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IMPROVING THE STATUS OF DEGRADED IRRIGATED MEADOW BY DIRECT UNDERSOWING

Summary

Described studies were performed in a long-term irrigated meadow experiment at varied fertilisation. The aim of the study was to assess the effectiveness of meadow renovation in terms of yielding, botanical composition of meadow sward and its protein content in relation to diverse fertilisation. Seven variants were compared including five fertilised with mineral fertilisers at a rate of 60, 120, 180, 180bis and 240 kg of N·ha^{-1} and two fertilised with organic-mineral fertilisers applied as cattle liquid manure at a rate of 180 kg of N ha^{-1} (G1) and 240 kg of N ha^{-1} (G2) with missing amounts of phosphorus and potassium supplemented with mineral doses proportional to nitrogen fertilisation. Fertilisation with phosphorus was abandoned in variant N-180bis 15 years before renovation. Inappropriate composition of meadow sward characterised by the share of low grasses up to 60 %, a lack of legumes and the presence of stubborn weeds in amounts from 12 to 26.5% were the reasons for renovation. The renovation was performed in spring 2012 with the method of direct undersowing with a special harrowing and seeding machine. Decreased weeding to a level of 5% and remarkable increase in yields and total protein content evidenced the effectiveness of renovation. Increased yields were observed since 2013 i.e. one year after renovation. Increased share of grasses, particularly of the oat-grass (Arrhenatherum elatius (L.) P. Beauv. ex J. & C. Presl), after renovation resulted in decreasing content in total protein in subsequent years of the experiment. High protein content of the sward before renovation was an effect of a large percent of dandelion (Taraxacum officinale F.H. Wigg) and other dicotyledons, all rich in protein. However, total protein yield was higher in the years after renovation (2013 and 2014) compared to the year 2011.
Key words: *grassland restoration, yield, protein content, fertilization*

EFEKTY POPRAWY STANU ZDEGRADOWANEJ ŁĄKI GRĄDOWEJ METODĄ PODSIEWU BEZPOŚREDNIEGO W WARUNKACH JEJ NAWODNIEŃ

Streszczenie

Omawiane badania zrealizowano na wieloletnim doświadczeniu ścisłym, nawadnianym w warunkach zróżnicowanego nawożenia. Celem pracy jest ocena skuteczności renowacji łąki w zakresie jej plonowania, składu botanicznego runi łąkowej oraz zawartości w niej białka na tle zróżnicowanego nawożenia. W badaniach porównywano siedem obiektów, w tym pięć nawożonych mineralnie na poziomie 60, 120, 180, 180bis i 240 kg N·ha^{-1} oraz dwa naturalno-mineralnie gnojówką bydlęcą na poziomie G1-(180) i G2-(240 kg N·ha^{-1}), a brakującą ilość fosforu i potasu w dawkach uzupełniano w odpowiednich proporcjach w zależności od poziomu nawożenia azotem. Na obiekcie N-180bis, na 15 lat przed renowacją zaniechano nawożenia fosforem. Nieodpowiedni skład botaniczny runi na tej łące charakteryzujący się udziałem traw niskich do ok. 60%, braku roślin bobowatych oraz występowaniem uporczywych chwastów na poziomie od 12 do 26,5 % wskazywał na celowość dokonania renowacji. Przeprowadzono ja wiosną 2012 r. metodą podsiewu bezpośredniego agregatem pasmowo gryzującym darń. zmniejszające zachwaszczenie do poziomu 5 % oraz wyraźny wzrost plonów runi jak również białka ogólnego dowodzą skuteczności zabiegu. Wyraźny wzrost plonów był widoczny od 2013 r., tj. od następnego roku po renowacji. Wzrost udziału traw po renowacji, a szczególnie rajgrasu wyniosłego (Arrhenatherum elatius (L.) P. Beauv. ex J. & C. Presl) powodował zmniejszanie się zawartości białka w kolejnych latach doświadczenia. Wyraźne wyższa zawartość białka w runi przed renowacją wynikała z dużego udziału w runi mniszka pospolitego (Taraxacum officinale F.H. Wigg) i innych roślin dwuliściennych o dużej jego zawartości. Jednak całkowity plon białka był wyższy w następnych latach po renowacji tj. roku 2013 oraz 2014 w porównaniu do 2011.
Słowa kluczowe: *renowacja TUZ, plonowanie, zawartość białka, nawożenie*

