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THE EFFECTIVENESS OF PERMANENT GRASSLAND RENOVATION UNDER DIFFERENT SOIL AND CLIMATIC CONDITIONS

Summary

The aim of the study to evaluate selected methods of permanent grassland renovation under different soil-climatic conditions in north-eastern Poland. Studies are carried out in three farms: in Dymnik (Rychliki commune, Warmińsko-Mazurskie Province), in Kąty Milewskie (Jasionówka commune, Podlaskie Province) and in Kodeń (Kodeń commune, Lubelskie Province) specialized in beef cattle breeding with bulk fodder from permanent grasslands. Renovation of permanent grasslands was performed in spring 2012. Depending on sward degradation, the method of undersowing or complete cultivation was applied by sowing mixtures of grasses and legumes with the consideration of soil-water conditions and the way of sward utilization. Botanical composition of sward and yielding are determined. Total protein and soluble carbohydrate content are determined using NIRFlex N-500 apparatus with ready calibrations of the INGOT® firm. Results of study presented in the paper come from the years 2012 and 2013. The enrichment of species composition resulted in significant increase of biomass and of the yield of total protein and soluble carbohydrates. Utility value of the sward was also improved. Due to direct undersowing with a slot seeder, the yield of total protein from permanent grasslands increased by 300 kg ha^{-1} on average (by 250 kg ha^{-1} on pastures and by 400 kg ha^{-1} on meadows) and the yield of soluble carbohydrates increased by 150 kg ha^{-1} (by 100 and 200 kg ha^{-1} on pastures and meadows, respectively).
Key words: *permanent grasslands, sward renovation methods, sward quality*

EFEKTY RENOWACJI TRWAŁYCH UŻYTKÓW ZIELONYCH W ZRÓŻNICOWANYCH WARUNKACH KLIMATYCZNO-GLEBOWYCH

Streszczenie

Celem pracy jest ocena efektów wybranych metod renowacji trwałych użytków zielonych w rożnych warunkach klimatyczno-glebowych na terenie północno-wschodniej Polski. Prace badawcze są prowadzone w trzech gospodarstwach rolnych: w Dymniku, woj. warmińsko-mazurskie, w Kątach w woj. podlaskim i w Kodniu, woj. lubelskie, specjalizujących się w produkcji bydła mięsnego, dla których głównym źródłem pasz objętościowych są trwałe użytki zielone. Renowację TUZ wykonano wiosną 2012 r. W zależności od stopnia degradacji runi, zastosowano metodę podsiewu lub metodę pełnej uprawy wysiewając mieszanki nasion traw i roślin motylkowatych z uwzględnieniem warunków glebowo-wodnych oraz sposobu użytkowania runi. Wyniki badań przedstawione w pracy pochodzą z lat 2012 i 2013. Kontrolowano zmiany składu botanicznego runi oraz plonowanie - na podstawie próbnych ukosów w czterech powtórzeniach. Z każdego poletka pobierano próby materiału roślinnego do analiz chemicznych i oceny wartości użytkowej runi. W próbach runi oceniano zawartość białka ogólnego i cukrów rozpuszczalnych metodą NIRS na aparacie NIRFlex N-500. Wzbogacenie składu gatunkowego runi spowodowało istotny wzrost plonów biomasy, a przede wszystkim plonu białka ogólnego i cukrów rozpuszczalnych. Podsiew bezpośredni wpłynął na zwiększenie plonu białka ogólnego średnio o 300 kg ha^{-1} (o 250 kg ha^{-1} na pastwiskach i 400 kg ha^{-1} na łąkach) oraz węglowodanów rozpuszczalnych – średnio o 150 kg ha^{-1} (na pastwiskach i łąkach odpowiednio o 100 i 200 kg ha^{-1}).
***Słowa kluczowe**: trwałe użytki zielone (TUZ), metody renowacji runi, jakość runi*

1. Introduction

Grassland management is intended to provide animals with valuable and healthy fodder which quality should cover the demands arising from species and racial properties, animal's efficiency or age. Energetic value and protein content are the most important criteria when estimating the quality of fibre bulk fodder for ruminants.

