not significant; *** ↕ ↔ ↓ ↑—the direction of comparisons.

There was no significant interaction between slurry and soil conditioners affecting ADL content, which was not significantly different from that in plants treated with slurry on its own and slurry with mineral fertilizers. It was the largest in the second harvest and the lowest in the first, but ADL average amounts in both growing seasons were comparable.

4. Discussion

Stachowicz [21] reported that crude fiber content in forage for ruminants should range from 200 to 250 g kg^{-1}DM. Additionally, Staniak and Księżak [22] argued that amounts of crude fiber exceeding 260 g kg^{-1}DM caused the feeling of satiety, but because of the low energy value of the forage, nutritional requirements were not met.

It was found that the interaction of slurry and soil conditioners resulted in more favorable raw fiber content than in plants treated with slurry on its own, or with slurry combined with mineral fertilizers, which confirms the second research hypothesis. In effect the grass treated with slurry and soil conditioners contained the amount of nutrients which, according to Staniak and Księżak [22] and Brzóska and Śliwiński [11], was more favourable.

In the present research crude fiber content of *Festulolium braunii* ranged within 260.0–310.0 g kg^{-1} and was above the standard set by Stachowicz [21], which was undoubtedly caused by very adverse temperature and water conditions in both growing seasons. In the first one (2016), optimal weather conditions were only in September. May was very wet, while June, July, and August, months with the greatest impact on plants, were fairly dry, dry, and extremely dry, respectively. During the next growing season (2017) the dry period lasted from May to August, and in other months the weather conditions were not conducive to plant growth either.

According to Grzelak [23], the minimum amount of fiber in forage for cattle should be 13%, while for dairy cows it should range from 18% to 22%. The results of the present studies were also confirmed by other authors [24–26]. Many of them [27–29] reported a much higher fiber content in hay, from 281.1 to 331.8 g kg^{-1}DM. Additionally, Jankowska-Huflejt and Wróbel [30] in their research on organic grassland recorded 300 g kg^{-1} of crude fiber in the forage.

Crude fiber content of *Festulolium braunii* significantly varied across harvests. Its smallest content in both years was in the first harvest. Water scarcity affects crude fiber content of grass, and according to Olszewska [31], a decrease in the amount of fiber caused by drought depends on the species of grass. On the other hand, Jankowski and Jodełka [32] suggested that high temperatures might increase fiber content. This was confirmed in the present studies, with the highest fiber content of *Festulolium braunii* in the second harvest of 2016, when air temperatures were high, reaching the average of 21 °C in August.

Neutral detergent fiber content in forage is strictly dependent on the harvest and, especially, on thermal conditions [28]. Its content in hay for dairy cows should be about 400 g kg^{-1} [33]. In the present studies, being generally higher than that recommended by Mertens [33], NDF content was significantly differentiated by treatments in both years of the experiment, but it complied with the feed requirements provided by Brzóska and Śliwiński [11]. The increase in NDF content was higher in plants treated with slurry and soil conditioners than in those treated with slurry on its own and slurry combined with NPK.

In the present research, both slurry combined with soil conditioners, and with mineral fertilizers, contributed to an increase in NDF fraction content in grass. However, studies on meadow plants conducted by Wróbel et al. [26] showed that the use of manure and slurry resulted in its significant reduction.

The components of acid detergent fiber such as cellulose, lignin, and silica are the least digestible [11]. Their optimum content in forage should range from 190 to 210 g kg^{-1}DM, as elevated values deteriorate its digestibility. Similar content of the ADF fraction in *Festulolium braunii* was reported by Sosnowski [34] in an experiment with the UGmax soil conditioner and mineral fertilizers.

Jankowska [35] reports that increasing nitrogen doses contribute to reducing the proportion of the ADF fraction in meadow hay. This was reflected in the present research, where integrated application of slurry with mineral fertilizer and slurry with soil conditioners also resulted in a reduction of the ADF amounts in grass.

The average content of the ADF fraction ranging from 320.0 to 350.0 g kg^{-1} was similar to that observed by Tomic et al. [36]. The interaction between slurry and soil conditioners or mineral fertilizers affected ADF content more than the use of slurry on its own. In turn, the content of the ADL fraction in *Festulolium braunii* was 40–45 g kg^{-1}DM and was comparable to that of Sosnowski [34] as well as of Wróbel et al. [26] in their experiment on another variety of the grass. Slurry combined with soil conditioners had no higher effect on ADL content in the grass than slurry used on its own or with NPK.