1. Introduction

Rather low dry weight yields from grasslands (3.3 to 6.0 t ha^{-1}) may exceed 8.5 t·ha^{-1} providing appropriate care and soil moisture [14]. Most important factors affecting the productivity of meadows and pastures are yield forming potential of the habitat, determined mainly by climatic (the amount and distribution of precipitation) and soil conditions, and technical measures [9]. Meadow plants forming the sward largely differ with respect to yielding, fodder quality and chemical composition [8, 9].

The main reasons of unsatisfactory yielding of permanent grasslands consist in their degradation and unfavourable distribution of precipitation during the growing season, particularly in dry meadows. According to Grabowski [11] more than half of meadows is degraded, which translates into chemical composition of the sward often unsuitable for cattle feeding [6]. The reason is in inappropriate botanical composition of the sward and resulting poor quality of fodder [3, 5, 19]. Unfavourable distribution of precipitation during the growing season, particularly prolonged periods of droughts [28] resulting in the decline of valuable grasses and legumes, is quite often the factor limiting yields and facilitating grassland degradation. Degradation may proceed even at irrigation and optimum soil moisture, especially in intensively fertilised meadows, which was shown by Ducka and Barszczewski [5]. Studies by Barszczewski [2] demonstrated markedly increased contribution of herbs and weeds in irrigated meadows, particularly those fertilised with liquid manure.

Economically profitable species of grasses and legumes are the largest and most valuable group of grassland plants [24], which determines the amount and quality of obtained fodder [8, 14]. Domination of these plant species in meadow sward enables to obtain bulk fodder of good quality decreasing thus the costs of production [17]. Meadows of inappropriate botanical composition are being subject to renovation (improvement of botanical composition) through the introduction of valuable species and varieties of grasses and legumes of better utility parameters [9, 14, 25]. Successful renovation brings about substantial increase in yielding and proper content of organic and mineral sward components in adequate proportions [16, 23].

2. Materials and methods

The studies were carried out in the years 2011-2014, out in a form of long-term experiment on irrigated permanent meadow on mineral soil classified as degraded black earth of grain size structure of medium loam to a depth of 80 cm underlined by loose sand. In 1997 the experimental variant N 180bis was deprived of phosphorus fertilisation. Analysed factors involved five levels of mineral fertilisation and two levels of organic-mineral fertilisation. Decision of renovation was undertaken due to inappropriate proportion of high and low grasses in meadow, to a lack or small share of legumes and a high percent of stubborn weeds. In autumn 2011 plants were sprinkled with selective herbicide and the meadow was limed. In spring 2012 before vegetation season the experiment was subject to renovation through undersowing with a mixture of grasses and legumes (tab. 1) using a special machine for turf processing.

Experimental variants were fertilised with mineral or organic-mineral fertilisers (tab. 2). Mineral fertilisers included ammonium saltpetre (34.5% N), triple superphosphate (46% P_2O_5) and potassium salt (57% K_2O). Organic-mineral fertilisation was performed with cattle liquid manure, which covered plant demands for potassium while nitrogen and phosphorus were supplemented to a complete dose with inorganic fertilisers. In autumn 2011 the meadow was limed with calcium-magnesium carbonate at a dose of 4 $t \cdot ha^{-1}$.

Meadow was mown three times. Botanical composition was determined with the Klapp's method [18], utility value of the sward was estimated with the method of Filipek [7]. Yields were calculated from sample cuts and expressed in dry weight. Protein content of the sward was analysed with the near-infrared spectroscopy method using the NIR Flex N500 apparatus.