An important factor affecting the amount of fodder ingested by ruminants includes its physical structure and palatability. Both are closely associated with botanical composition of sward and is of special importance in grazing. Palatability increases with increasing content of soluble carbohydrates, which may be associated with gustatory features and with faster digestion of fodder in the rumen. This property depends on plant growth and development, on chemical composition of plant cells and on fertilisation. Taste preferences are species- or even race-specific in animals.

Green fodder, fresh or preserved, being the base feed for farm animals must have high yields and energy concentration, optimum content and quality of fibre, good digestibility and palatability [1]. Good grasslands and mixed crops of grasses and legumes are best in view of harvesting utilizable energy for animals while fresh green fodder definitely predominates with respect to economic effectiveness since the cost of feed unit is lowest there [2, 3]. Therefore, grass-

legume sward gathers more and more importance for animal feeding in the present grassland management systems. This is both an effect of sustainable grassland management methods and of a possibility of obtaining fodder of higher nutritive value [4, 5, 6].

Limitation of mineral fertilisation, particularly that with nitrogen fertilisers, facilitates the introduction of legume plants to grassland systems [7, 8]. This pertains not only to grazing but also to the production of silage, hay and dry fodder. The enrichment of meadow sward, particularly with clovers, is one of the ways of avoiding protein deficit. Pasture sward with white clover may completely fulfil the nutritive demands of beef cattle in the grazing season [9].

Rational fertilisation, application of appropriate care and periodical renovation are the precondition of high productivity of grasslands [10]. Unfortunately, due to decreasing interest in the production of bulk fodder from permanent grasslands in the 1990s, the sward of meadows and pastures became degraded. Hence, their re-use as a valuable source of bulk fodder requires renovation methods. Technological innovations are mainly directed to renovation of grasslands and to the enrichment of their botanical composition with modern varieties of grasses and legumes of high nutritive value and palatability. Direct undersowing and complete cultivation are distinguished among the active methods of grassland renovation. The use of tetraploid hybrid mixtures of *Lolium perenne* varieties is a novelty in renovation. Their creation was based on specific chemical and biological properties of the varieties which determine yield and quality of the fodder. Particularly valuable in these mixtures is the differentiation of ploidy and phenology of ryegrass varieties which is decisive for an even fodder supply in the vegetation season [11]. Undersowing pastures with a mixture of *Lolium perenne* varieties favourably affects their contribution to the sward in both the year of undersowing and the first year of grazing [12]. The improvement of chemical composition of sward, including the increased content of protein and soluble carbohydrates, was the effect of undersowing. An actual trend in the selection of grasses for undersowing is manifested by the use of short-term species, the Italian ryegrass, hybrid ryegrass and inter-species hybrids of *Lolium* and *Festuca* despite the need of more frequent sowing of these grasses in the sward of permanent meadows. The benefits associated with the improved yielding and nutritive value of the sward are, however, bigger than the costs. The method of undersowing enables also the enrichment of grassland sward with legumes and special varieties of pasture grasses [13, 14].

The aim of the study is to evaluate preliminarily the effects of selected methods of permanent grassland renovation in diverse climatic and soil conditions of north-eastern Poland.

2. Material and methods

2.1. Farm characteristics

Studies are carried out in three farms specialised in beef cattle production for which grasslands are the main source of bulk fodder.

