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RENOVATION OF VARIABLY FERTILISED DRY MEADOWS AND ITS ECONOMIC EFFECT

Summary

Studies were carried out in a long-term experiment at different fertilisation. The aim was to assess the effects of renovation in terms of yielding, botanical composition and the content of proteins and soluble carbohydrates in meadow sward at different fertilisation. Five experimental plots were fertilised with mineral fertilisers at a rate of 60, 120, 180, 180bis and 240 kg N·ha^{-1}, respectively and two plots were fertilised with both mineral fertilisers and cattle liquid manure at a combined rate of 180 and 240 kg N·ha^{-1} (plots G1 and G2, respectively). Phosphorus and potassium were applied in doses proportional to N fertilisation. In plot N-180bis fertilisation with phosphorus was abandoned since 1997. Distinctly worsening botanical composition of the sward with a great share of low grasses (>60% in most plots), a lack of legume plants and a substantial weeding (from 14 to 28%) by stubborn weeds, particularly on plots of higher fertilisation, indicated the need for renovation. The renovation by direct undersowing with a special turf-processing machine was made in spring 2012. In subsequent years a distinct domination of tall grasses and decreased weeding was observed. The yield significantly increased in 2013 compared with that in 2011 was noted on plots N-180, N-240 and G2. In 2014 the yield was larger on all plots regardless of fertiliser doses. Total protein content in sward was optimum in 2011 and markedly decreased after undersowing. Decreased protein content resulted from the elimination of dandelion and other protein-rich dicotyledons from the sward and from the increased share of grasses (mainly oat-grass) in 2014. Nevertheless, total protein yield was higher in 2013 and 2014 than in 2011.
Key words: *dry meadow, renovation, direct undersowing, fertilisation*

RENOWACJA ŁĄKI GRĄDOWEJ W WARUNKACH ZRÓŻNICOWANEGO NAWOŻENIA I JEJ EFEKTY GOSPODARCZE

Streszczenie

Badania przeprowadzono na wieloletnim doświadczeniu ścisłym w warunkach zróżnicowanego nawożenia. Celem pracy jest ocena skutków renowacji w zakresie plonowania, składu botanicznego runi łąkowej oraz zawartości w niej białka i cukrów rozpuszczalnych na tle zróżnicowanego nawożenia. Badania przeprowadzono na następujących obiektach nawożonych mineralnie stosując 60, 120, 180, 180bis i 240 kg N·ha^{-1} oraz dwa naturalno-mineralnie na poziomie G1-180 i G2-240, tj. kg N·ha^{-1} nawożonych gnojówką bydlęcą. Fosfor i potas uzupełniono w odpowiednich proporcjach w zależności od poziomu nawożenia azotem. Na obiekcie (N-180bis), od 1997 r. zaniechano nawożenia fosforem. Wyraźnie pogarszający się skład botaniczny runi, z dużym udziałem traw niskich przekraczający na większości obiektów 60%, braku roślin motylkowatych (bobowatych) oraz znacznym zachwaszczeniu od 14 do 28% z udziałem uporczywych chwastów szczególnie na obiektach o wyższych poziomach nawożenia, wskazywały na potrzebę przeprowadzenia renowacji. Renowację metodą podsiewu bezpośredniego agregatem pasmowo gryzującym darń przeprowadzono wiosną 2012 r. W kolejnych latach po tym zabiegu notowano wyraźną dominację traw wysokich oraz wyraźne zmniejszenie zachwaszczenia. Istotny wzrost plonów w 2013 r. w porównaniu do 2011 r. odnotowano na obiektach N-180, N-240 oraz G2, a w 2014 r. na wszystkich obiektach, niezależnie od poziomu nawożenia. Zawartości białka ogólnego w runi w 2011 r. były optymalna, po podsiewie uległy one wyraźnemu zmniejszeniu. Zmniejszenie zawartości białka spowodowało wyeliminowanie z runi mniszka pospolitego i innych roślin dwuliściennych o dużej jego zawartości, natomiast w 2014 r. wzrostem udziału traw a głównie rajgrasu wyniosłego. Mimo to całkowity plon białka był wyższy w 2013 oraz 2014 r. w porównaniu do roku 2011.
Słowa kluczowe: *łąka grądowa, renowacja, podsiew bezpośredni, nawożenie*

1. Introduction

Permanent grasslands are characterised by differentiated botanical composition of the sward, which determines the amount and quality of so obtained fodder [1, 2]. Meadow plants largely differ in yielding, fodder value and chemical composition depending on species and variety [3, 4] and reflect habitat conditions. From among many factors affecting grassland productivity, the most important are yield-forming potential of the habitat, soil and climatic conditions and cultivation measures [5].