Table 1. The composition of the mixture of seeds used for sowing

Tabela. 1. Skład mieszanki nasion zastosowanej do podsiewu

Species	Variety	Percentage share (%)
Festuca pratensis	Anturka	25
Phleum pratense	Granolia	20
Lolium perenne	Flinston (4n)	20
Arrhenatherum elatius	Median	10
Poa pratensis	Skiza	10
Dactylis glomerata	Amila	5
Trifolium pratense	Kvarta (4n)	10

Source: own study / *Źródło*: opracowanie własne

Results concerning dry weight yield were statistically processed with the Statistica software. Analysis of variance was tested with Tukey HSD test at significance level α = 0.05.

3. Results

The share of grasses in meadow sward before renovation was 73.0 – 92.0% (tab. 3). In variant N-60 grasses contributed in 92% to meadow sward but the share of tall grasses was only 5%. Legumes were present in 2% and herbs and weeds in 6% of the sward. In N-120 variant the share of grasses was 88% (including 7% of high grasses), that of herbs and weeds was12%. Here and in variants fertilised with higher doses of nitrogen no legumes were found. Variant N-180 was characterised by 83% share of grasses (including 16% of high grasses) and 17% share of herbs and weeds. The percent of grasses was lowest (73% including 11% of high grasses) in variant N-180bis, which was also most weeded (27%). In variant N-240 the share of grasses was similar to that in N-180bis and amounted 76% but with higher percent of high grasses (21%). There were also 24% of herbs and weeds in variant N-240. Variant G1 supported 81% of grasses (including 11% of high grasses) and 19% of herbs and weeds. Variant G2 had most favourable botanic composition made of 87% of grasses (including as much as 43% of high grasses) and 12% of herbs and weeds. There was also one percent of legumes in variant G2.

Table 2. Fertilization scheme on the experimental fields

Tabela 2. Poziom nawożenia na obiektach doświadczalnych

Experimental fields	Fertilizers dose ($kg \cdot ha^{-1}$)						
	N-60	N-120	N-180	N-180bis	N-240	G1	G2
Fertilization	Mineral					Organic-mineral	
N	60	120	180	180	240	180	240
P	10,9	21,8	31,7	0	43,6	31,7	43,6
K	33,2	66,4	99,6	99,6	132,8	99,6	132,8

Source: own study / *Źródło*: opracowanie własne

Table 3. Share of dominant grass species in the sward and legumes, herbs and weeds along with its value in use
Tabela 3. Udział dominujących gatunków traw, roślin bobowatych oraz ziół i chwastów w runi wraz z jej wartością użytkową (LWU)