Farm in Dymnik is situated in Warmińsko-Mazurskie Province, in northern part of Iława Lakeland Mesoregion (Elbląg County, Rychliki commune). The farm is located in young-glacial areas built of boulder clay. Grasslands of the farm are located on brown outwash soil made of light silty loams. In meadow classification the habitats are facultative, so in the case of permanent mown-grazed use they were attributed to periodically drying proper dry grounds.
The whole study area of grasslands (40 ha) was divided into quarters of an area of 3.5 – 4.5 ha. Part of the quarters is mown and the sward is ensilaged in bales wrapped in foil.
Grasslands are exclusively fertilised with mineral fertilisers at a rate of 146 kg N, 40 kg P and 60 kg K ha^{-1} y^{-1} in a form of complex fertiliser (POLIFOSKA) and ammonium nitrate. Cows with calves are bred in Dymnik in the quarter system. Each quarter is grazed for about 6 to 7 days. Market hybrids of beef cattle races are bred in the farm.
Farm in Kąty Milewskie is situated in Podlaskie Province, Mońki County, commune Jasionówka. The total farm area is 62.1 ha. About 40 ha of ground are close to farm building, the rest is 11 km apart. Part of grounds directly neighbouring farm buildings is located on mineral soil built of light loam. Grasslands remote from farm houses are located on soil made of medium loam and *ca*. 2 ha of meadows – on peat-muck soils. Grasslands were classified to proper dry-ground habitats and on some elevations – to impoverished grounds.

Mineral and organic fertilisers were applied on permanent grasslands. Nitrogen fertilisation (in a form of urea) amounted to 100 kg N ha^{-1} and was applied under each cut. Fertilisation with phosphorus and potassium amounted to 24 kg ha^{-1} of POLIFOSKA in spring and two doses of 50 kg of potassium salt in spring and after the first meadow cut or the second regrowth on a pasture which in total made up 84 kg K ha^{-1}. Meadows fertilised with manure (15 t·ha^{-1}) did not receive the spring doses of mineral nitrogen. The farm specialises in breeding Limousin cattle. Pasture grazing is used for cows with calves during the vegetation season.
Farm in Kodeń is situated in Lubelskie Province, Biała Podlaska County, commune Kodeń. This is the smallest farm participating in the Programme. Its total area is 32.0 ha. About 90% of agricultural lands are in the close vicinity of farm buildings. Significant part of agricultural lands is situated on sandy or loamy-sandy soils.
Grasslands occupy an area of 25 ha including 19 ha of permanent grasslands. Prevailing part of grasslands was classified to proper dry-ground habitats and the rest – to impoverished grounds. On both permanent and alternate grasslands, land is used as mown meadows and pastures.

Grasslands are fertilised with mineral fertilisers in two or three doses of 60 kg N, 30 kg P and 60 kg K·ha^{-1} in a form of POLIFOSKA under each regrowth. Manure is applied once a year on an area of ca. 4 ha. The farm specialises in breeding Limousin cattle.

Due to low pH (<4.5) soils in all farms are limed. Grassland renovation was performed in spring 2012. Depending on sward degradation, the methods of complete cultivation or undersowing mixtures of grasses and legumes were applied with the consideration of soil and water conditions and the ways of sward utilisation.

2.2. Climatic conditions

The success of sprouting and growth of undersown species of grasses and legumes depends on ecological conditions in grassland habitats and on anthropogenic factors. The effectiveness of meadow and pasture renovation by direct undersowing is largely determined by soil moisture

[15]. Climatic conditions, particularly the amount and distribution of precipitation during sprouting and the initial growth period of plants undersown in studied farms were differentiated (table 1). Monthly sums of atmospheric precipitation in Kąty in the years 2012 and 2013 were close to the long-term mean and in August 2012 the monthly mean was by 76% higher than the long-term one. Precipitations lower than the long-term means, and thus important for the success of undersowing, were noted for farms in Dymnik and Kodeń. Because renovation in all farms was performed in April 2012, meteorological data (precipitation and temperature) for this month are given in division into 10-day long periods.

3. Methods

Plant cover was assessed with methods commonly used in meadow studies. Botanical composition was determined acc. to Klapp [16], utility value of the sward – with the method of Filipek [17]. The base for determination of the value was the number of utility value attributed to particular plant species. Meadow plants are divided into 14 classes.

The number takes into account:
- productivity,
- ability for regeneration and sward forming,
- usefulness for mowing and pasture use,
- adaptation to habitat conditions,
- competitiveness,
- nutritive value and direct harmfulness.