Productive possibilities of permanent grasslands are not fully utilised in Poland. Grzegorczyk [6] indicates that at an appropriate care, one may obtain yields of 8.5 t·ha^{-1} while at present they vary between 3.3 and 6.0 t ha^{-1} depending on site. Lower yielding is typical of degraded grasslands (more than 50% in the country) of inappropriate botanical composition [7]. The sward from such grasslands has inappropriate botanical composition, poor quality, unfavourable chemical composition and is unsuitable for conservation and cattle feeding [8]. Good quality bulk fodder decreases the production costs and, therefore, the quality translates into productive effect [9]. An excellent way of improving low quality of bulk fodder from permanent grasslands is introducing the missing species to meadow sward through renovation [1, 10]. So introduced new species and varieties of grasses and legumes of better parameters increase yielding but mainly provide appropriate content of organic and inorganic components and their proper proportions in the sward [7, 11].

2. Material and methods

Studies were carried out on permanent meadow growing on mineral soil classified as black degraded earth of the grain size structure of medium loam to the depth of 80 cm with loose sand beneath. The experiment was set up in 1987 with the random block method in four repetitions. In 1997 phosphorus fertilisation was abandoned on one of the plots. This paper presents results obtained in the years 2011 – 2014. The factors included five levels of mineral fertilisation and two organic-mineral fertilisations. Despite a great share of grasses in the year 2011, meadow sward contained few tall grass species and many stubborn weeds, which indicated the need for renovation. In autumn 2011 the meadow was sprayed with selective herbicide and limed. Renovation was performed in spring 2012 through undersowing a mixture of grasses and legumes (tab. 1) with the use of turf-processing machine.

Table 1. The composition of the mixture of seeds used for sowing
Tab. 1. Skład mieszanki nasion zastosowanej do podsiewu

Species	Variety	Participation (%)
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 work / Źródło: opracowanie własne

Mineral and organic-mineral fertilisation was applied during the study period (tab. 2). Ammonium saltpetre (34.5% N), triple superphosphate (46% P_2O_5) and potassium salt (57% K_2O) were used in mineral fertilisation. In organic-mineral fertilisation, cattle liquid manure completely covered plant demands for potassium but nitrogen and phosphorus were supplemented in the inorganic form to the full required dose. In autumn 2011 the meadow was limed with calcium-magnesium carbonate at a rate of 4 t ha^{-1}.

The meadow was mown three times a year. Botanical composition was determined with the Klapp's method [12], utility value of sward was assessed with the method by Filipek [13]. Dry weight yields were determined from sample cuts and the content of proteins with the method of near infrared spectroscopy using NIR Flex N 500 apparatus. Dry weight yields were statistically processed with the STATISTICA software using analyses of variance followed by Tukey HSD test at α=0.05.

3. Results

A great share of low grasses in meadow sward ranging from 72 to 94.55 was found in 2011 (tab. 3). On N-60 plots, grasses constituted 94.5% of vegetation but the share of tall grasses amounted only to 4%. Legumes constituted only 1% and herbs and weeds – 4.5% of vegetation on these plots. The share of grasses on plots N-120 was about 86% including 4% of tall grasses (as on plots N-60). Herbs and weeds constituted 14% of vegetation. Plots N-180 and G2 of the same level of fertilisation showed similar share of grasses (about 83%) including 16% of tall grasses. The share of herbs and weeds was about 15%. The smallest share of grasses (72%) including only 11% of tall grasses was found on plots N-180bis. Weeding on these plots reached 28%. Grasses constituted 86.5% of plants on plots N-240, 27.5% in this amount were tall grasses. Herbs and weeds contributed in 14% to botanical composition of these plots. Plots G2 showed 81% share of grasses and the highest per cent of tall grasses (40%). The share of herbs and weeds was estimated at 19% there.