Year	Group of plants		Research treatment						
			N-60	N-120	N-180	N-180bis	N-240	**G1**	**G2**
2011	Grass		92	88	83	73	76	81	87
	High		5	7	16	11	21	11	43
	dominant species	*Dactylis glomerata L.*	3	4	8	7	12	8	22
		Arrhenatherum elatius	-	-	-	-	-	-	-
		Elymus repens (L.) Gould	-	-	6	4	9	2	20
	Low		87	81	67	62	55	70	44
	dominant species	*Festuca pratensis* Huds	39	21	2	3	-	3	-
		Poa pratensis L.	42	52	56	52	52	53	34
	legumes		2	-	-	-	-	-	1
	herbs and weeds		6	12	17	27	24	19	12
	totally		100	100	100	100	100	100	100
	The number of utility value		6,2	6,4	6,8	6,3	6,4	6,9	7,9
2012	Grass		92	91	91	91	90	89	90
	High		9	13	26	20	32	16	46
	dominant species	*Dactylis g.*	3	4	7	7	11	8	23
		Arrhenatherum e.	1	+	+	+	1	+	+
		Elamus r.	-	1	12	10	18	5	21
	Low		83	78	65	71	58	73	44
	dominant species	*Festuca p.*	35	19	1	3	+	3	-
		Poa p.	38	47	50	53	49	50	26
	legumes		4	3	1	2	0	2	1
	herbs and weeds		0	3	5	5	8	7	6
	empty spaces.		4	3	3	2	2	2	3
	totally		100	100	100	100	100	100	100
	the number of utility value		6,9	7,4	7,9	8,0	7,5	8,1	8,2
2013	Grass		93	94	95	92	99	93	94
	High		18	23	38	32	51	27	53
	dominant species	*Dactylis g.*	5	5	12	9	14	9	23
		Arrhenatherum e.	4	7	7	7	11	7	9
		Elymus r.	1	1	9	9	20	4	17
	Low		75	71	57	62	48	66	41
	dominant species	*Festuca p.*	29	16	1	3	-	2	-
		Poa p.	38	44	44	48	40	47	32
	legumes		6	4	2	2	0	3	2
	herbs and weeds		0	1	1	2	0	2	2
	empty spaces.		0	1	2	3	1	2	2
	totally		100	100	100	100	100	100	100
	the number of utility value		7,3	7,5	8,1	7,6	8,0	8,0	8,0
2014	Grass		93	94	95	92	99	93	94
	High		24	34	52	49	57	41	64
	dominant species	*Dactylis g.*	5	7	13	10	15	11	25
		Arrhenatherum e.	10	15	15	20	14	15	15
		Elymus r.	+	1	13	7	19	5	18
	Low		67	59	40	41	36	48	27
	dominant species	*Festuca p.*	25	11	1	2	-	2	-
		Poa p.	35	38	30	30	30	33	20
	legumes		4	2	1	2	1	3	1
	herbs and weeds		2	2	4	4	2	4	4
	empty spaces.		3	3	3	4	4	4	4
	totality		100	100	100	100	100	100	100
	the number of utility value		7,2	7,7	8,1	8,3	8,1	8,2	8,1

Source: own study / *Źródło*: opracowanie własne

After autumnal liming in 2011 and spring renovation in 2012 the share of grasses increased to about 90% in all variants. Significant differences were found among variants in the proportion of particular groups of grasses. In variant N-60 the share of high grasses was estimated at 9%, that of legumes at 4% and herbs and weeds – less than 1%. In variant N-120 high grasses constituted 13% of plants, legumes and herbs and weeds - 3% each. Variant N-180 contained 26% of high grasses, 1% of legumes and 5% of herbs and weeds. In the devoid of phosphorus variant N-180bis high grasses constituted 20% of plants, legumes - 2% and herbs and weeds – 5%. Tall grasses contributed in 32% to the total plant biomass in variant N-240, legumes were absent and herbs and weeds constituted 8% of plants. In variant G1 high grasses constituted only 16% of the sward, legumes – 2% and herbs and weeds – 7%. The highest contribution of high grasses (46%) was noted in variant G2, legumes constituted about 1% there and herbs and weeds – 6%.

In 2013 the share of grasses in meadow sward varied from 92 to 99%, that of legumes was up to 4% and weeding reached 8%. The share of high grasses in all variants markedly increased compared to the previous years. In variant N-60 it was 18%, the share of legumes was about 6% while herbs and weeds were represented by single specimens. Variant N-120 was characterised by 23% share of high grasses, 4% share of legumes and 1% share of herbs and weeds. In variant N-180 there were 3% of tall grasses, 2% of legumes and about 1% of herbs and weeds. Variant N-180bis was characterised by 32% share of tall grasses, 2% share of legumes and 25% share of herbs and weeds. More than 50% of high grasses were found in variant N-240, where no legumes were noted and herbs and weeds were rare. In variant G1 tall grasses constituted 27% of plants, legumes about 3%, and herbs and weeds – 2%. Similarly to N-240 variant G2 was characterised by a high contribution of high grasses (53%) Legumes and herbs and weeds constituted 2% of plants each.