Very good pasture plants obtained the numbers 10-9, good: 8-7, mean: 6-4. Plants of small utility value have the numbers from 3 to 1. Species of no pasture value, not gathered when mown or neglected by animals obtained the value of 0. Negative numbers of utility value from -3 to -1 were attributed to toxic plants depending on the degree of their toxicity. Nuisance clumpy weeds such as the tussock grass and tall sedges obtained smaller numbers of utility value if present in big amount. The same was true for some herbs. The numbers of utility value cover the range from -3 to 10. Weighed mean number of utility value is calculated as a product of percentage share of a given species in the yield and its number of utility value. So obtained products are summed up and the sum is divided by 100 to get the number of utility value of the sward.

Table 1. Meteorological conditions (monthly mean temperatures and sums of precipitations) during sward renovation and observation period.
Tab. 1. Warunki meteorologiczne (miesięczne średnie temperatury i sumy opadów) podczas renowacji i prowadzenia obserwacji na TUZ w wybranych gospodarstwach

Year	Month								
	IV - decades			V	VI	VII	VIII	IX	IV-IX
	I	II	III						
Dymnik – data from Elbląg									
Temperature [^{0}C]									
2012*	3,3	6,6	14,1	13,8	15,3	18,9	18,0	14,2	14,77
	8,0								
2013*	5,3			14,1	16,4	17,2	17,5	12,6	13,85
1971-2000**	**7,2**			**12,6**	**15,5**	**17,3**	**17,1**	**12,9**	**13,77**
Precipitation [mm]									
2012	13,7	7,4	11,9	18,4	82,6	88,2	38,1	27,9	288,2
	33,0								
2013	26,8			40,9	37,8	95,2	34,1	14,7	249,5
1971-2000	**40,0**			**49,0**	**80,0**	**81,0**	**77,0**	**74,0**	**401,0**
Kąty Milewskie – data from Białystok									
Temperature [^{0}C]									
2012	1,9	14,5	13,5	13,7	15,2	19,3	16,8	13,1	14,33
	7,9								
2013	6,4			15,3	17,7	18,1	17,4	12,0	14,48
1971-2000	6,8			12,8	15,7	17,2	16,5	11,9	13,48
Precipitation [mm]									
2012	11,3	29,2	4,2	51,8	88,9	87,4	111,3	24,6	408,7
	44,7								
2013	61,0			92,5	75,2	75,2	64,5	166,1	534,5
1971-2000	**39,0**			**52,0**	**71,0**	**86,0**	**63,0**	**57,0**	**368,0**
Kodeń – data from Terespol									
Temperature [^{0}C]									
2012	3,5	9,3	14,7	14,9	16,9	21,0	18,2	14,2	15,73
	9,2								
2013	8,1			16,1	18,4	18,9	18,4	12,4	15,48
1971-2000	**7,8**			**13,7**	**16,4**	**17,8**	**17,3**	**12,6**	**14,27**
Precipitation [mm]									
2012	12,8	20,2	0,0	30,2	48,8	37,9	109,5	19,8	279,2
	33,0								
2013	63,0			102,9	80,5	33,3	13,0	103,0	395,7
1971-2000	**37,0**			**52,0**	**65,0**	**71,0**	**62,0**	**53,0**	**340,0**

**Source / Źródło:* http://www.tutiempo.net/en/Climate/TERESPOL/04-2012/123990.htm
** http://www.stc.pl/dhttp.php?co=2010_02_20_swietlicki.pdf

Yielding was determined based on sampling cuts in four replications (each plot – 20 m^2) taken from selected fragments (0.5 ha) of each grassland. Plant material for chemical analyses was taken from each plot. In all sward samples total protein and soluble carbohydrates were determined with the NIRS method using NIRFlex N-500 apparatus with ready calibration by the INGOT® firm. Yields of total protein and soluble carbohydrates from meadows and control pastures in the study farms subjected to renovation with undersowing or complete cultivation were calculated. Obtained results on yielding and some quality parameters of fodder were statistically processed with F-Snedecor test and Newman-Keuls procedure.

4. Results

4.1. Vegetation cover

In the assessment of grasslands (meadows and pastures) of three analysed farms, the floristic composition of sward in the years 2012 and 2013 was compared with that from before renovation (2011). Floristic composition of meadow and pasture sward and their utility value is presented in table 2. Part of grasslands served as a control object during this study.