After liming in autumn 2011 and renovation in spring 2012, the share of grasses increased to more than 95%. Parallel increase in the contribution of tall grasses was particularly visible on most fertilised plots. The proportion of tall and low grasses varied markedly among study plots. On plots N-60 the share of tall grasses was about 9%, legume plants 2% and herbs and weeds – only 1%. Tall grasses constituted 9.5%, legumes 1.5% and herbs and weeds 4% on plots N-120. Plots N-180 showed the participation of tall grasses at 31.5%, 1% of legumes and 2.5% of herbs and weeds. The share of tall grasses on plots N-180bis was 28%, that of legumes 1% and of herbs and weeds – 4.5%. Respective figures for plots N-240 were 41%, 0.5% and 1%. On plots G1, tall grasses constituted 23%, legumes 2% and herbs and weeds 2% of the sward. The highest per cent of tall grasses (54.5%) was found on plots G2, the participation of legumes was 0.5% and herbs and weeds 3.5% there.

In the year 2013 the share of grasses exceeded 95% and weeding did not exceed 3% on all plots with the exception of N-60. As in the previous year, particular plots differed in the proportion of tall and low grasses. Plots N-60 of the lowest share of grasses (about 93%) showed marked increase in the participation of tall grasses to 14% and legumes to 5%. Similar increase in the share of tall grasses (to 19.5% and 36%) and legumes (to 2.5% and 2%) was also noted on plots N-120 and N-180, respectively. Plots N-180bis were characterised by a smaller participation of tall grasses (33.5%).

Table 2. Fertilization scheme on the experimental fields
Tab. 2. Schemat nawożenia na obiektach doświadczalnych

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

Source: own work / Źródło: opracowanie własne

Table 3. Share of dominant grass species in the sward and legumes, herbs and weeds along with its utility value
Tab. 3. Udział dominujących gatunków traw w runi oraz grup roślin bobowatych, ziół i chwastów 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		**94,5**	**86,0**	**83,0**	**72,0**	**86,5**	**83,5**	**81,0**
	High		4,0	4,5	16,5	11,0	27,5	15,0	40,0
	dominant species	*Dactylis glomerata L.*	1,8	2,3	6,8	5,8	13,8	11,3	27,5
		Arrhenatherum elatius	-	-	-	-	-	-	-
	Lwu		90,5	81,5	66,5	61,0	59,0	68,5	41,0
	dominant species	*Festuca pratensis* Huds	42,3	24,3	2,8	3,0	-	3,5	-
		Poa pratensis L.	43,8	50,5	55,5	51,8	55,0	52,8	34,0
	legumes		1,0	-	-	-	-	-	-
	herbs and weeds		4,5	14,0	17,0	28,0	14,0	16,5	19,0
	totally		100	100	100	100	100	100	100
	The number of utility value		6,1	6,3	6,9	6,4	6,9	6,9	7,1
2012	Grass		**95,5**	**95,5**	**97,0**	**94,5**	**97,0**	**96,5**	**96,5**
	High		8,5	9,5	31,5	28,0	41,0	23,0	54,5
	dominant species	*Dactylis g.*	2,5	3,5	9,0	7,5	10,5	11,5	13,0
		Arrhenatherum	1,0	0,5	1,0	2,0	4,0	3,0	5,0
	Low		87,0	81,0	65,5	66,5	56,0	73,5	42,0
	dominant species	*Festuca p.*	36,5	23,5	2,5	4,0	-	4,0	-
		Poa p.	39,5	46,5	50,5	50,5	49,0	50,5	5,5
	legumes		2,0	1,5	0,5	1,0	0,5	1,5	0,5
	herbs and weeds		1,5	4,0	2,5	4,5	0,5	2,0	3,5
	totally		100	100	100	100	100	100	100
	the number of utility value		6,3	7,0	7,6	8,5	8,0	8,7	6,8
2013	Grass		**93,5**	**96,5**	**96,0**	**96,0**	**95,5**	**95,5**	**97,5**
	High		14,0	19,5	36,0	33,5	30,5	28,0	56,0
	dominant species	*Dactylis g.*	3,0	5,0	10,0	8,0	7,5	10,5	26,0
		Arrhenatherum	4,0	5,0	5,5	8,0	7,0	4,5	7,0
	Low		79,5	77,0	60,0	62,5	65,0	67,5	41,5
	dominant species	*Festuca p.*	32,9	20,0	1,5	2,5	3,0	3,0	-
		Poa p.	40,5	46,0	48,0	48,0	50,0	48,5	31,0
	legumes		5,0	2,5	2,0	2,0	1,5	3,0	1,0
	herbs and weeds		1,5	1,0	2,0	2,0	3,0	1,5	1,5
	totally		100	100	100	100	100	100	100
	the number of utility value		6,9	7,3	7,8	7,9	7,7	7,9	8,1
2014	Grass		**95,5**	**97,0**	**97,5**	**96,5**	**95,5**	**96,0**	**96,5**
	High		29,5	41,0	59,0	56,5	64,5	49,0	70,5
	dominant species	*Dactylis g.*	5,0	7,5	15,5	12,5	16,5	12,0	26,0
		Arrhenatherum	15,0	18,5	22,0	25,5	19,5	22,5	21,5
	Low		66,0	56,0	38,5	40,0	31,0	47,0	26,0
	dominant species	*Festuca p.*	21,5	11,0	1,0	2,0	-	1,0	-
		Poa p.	36,5	35,0	27,5	26,5	24,0	32,0	19,0
	legumes		3,5	2,0	1,0	2,5	1,0	2,0	1,5
	herbs and weeds		1,0	1,0	1,5	1,0	3,5	2,0	2,0
	totality		100	100	100	100	100	100	100
	the number of utility value		7,5	8,0	8,4	8,4	8,2	8,4	8,4