In 2014 the share of grasses was similar to that in 2013 but the share of high grasses markedly increased varying from 24% in variant N-60 to 64% in variant G2. The share of legumes in the former was highest but amounted only to 4% and the share of herbs and weeds was only 2%. In variant N-120 the share of tall grasses increased to 34% and that of legumes and of herbs and weeds increased by 2%. In variants N-180 and N-180bis the share of high grasses was similar (52% and 49%, respectively), legumes were estimated at 1-2% and herbs and weeds – at 4%. The share of high grasses in variant N-240 was 57%. Variant G1 was characterised by 41% share of high grasses and by 3% share of legumes. In G2 as in the previous years the highest percent of high grasses (64%) was noted while herbs and weeds contributed in about 4% to plant biomass.

The number of utility value of meadow sward (tab. 3) was good in the year 2011 and ranged from 6.1 to 7.9. After renovation in 2012 the number increased in all variants to reach very good class in N-180bis, G1 and G2 and good class in N-60, N-120 and N-180. In the year 2013 the number of utility value was good in variants N-60, N-210 and N-180bis and very good in variants N-180, N-240, G1 and G2. In the year 2014 only variants N-60 and N-120 had the value in the upper limits of good class. Other variants represented very good utility value.

In 2011 meadows in intensively fertilised variants yielded significantly more than in variant N-60 (tab. 4). After spring renovation in 2012 the yields of meadow sward in variants N-60, N-120 and N-180 were significantly smaller than in the previous year. All variants of intensive fertilisation yielded more than meadow in variant N-60. In variants N-180, N-240 and G2 yields were significantly higher than in variants N-120, and yields in N-240 were significantly higher compared with variants N-180 and G1. In 2013 all variants gave high yielding, which confirmed the efficiency of undersowing. Meadows in variants N-180, N-180bis, N-240, G1 and G2 yielded more than meadow in variant N-60. Moreover, meadows in variants N-180, N-180bis, N-240 and G2 gave significantly higher yields than that in variant N-120. In 2014 further increase in yielding was observed and intensively fertilised meadows gave, as before, higher yields than meadow in variant N-60. Moreover, variants N-180, N-240 and G2 gave yields significantly higher than N-120 and meadows in variants N-240 and G2 yielded more compared with meadows in variants N-180bis and G1.

Mean annual content of total protein in meadow sward in 2011 in variants N-180, N-180bis, N-240, G1 and G2 was significantly higher than that in variant N-60 (tab. 5). Moreover, sward from variants N-180, N-240 and G2 had significantly higher content of total protein than that from variant N-120 and from variant G1. Meadow sward in variant N-240 had higher total protein content compared to variant N-180bis. In 2012, after renovation meadow sward from variants N-180, N-180bis, N-240 and G2 had higher content of total protein than that in variant N-60. Sward from variant N-240 was richer in total protein than that in variants N-180 and N-180bis. Increasing content of total protein in meadow sward with increasing fertilisation was noted in the year 2013. In 2014 the content of protein in sward markedly decreased, which resulted from increasing share of high grasses, particularly of the oat-grass, in meadow sward. Plants in variant N-240 had significantly higher content of total protein compared to plants in variants N-60, N-120 and G2.

Table 4. Annual yield of the dry mass (t ha^{-1}) in years 2011-2014
Tabela 4. Porównanie plonów suchej masy runi łąkowej z poszczególnych obiektów w latach 2011-2014 (t·ha^{-1})

Year	Research treatment						
	N-60	N-120	N-180	N-180bis	N-240	G1(180)	G2(240)
2011	5,43a	8,12b	9,04b	8,10b	8,65b	8,25b	9,41b
2012	4,06a	6,74b	7,98bc	8,45cd	10,08d	7,83bc	9,39cd
2013	8,81a	10,09ab	12,99c	12,20c	13,27c	11,78bc	12,89c
2014	8,06a	11,47b	13,47cd	12,40bc	14,97d	11,92bc	14,35d

Source: own study / *Źródło*: opracowanie własne

a, b, c – values in rows with different letters are significantly different (α = 0,05),
(G_1) – fertilized with liquid manure (N-180 kg·ha^{-1}),
(G_2) – fertilized with liquid manure (N-240 kg·ha^{-1}).