Table 2. Share of plant groups [%] in meadow and pasture swards and their utility value [Lwu] in 2011 year
Tab. 2. Udział grup roślin [%] w runi łąkowej i pastwiskowej oraz ich wartość użytkowa [Lwu] w 2011 roku

Group of plant	Farm in:		
	Dymnik	**Kąty**	**Kodeń**
Meadow sward			
Grasses	-	65,7* 40-85	77,5 70-85
Legumes	-	6,7 2-15	7,5 5-10
Herbs and weeds	-	27,4 10-45	15,0 5-25
Sedges, rushes, horsetails	-	0,2 0-2	0 0
Number of species	-	27	19
Lwu	-	7,2	8,2
Pasture sward			
Grasses	57,5 57-58	62,5 60-65	70,0 70
Legumes	20,0 20	12,5 10-15	5,0 5
Herbs and weeds	22,5 22-23	25,0 25	25,0 25
Sedges, rushes, horsetails	0 0	0 0	0 0
Number of species	18	17	11
Lwu	7,7	7,8	7,4

* above the line – mean values, below – „from-to"

Source: own work / Źródło: opracowanie własne

Before renovation the dominating grass species in pasture sward in Dymnik were: perennial ryegrass (*Lolium perenne* L.) – 18.5%, cock's foot (*Dactylis glomerata* L.) – 16.0%, timothy grass (*Phleum pratense* L.) and tall fescue *(Festuca arundinacea* Schreb.) – 7.0% (table 2). Herbs and weeds were represented by curly dock (*Rumex crispus* L.), and broad-leaved dock (*Rumex obtusifolius* L.) which constituted as much as 17% of botanical composition of the sward. The share of other species did not exceed several per cent. From among legumes, two basic clover species were present: white clover (*Trifolium repens* L) – 12.0% and red clover (*Trifolium pratense* L.) – 8.0%.

In total 18 species were determined in the pasture sward of this farm including 9 grass species, 2 species of legume plants and 7 species of herbs and weeds. Compared with the botanical composition of the control object, pastures in Dymnik were slightly diversified with respect to plant cover. Plant communities were classified as grassy and herbal with the dominating role of perennial ryegrass (*Lolium perenne*) and cock's foot (*Dactylis glomerata*).

Grasses dominated in grasslands of the farm in Kąty and constituted 65.7% (from 40 to 85) and 62.5% (from 60 to 65) of the yield from meadows and pastures, respectively. The greatest share in meadow sward had: cock's foot (*Dactylis glomerata* L.), red fescue (*Festuca rubra* L.) and meadow grass (*Poa pratensis* L.). Most common among herbs were: dandelion (*Taraxacum officinale* F.H.Wigg.) and common yarrow (*Achillea millefolium* L.) and among legumes – white clover (*Trifolium repens* L.) with a small participation of red clover (*Trifolium pratense* L.) (tab. 2). Before renovation the pasture sward in Kąty, as the meadow sward, was dominated by meadow grass (*Poa pratensis* L.), cock's foot (*Dactylis glomerata* L), perennial ryegrass (*Lolium perenne* L.), red fescue (*Festuca rubra* L.) and by patches of couch grass (*Elymus repens* (L.). Herbs and weeds consisted mainly of dandelion (*Taraxacum officinale* F.H.Wigg.) and common yarrow (*Achillea millefolium* L.). A large per cent (12.5%) of white clover (*Trifolium repens* L.) was noted from legume plants (table 2).

Ten grass species, 2 species of legumes and 13 species of herbs and weeds were found in meadow sward of this farm. Sedges were represented by 2 species. There were, however, only 7 grasses, 1 species of legumes and 10 species of herbs and weeds in the pasture sward.

Based on botanical composition of the sward, meadow communities in Kąty were classified to the cock's foot - fescue – meadow grass community (*Dactylis glomerata - Festuca rubra - Poa pratensis*) while pasture communities – to the meadow grass - cock's foot community (*Poa pratensis - Dactylis glomerata*).