Source: own work / Źródło: opracowanie własne

Legumes constituted 2% of the sward there. The share of tall grasses was estimated at 30.5% and of legumes at 1.5% on plots N-240. Substantial increase of tall grasses to 28% and legumes to 3% was recorded on plots G1. As before, the highest per cent of tall grasses (56%) was found on plots G2, legumes constituted 1% of the sward.

In 2014, as in the previous years following renovation, the share of grasses was more than 95% and that of legumes, herbs and weeds was 1 – 3.5% on all plots. The greatest differences among the plots were found in the proportion of tall and low grasses. The former markedly increased to 29.5% on plots N-60 while the share of legumes decreased to 3.5%. Plots N-120 showed the share of tall grasses at 41%. On plots N-180 and N-180bis tall grasses participated in 59% and 56.5% in the sward, respectively. The share of tall grasses reached 64.5% on plots N-240. On the objects fertilized naturally - mineral of high grass was 49% for G1 and 70% for G2.

The number of utility value of meadow sward in 2011 (tab. 5) indicated good value and varied between 6.1 and 7.1. After renovation in 2012 the value was assessed as very good for plots N-180bis, N-240 and G1 and as good for plots N-60, N120 and N-180. In the year 2013 the value was good for N-60 and N-120 and very good for G2. For other plots the number remained near the upper limit for good value. In the year 2014 the value was good for N-60 and N-120 and very good for other plots.

Table 4. Annual yield of the dry mass (t ha^{-1}) in the years 2011-2014

Tab. 4. Porównanie plonów suchej masy runi łąkowej z poszczególnych obiektów w (t·ha^{-1}) w latach 2011-2014

Year	Research treatment						
	N-60	N-120	N-180	N-180bis	N-240	G1(180)	G2(240)
2011	5,33a	7,80ab	8,35b	8,00ab	8,41b	9,05b	8,73b
2012	2,96a	4,93b	6,42bcd	5,90bc	7,60d	5,22b	7,33cd
2013	6,15a	8,46abc	10,31bc	8,02ab	11,05c	9,46bc	10,64bc
2014	6,99a	9,95ab	11,53bc	11,00bc	13,50c	10,98bc	13,39c

a, b, c –values in rows with defferent 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});

Source: own work / Źródło: opracowanie własne

Table 5. Annual mean content of total protein in meadow sward (w g·kg^{-1})

Tab. 5. Średnie roczne zawartość białka ogólnego w runi łąkowej (w g·kg^{-1})