Table 5. Annual mean content of total protein in meadow sward (w g·kg^{-1})
Tabela 5. Średnie roczne zawartość białka ogólnego w runi łąkowej (g·kg^{-1})

Year	Research facilities						
	N-60	N-120	N-180	N-180bis	N-240	G1(180)	G2(240)
2011	109,93a	119,93ab	142,63de	137,63cd	157,06e	125,44bc	144,10de
2012	114,79a	117,94a	137,60bc	139,79bc	154,62d	126,77ab	144,19cd
2013	115,06	116,95	120,15	125,83	131,20	114,81	120,17
2014	86,77a	93,35a	94,08ab	100,62ab	107,69b	91,56a	97,35ab

Explanations as in Table. 4.
Source: own study / *Źródło*: opracowanie własne

Table 6. Mean annual yields of total protein in meadow sward in study years (in kg ha^{-1})
Tabela 6. Średnie roczne plon białka ogólnego w runi łąkowej w porównywanych latach (kg ha^{-1})

Year	Research facilities						
	N-60	N-120	N-180	N-180bis	N-240	G1(180)	G2(240)
2011	596,9	973,8	1289,4	1114,8	1358,6	1034,9	1356,0
2012	466,1	794,9	1098,1	1181,2	1558,6	992,6	1353,9
2013	1013,7	1180,0	1560,8	1535,1	1741,0	1352,5	1549,0
2014	699,4	1070,7	1267,3	1247,7	1612,1	1091,4	1397,0

Source: own study / *Źródło*: opracowanie własne

The yield of total protein clearly increased with fertilisation. In 2011 it amounted from 596.9 to 1358.6 kg ha^{-1}. In the first year after renovation the yield of protein decreased by 42.3 to 191.3 kg ha^{-1} in variants N-60, N-120, N-180 and G1 but increased by 200 kg ha^{-1} in variant N-240. In 2013 the yields of protein in all variants (1013.7 to 1741.0 kg ha^{-1}) were markedly higher than in 2011, which meant for example an increase by 206.2 kg ha^{-1} in variant N-120 or an increase by 420.3 kg ha^{-1} in variant N-180bis. In variant N-180 the yield of total protein in 2014 was smaller by 22.1 kg ha^{-1} than in 2011. In other variants, despite lower content of protein in meadow sward, protein yields were larger by 41.0 to 253.5 kg ha^{-1} depending on variant.

4. Discussion and summary

Meadow sward should contain about 50% of high and about 30% of medium and low grasses [4]. In 2011 before renovation all variants were dominated by low grass species. The share of high grasses was higher in variants fertilised with higher doses of nitrogen similarly as in Wesołowski [26] and Mendra and Barszczewski [21]. Intensive fertilisation resulted, however, in more frequent occurrence of nitrophilous weeds as shown also by Ducka and Barszczewski [5] and Wesołowski [26].

Significant change in botanical composition of the sward and increased yielding was noted in subsequent years after renovation (compare [12, 14, 15 and 28]). Botanical composition was similar to that observed by Mendra and Barszczewski [21] in non-irrigated meadows. Main effect consisted in the increasing share of high grasses and elimination of weeds like the dandelion (*Taraxacum officinale* F.H. Wigg.), bitter dock *(Rumex obtusifolius* L.) and common sorrel *(Rumex acetosa* L.). Undersowing meadows with valuable fodder grasses gave significant increase in yields, which was also noted by Baryła [3] and Kostuch [19] and improved utility value of meadow sward in all variants. After renovation the intensity of fertilisation was the main factor affecting yields, which confirmed earlier findings presented by Barszczewski [1] and Grzegorczyk and Olszewska [14]. This effect was even more pronounced in this study. Irrigation clearly translated into increased yielding, which may be seen when comparing our results with those obtained by Mendra and Barszczewski [21] from non-irrigated meadows. In agreement with results obtained by Sapek and Sapek [22] a lack of phosphorus fertilisation in soils rich in this nutrient did not cause decreased yielding.