Table 3. Mixtures for direct undersowing and complete cultivation in Dymnik
Tab. 3. Skład mieszanek do podsiewu i renowacji metodą pełnej uprawy w gospodarstwie w Dymniku

Species	Direct undersowing		Complete cultivation	
	Variety	Share [%]	Variety	Share [%]
Meadow fescue	PASJA	15	PASJA	20
Meadow timothy	KABA	15	-	-
Cock's foot	BERTA	5	BERTA	5
Meadow-grass	SKIZ	10	SKIZ	15
Festulolium (4n)	SULINO	15	-	-
Perennial ryegrass	BAJKA	10	BAJKA	15
Perennial ryegrass (4n)	JARAN	10	JARAN	15
Red clover	ROZETA	10	-	-
White clover	ROMENA	10	ROMENA	20
Hybrid ryegrass (4n)	-	-	NADZIEJA	5
Italian ryegrass (4n)	-	-	TURTETRA	5

Source: own work / Źródło: opracowanie własne

Table 4. Mixtures for meadow and pasture swards renovation in Kąty and Kodeń
Tab. 4. Skład mieszanek zastosowanych do renowacji runi na pastwisku i łące w gospodarstwach w Kątach oraz Kodniu

Species	Pasture		Meadow	
	Variety	Share [%]	Variety	Share [%]
Cock's foot	AMERA	10	-	-
Meadow fescue	PASJA	10	PASJA	15
Meadow-grass	SKIZ	25	SKIZ	5
Perennial ryegrass	BAJKA	10	BAJKA	10
Perennial ryegrass (4n)	JARAN	15	JARAN	10
Italian ryegrass (4n)	TURTERA	10	-	-
Meadow timothy	-	-	SKALA	15
Hybrid ryegrass	-	-	GOSIA	5
Festulolium (4n)	-	-	FELOPA	10
Tall oat-grass	-	-		10
Red clover	-	-	BONA	15
White clover	ROMENA	20	ROMENA	5

Source: own work / Źródło: opracowanie własne

Table 5. Share of groups of plant [%] in sward and its utility value (Lwu) in Dymnik
Tab. 5. Udział [%] grup roślin w runi oraz jej wartość użytkowa (Lwu)w Dymniku

Groups of plant	Control		Undersowing		Complete cultivation	
	2012	2013	2012	2013	2012	2013
Grasses	60,00	59,00	64,00	66,00	82,00	46,00
Legumes	10,00	5,00	15,00	4,00	16,00	45,00
Herbs and weeds	30,00	33,00	21,00	26,00	2,00	3,00
Ground without plants	-	3,00	-	4,00	-	6,00
Together	100,00	100,00	100,00	100,00	100,00	100,00
Lwu	**7,16**	**6,48**	**8,07**	**7,15**	**9,60**	**9,14**

Source: own work / Źródło: opracowanie własne

Table 6. Share of groups of plant [%] in sward and its utility value (Lwu) in Kąty
Tab. 6. Udział [%] grup roślin w runi oraz jej wartość użytkowa (Lwu) w Kątach

Groups of plant	Meadow				Pasture			
	control		undersown		control		undersown	
	2012	2013	2012	2013	2012	2013	2012	2013
Grasses	58,00	65,00	63,00	66,00	55,00	61,00	60,00	66,00
Legumes	5,00	6,00	18,00	22,00	20,00	14,00	25,00	23,00
Herbs and weeds	37,00	29,00	19,00	12,00	25,00	25,00	15,00	11,00
Together	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
Lwu	**7,40**	**7,47**	**8,47**	**8,42**	**7,85**	**7,43**	**8,67**	**8,64**

Source: own work / Źródło: opracowanie własne

Table 7. Share of groups of plant [%] in sward and its utility value (Lwu) in Kodeń
Tab. 7. Udział [%] grup roślin w runi oraz jej wartość użytkowa (Lwu) w Kodniu