5. Conclusions

Crude fiber content in *Festulolium braunii* varied significantly across harvests. Slurry applied together with mineral fertilizers (NPK) resulted in a 7% increase in crude fiber content compared to plants treated with slurry only. The treatment significantly influenced NDF content in *Festulolium braunii*. It increased by 10% in plants treated with the combination of slurry and mineral fertilizers. The content of the ADF fraction in *Festulolium braunii* significantly changed across the growing seasons. Compared to plants treated with slurry only, slurry supplement with both soil conditioners or with mineral fertilizers, decreased ADF content in the biomass. The content of acid detergent lignin in the grass did not reveal a significant differentiation as a response to treatments.

Slurry applied together with soil conditioners affected raw fiber content, including that of NDF and ADF fractions, more than slurry combined with mineral fertilizers, although the differences were not always significant. To a large extent, the interaction between treatments and growing periods affected this content, this way reflecting the difficult meteorological conditions throughout the experiment. The results clearly indicated that there was a need for further research into the possibility of replacing mineral fertilizers with soil conditioners, which would be of great ecological importance.

Author Contributions: B.W.: conceptualization, methodology, writing–original draft; G.S.: formal analysis, software. All authors have equally contributed to this article. All authors have read and agreed to the published version of the manuscript.

Funding: The results of the research carried out under research theme No.39/20/B were financed from the science grant granted by the Ministry of Science and Higher Education.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Łuczak, W.; Rogalski, M. *Grassland Feed for Animal Nutrition*; Grassland, Kurpisz: Poznań. Poland, 2004; pp. 193–204. (In Polish)
2. Rogulski, W. Principle of basic feed analysis. In *Basics of Animal Nutrition*; SGGW: Warsaw, Poland, 2001; pp. 21–33. (In Polish)
3. Domański, P.J. Evaluation of the effects in breeding *Festuca pratensis* Huds. and *Lolium perenne* L. *Water-Environ. Rural Areas* **2004**, *4*, 233–254. (In Polish)
4. Łyszczarz, R.; Dembek, R. Long-term studies on earlines, yields and nutritional value of Polish common orchard grass varieties. *Bull. Inst. Plant Breed. Acclim.* **2003**, *225*, 29–42. (In Polish)
5. Jankowska-Huflejt, H.; Wróbel, B. Evaluation of influence of fertilization with manure on the nutritive value of meadow sward and their usefulness to silage production. *J. Res. Appl. Agric. Eng.* **2010**, *53*, 133–136. (In Polish with English abstract)
6. Aufrere, J.; Carrere, P.; Dudilieu, M.; Baumont, R. Estimation of nutritive value of grasses from semi-natural grasslands by biological, chemical and enzymatic methods. *Grassl. Sci. Eur.* **2008**, *13*, 426–428.
7. Van Soest, P.J.; Robertson, J.B.; Lewis, B.A. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* **1991**, *74*, 3583–3597. [CrossRef]