Markedly differentiated and lower protein content of meadow sward compared with that in non-irrigated meadows[21] may be explained by faster growth of grasses, which was confirmed by larger yields. Nevertheless, the content of total protein both before and after renovation (2011 and 2012-2013) fell within the optimum range [20]. The content of protein clearly decreased in the year 2014 due to dynamic growth of the oat-grass and to a lower competitiveness of other undersown species [12, 13, 15].

5. Conclusion

1. Increase in the share of high grasses increased yielding and utility value of the on all plots.
2. Clover seeds used for undersowing caused a very small increase in the share of legumes and a small increase of protein.
3. The oat-grass was the most dynamically developing species in irrigated meadows. Its dominant share resulted in substantial decrease in protein content in sward of all variants in 2014.

6. References

[1] Barszczewski J.: Dynamika plonowania wieloletnich doświadczeń łąkowych. Woda Środowisko Obszary Wiejskie, 2006, T. 6. Z. spec. (17) s. 119-131.

[2] Barszczewski J.: Wpływ zróżnicowanego nawożenia na plon i jakość runi łąkowej trwałej deszczowanej. Woda-Środowisko-Obszary Wiejskie, 2002, T. 2. Z. 1 (4), 29-55.

[3] Baryła R.: Renowacja trwałych łąk i pastwisk w siedliskach grądowych ze szczególnym uwzględnieniem podsiewu. Zesz. Probl. Post. Nauk Roln., 1996, 442, 23-30.

[4] Burs W., Jankowska-Huflejt H., Wróbel B., Zastawny J.: Użytkowanie kośne użytków zielonych. Radom. Krajowe Centrum Rolnictwa Ekologicznego – Regionalne Centrum Doradztwa Rozwoju Rolnictwa i Obszarów Wiejskich, 2004, ss. 42.

[5] Ducka M., Barszczewski J.: Degradacja runi łąkowej w warunkach optymalnego uwilgotnienia i zróżnicowanego nawożenia. Woda Środowisko Obszary Wiejskie, 2012, T. 12, z. 3 (39), 39-51.

[6] Falkowski M., Kukułka I., Kozłowski S.: Właściwości chemiczne roślin łąkowej. Wyd. 2. Poznań, 2000, ss 132.

[7] Filipek J.: 1973 Projekt klasyfikacji roślin łąkowych i pastwiskowych na podstawie liczb wartości użytkowej.] Post. Nauk Roln., z. 4, 51-68.

[8] Golińska B., Kozłowski S.: Zmienność w występowaniu składników organicznych i mineralnych w *Phalaris arundinacea.* Annales UMCS, Sectio E, 61, 2006, 353-360.

[9] Goliński P.: Możliwości zwiększenia efektywności ekonomicznej pasz z użytków zielonych w żywieniu bydła mlecznego. Ferma Bydła 2010. http://agrosukces.pl/mozliwosci-zwiekszenia-efektywnosci-ekonomicznej-pasz-z-uzytkow-zielonych-w-zywieniu-bydla-mlecznego/.

[10] Goliński P.: Nowoczesne sposoby podsiewu użytków zielonych. Łąkarstwo w Polsce, 1998, nr 1, 17-29.

[11] Grabowski K.: Sposoby odnawiania zdegradowanych użytków zielonych. Hodowca Bydła, 2013, Nr 3, 40-47.