Year	Research facilities						
	N-60	N-120	N-180	N-180bis	N-240	G1(180)	G2(240)
2011	115,2a	127,6ab	147,2cd	143,4bc	163,3d	137,8bc	160,0d
2012	112,9a	113,6a	145,0bc	136,5abc	156,2c	130,2ab	149,8bc
2013	119,7a	125,5ab	136,6bc	138,1cd	152,1d	132,4bc	134,7bc
2014	88,7a	91,0ab	101,8bcd	105,7cd	114,2cd	93,7abc	98,1abc

Explanations as in Table. 4

Source: own work / Źródło: opracowanie własne

In the year 2011 plots N-180, N-240, G1 and G2 gave significantly bigger yields than plots N-60. After renovation in spring 2012 the yields of meadow sward from these plots were diverse and smaller than in the previous year. The smallest yields were obtained from plots N-60 and the yields from other plots of higher intensity of fertilisation were significantly bigger. The yields from N-190, N-240 and G2 were significantly bigger than those from N-120 and the yields from N-240 were significantly bigger compared with those from N-180 and N-180bis. In the year 2013 all plots gave big yields, which confirmed the effectiveness of undersowing. Plots N-180, N-240, G1 and G2 yielded significantly more than N-60. Plot N-240 gave significantly bigger yields compared with N-180bis. Further increase in yielding from all plots was noted in 2014. Plots N-180, N-180bis, N-240, G1 and G2 yielded significantly more than N-60 and the yields from plots N-240 and G2 were also significantly bigger than those from N-120.

Annual mean content of total protein in meadow sward from plots N-180, N-180bis, N-240, G1 and G2 in 2011 (tab. 5) was significantly higher than that from plot N-60. Moreover, the sward from plots N-180, N-240 and G2 contained significantly more proteins than that from N-120. Total protein content in the sward from N-240 and G2 was significantly higher than that from N-180bis and G1. After renovation of meadow sward in 2012 the sward from plots N-180, N-240 and G2 contained significantly more proteins compared with the sward from N-60 and N-120. Protein content in the sward from N-240 was higher than that from G1. In the year 2013 mean content of total protein from N-180, N-180bis, N-240 and G2 was significantly higher than that from N-60. Total protein content in the sward from N-180bis and N-240 was significantly higher than that from N-120 and the sward from N-240 contained more protein than that from G1 and G2. Marked decrease of total protein content in the sward from all plots was noted in 2014. This was caused by a large increase of tall grasses, particularly of oat grass, in the sward.

4. Discussion and summary

Intensive fertilisation with nitrogen resulted in the mass appearance of nitrophilous weeds on plots with higher rates of N application similarly to the studies by Ducka and Barszczewski [14] and Wesołowski [15]. Renovation of meadow after application of selective herbicide and liming markedly modified botanical composition of the sward and increased yielding in subsequent years, which was also demonstrated by Baryła, Janicka, Wolski and Grabowski [1, 16, 17, 18]. Increasing share of tall grasses and elimination of weeds resulted in the increase of yielding. Undersowing meadow with valuable fodder grasses significantly improved utility value of the sward [13]. The rate of fertilisation significantly affected meadow yielding, which confirms earlier results obtained by Barszczewski [19] and by Grzegorczyk and Olszewska [20]. Despite the lack of fertilisation with phosphorus, the yields from plots N-180bis did not decrease, which is in accordance with earlier studies by Sapek and Sapek [21].

In spite of a great variability among plots both before (2011) and after (2012 and 2013) renovation, protein content in the sward was mainly within the optimum range [22]. The decline of protein content in meadow sward noted in 2014 was a result of less intensive development of some undersown species [16, 18, 23] and of a dynamic growth of oat grass.

5. Conclusions

1. Ten per cent of seeds of legume plants in undersown mixture did not bring expected increase in the plants share in meadow sward, even at the lowest nitrogen fertilisation. This is an evidence for the need for increasing their percentage in seed mixtures.
2. Distinct increase in the share of tall grasses on all plots regardless of the rate of fertilisation improved yielding and utility value of sward expressed by the numbers of utility value.

3. Oat grass (*Arrhenatherum elatius*) was the most dynamically growing grass species that dominated meadow sward in the year 2014.
4. The reason for marked decrease in the protein content of the sward in 2014 was an unfavourable ratio of leaf blades to stems resulting from the domination of oat grass in favourable dry meadow conditions and from the presence of cock's foot of high competitive advantages.

6. References

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