8. Bélanger, G.; Virkajärvi, P.; Duru, M.; Tremblay, G.F.; Saarijärv, K. Herbage nutritive value in less-favoured areas of cool regions. *Grassl. Sci. Eur.* **2013**, *18*, 57–70.
9. Baert, J.; van Waes, C. Improvement of the digestibility of tall fescue (*Festuca arundinacea* Schreb.) inspired by perennial ryegrass (*Lolium perenne* L.). *Grassl. Sci. Eur.* **2014**, *19*, 172–174.
10. Linn, J.G.; Martin, N.P. *Forage Quality Test and Interpretation*; Minnesota Extension Service, University of Minesota: Minneapolis, MN, USA, 1989; pp. 1–5.
11. Brzóska, F.; Śliwiński, B. Quality of roughages in ruminant nutrition and methods for its evaluation. Part II. Methods for analysis and evaluation of nutritive value of roughages. *Wiadomości Zootech.* **2011**, *4*, 57–68. (In Polish)
12. Nekrošas, S.; Kemešytė, V. Breeding of ryegrass and festulolium in Lithuania. *Agriculture* **2007**, *94*, 29–39.
13. Jankowski, K. Effects of the interaction between slurry, soil conditioners, and mineral NPK fertilizers on selected nutritional parameters of *Festulolium braunii* (K. Richt.) A. Camus. *Agron. Res.* **2020**, *18*, 1573–1583.
14. Czępińska-Kamińska, D. Polish Soil Classification. *Ann. Soil Sci.* **2011**, *62*, 1–193. (In Polish)
15. Bac, S.; Koźmiński, C.; Rojek, M. *Agrometeorology*; PWN: Warsaw, Poland, 1993; pp. 32–33. (In Polish)
16. Skowera, B.; Puła, J. Pluviometric extreme conditions in spring season in Poland in the years 1971–2000. *Acta Agrophys.* **2004**, *3*, 171–177. (In Polish)
17. Burns, G.A.; Gilliland, T.J.; McGilloway, D.A.; O'Donovan, M.; Lewis, E.; Blount, N.; O'Kely, P. Using NIRS to predict composition characteristics of *Lolium perenne* L. cultivars. *Adv. Anim. Biosci.* **2010**, *1*, 321. [CrossRef]
18. Reddersen, B.; Fricke, T.; Wachendorf, M. Influence of NIRS—Method on the calibration of N-, ash- and NDF-content of grassland hay and silage. *Grassl. Sci. Eur.* **2012**, *17*, 385–387.
19. Trętowski, J.; Wójcik, A.R. *Methodology of Agricultural Experiments*; WSRP: Siedlce, Poland, 1991; pp. 355–356. (In Polish)
20. StatSoft, Inc. STATISTICA Data Analysis Software System, V.10.Statsoft, Inc.: USA. 2011. Available online: www.statsoft.com (accessed on 20 May 2020).
21. Stachowicz, T. *Rational Use of Grassland in an Organic Farm*; Agricultural Advisory Center in Brwinów: Brwinów, Poland, 2010. (In Polish)
22. Staniak, M.; Księżak, J. Chemical composition of *Festulolium braunii-Trifolium pratense* mixtures in relation to nitrogen fertilization and the share of components. *Water-Environ. -Rural Areas* **2008**, *8*, 163–173. (In Polish)
23. Grzelak, M. The productivity and fodder value of hay from extensively utilised Noteć river valley meadows. *Sci. Natur. Technol.* **2010**, *1*, 1–8. (In Polish)
24. Wróbel, B.; Zielińska, K.J.; Fabiszewska, A.U. The effect of mineral NPK and organic fertilization on the content of nutritive components and microbiological quality of the first regrowth of meadow sward. *J. Res. Appl. Agric. Eng.* **2012**, *60*, 129–134.
25. Wróbel, B.; Zielińska, K.J.; Fabiszewska, A.U. Evaluation of bacterial inoculation effectiveness in ensilage of meadow sward fertilized with natural fertilizers. *J. Res. Appl. Agric. Eng.* **2013**, *58*, 233–237.
26. Wróbel, B.; Zielińska, K.J.; Fabiszewska, A.U. The effect of fertilization with liquid cattle manure on meadow sward quality and its usefulness to ensilage. *Probl. Agric. Eng.* **2013**, *2*, 151–164. (In Polish)
27. Nazaruk, M.; Jankowska-Huflejt, H.; Wróbel, B. Evaluation of nutritive value of fodders from permanent grasslands in organic farms. *Water-Environ. -Rural Areas* **2009**, *9*, 61–76. (In Polish)
28. Kotlarz, A.S.; Stankiewicz, S.; Biel, W. Botanic and chemic composition of hay from semi-natural meadow and its nutritive value for horses. *Acta Sci. Pol. Zootech.* **2010**, *9*, 119–128. (In Polish)
29. Grygierzec, B. The content of basic nutrients and fibre fractions in hay from extensively used *Alopecuretum pratensis* and *Holcetum lanati* communitie. *Grassl. Sci. Pol.* **2012**, *15*, 53–65. (In Polish)
30. Jankowska-Huflejt, H.; Wróbel, B. Evaluation of usefulness of forages from grasslands in livestock production in examined organic farms. *J. Res. Appl. Agric. Eng.* **2008**, *53*, 103–108. (In Polish)
31. Olszewska, M. Response of cultivars of meadow fescue (*Festuca pratensis* Huds.) and timothy (*Phleum pratense* L.) grown on organic soil to moisture deficiency. *Acta Sci. Pol. Agric.* **2009**, *8*, 37–46. (In Polish)
32. Jankowski, K.; Jodełka, J. Analysis of the impact of climatic factors on the yield and nutritional value of four legume-grass mixtures. *Not. Sci. AP Siedlce. Agric.* **2000**, *57*, 93–101, (In Polish with English abstract).
33. Mertens, D.R.; Mertens Innovation & Research LLC, Belleville, WI, USA. Personal communications, 2012.
34. Sosnowski, J. The value of production, energy and food of *Festulolium braunii* (K. Richt.) A. Camus microbiologically and mineral suppled. *Fragm. Agron.* **2012**, *29*, 115–122, (In Polish with English abstract).

35. Jankowska, J. Impact of different nitrogen fertilization and Starane 250 EC on the NDF and ADF content in the hay meadow. *Fragm. Agron.* **2013**, *30*, 59–67. (In Polish)
36. Tomic, Z.; Bijelic, Z.; Zujovic, M.; Simic, A.; Kresovic, M.; Mandic, V.; Stanisic, N. The effect of nitrogen fertilization on quality and yield of grass—Legume mixtures. *Grass. Sci. Eur.* **2012**, *17*, 187–189.