[12] Grabowski K., Grzegorczyk S., Bandycki S.: Wpływ różnych technologii podsiewu na zmiany składu florystycznego runi łąkowej. Annals UMCS, 1995, SectioE, 50, Suppl., 157-160.

[13] Grzegorczyk S., Grabowski K., Alberski J.: Nitrogen accumulation by selected species of grassland legumes and herbs. Ecol. Chem. Eng., 2011, 18(4), 531-536.

[14] Grzegorczyk S., Olszewska M.: Wpływ nawożenia azotowego na plon i skład botaniczny runi mieszanki Festuca Pratensis/Lotus Corniculatus. Mat. Sem 38, IMUZ, 1997, 131-136.

[15] Janicka M.: 2012. Uwarunkowania wzrostu i rozwoju ważnych gospodarczo gatunków traw pastewnych i *Triforium pratense* L. po renowacji łąk grądowych metodą podsiewu.

[16] Jankowska-Huflejt H., Wróbel B.: Evaluation of usefulness of forages from grasslands In livestock production In examined organic farms. Journal of Research and Applications in Agricultural Engineering, 2008, Vol. 53(3) 103-108.
[17] Kapturowska A., Zielińska k., Stecka K.: Ocena jakości mleka surowego w powiązaniu z jakością kiszonych pasz objętościowych w wybranych gospodarstwach ekologicznych. Journal of Research and Applications in Agricultural Engineering, 2012, Vol. 57(3), 194-197.
[18] Klapp E: Grünlandvegetation Und Standort. Berlin – Hamburg: P. Parey, 1965, ss. 620.
[19] Kostuch R.: Synteza krajowych badań oraz osiągnięć w gospodarce pastwiskowej XX wieku. Zesz. Nauk. AR Kraków, 2000. Sesja Naukowa 73 s.159-173.
[20] Kuczaj M., Preś J.: Wybrane elementy żywienia a problemy zdrowotne krów mlecznych cz. II wyd. MedPharm, 2013, ss. 175.
[21] Mendra M., Barszczewski J.: Renovation of variably fertilised dry meadows and its economic effect. Journal of Research and Applications in Agricultural Engineering 2015, Vol. 60(4), 36-40.
[22] Sapek B., Sapek A.: Zmiany zawitości fosforu w glebie i roślinności łąkowej w siedem lat po zaniechaniu nawożenia tym składnikiem.. Woda- Środowisko-Obszary Wiejskie, 2006. t. 6 z. specj. (17), 83-91.
[23] Terlikowski J.: The effect of permanent grassland sward enrichment witch special varieties of grassem and legumes on the quality of produced bulk fodder. Journal of Research and Applications in Agricultural Engineering, 2014, Vol. 59(4), 107-109.
[24] Warda M.: Wpływ roślin motylkowatych na wartośćpaszy pastwiskowej. Biuletyn Naukowy ART Olsztyn, 1998, Nr 1 s. 411-417.
[25] Wasilewski Z.: Zbiór pojęci i nazw używanych w łąkarstwie Woda-Środowisko-Obszary Wiejskie. Rozprawy naukowe i monografie, 2004, nr 12. ss. 120.
[26] Wesołowski P.: Wyniki nawożenia gnojówką bydlęcą i nawozami mineralnymi łąki na glebie torfowo-murszowej. Woda-Środowisko-Obszary Wiejskie, 2003, T. 3. Z. 1 (7), 39-51.
[27] Wolski K.: Możliwości poprawy składu botanicznego i plonowania runi łąkowej metodą siewu bezpośredniego w warunkach klimatyczno-glebowych Dolnego Śląska .Zesz. Nauk. AR Wroc., 1997, Nr 316 Rol.70, 49-75.
[28] Żurek G.: Reakcja traw na niedobory wody – metody oceny i ich zastosowanie dla gatunków trawnikowych. Rozprawa habilitacyjna. Monografie i rozprawy naukowe IHAR, 2006, Nr 25. ss.106.