Groups of plant	Meadow				Pasture			
	control		undersown		control		undersown	
	2012	2013	2012	2013	2012	2013	2012	2013
Grasses	60,00	59,00	65,00	73,00	85,00	70,00	70,00	ploughed
Legumes	20,00	16,00	20,00	7,00	3,00	5,00	5,00	
Herbs and weeds	20,00	25,00	15,00	20,00	12,00	25,00	25,00	
Together	100,00	100,00	100,00	100,00	100,00	100,00	100,00	
Lwu	**7,90**	**7,40**	**8,20**	**8,23**	**7,60**	**7,04**	**8,10**	

Source: own work / Źródło: opracowanie własne

Before renovation the sward of meadows in Kodeń was dominated by grasses whose share was 77.5% on average (from 70 to 85%) (tab. 2). The share of legumes was 5 to 10% and that of herbs and weeds 15.0% (from 5 to 25%). No sedges were found. Most common grasses in meadow sward were: meadow grass (*Poa pratensis* L.), cock's foot (*Dactylis glomerata* L.), rye fescue (*Festulolium brauni*), meadow and red fescue (*Festuca pratensis* L. and *Festuca rubra* L.). Dandelion (*Taraxacum officinale* F.H.Wigg.) was the most common herb and legumes were chiefly represented by red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.).

Pasture sward in the farm in Kodeń (table 2) was dominated by meadow grass (*Poa pratensis* L.), red fescue (*Fes-*

tuca rubra L.) and cock's foot (*Dactylis glomerata* L). Herbs and weeds were mainly represented by dandelion (*Taraxacum officinale* F.H.Wigg.). White clover (*Trifolium repens* L.) constituted a small (5.0%) part of the sward.

Based on botanical composition of the sward, meadow communities in Kąty were classified to the cock's foot - fescue – meadow grass community (*Dactylis glomerata - Festuca rubra - Poa pratensis*) while pasture communities – to the meadow grass - cock's foot community (*Poa pratensis - Dactylis glomerata*).

Before renovation the sward of meadows in Kodeń was dominated by grasses which share was 77.5% on average (from 70 to 85%) (tab. 2). The share of legumes was 5 to 10% and that of herbs and weeds 15.0% (from 5 to 25%). No sedges were found. Most common grasses in meadow sward were: meadow grass (*Poa pratensis* L.), cock's foot (*Dactylis glomerata* L.), rye fescue (*Festulolium brauni*), meadow and red fescue (*Festuca pratensis* L. and *Festuca rubra* L.). Dandelion (*Taraxacum officinale* F.H.Wigg.) was the most common herb and legumes were chiefly represented by red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.).

Pasture sward in the farm in Kodeń (table 2) was dominated by meadow grass (*Poa pratensis* L.), red fescue (*Festuca rubra* L.) and cock's foot (*Dactylis glomerata* L). Herbs and weeds were mainly represented by dandelion (*Taraxacum officinale* F.H.Wigg.). White clover (*Trifolium repens* L.) constituted a small (5.0%) part of the sward.

Meadow sward of this farm was composed of 8 grass species, 2 species of legumes and 9 species of herbs and weeds. Only 4 species of grasses were found, however, in pasture sward accompanied by 1 species of legumes and 6 species of herbs and weeds.

Described meadow community in Kodeń was attributed to the meadow grass – fescue - cock's foot (*Poa pratensis - Festuca pratensis - Dactylis glomerata*) type with a large share of herbs and weeds while pasture vegetation – to the meadow grass - fescue (*Poa pratensis - Festuca rubra*) community.

Grassland sward in analysed farms assessed with the number of utility value (table 2) was in general good and the meadow sward in Kodeń before renovation was even of very good utility value (8.2 points).

Mixtures of special grass and legume varieties adapted to habitat conditions and land use were prepared to improve and enrich floristic composition of grasslands in studied farms. Composition of these mixtures is given in tables 3 and 4.

Changes in utility value of meadow and pasture sward due to its enrichment with the direct undersowing method or complete cultivation in analysed farms are presented in tables 5, 6 and 7. As a result of undersowing meadows and pasture in Kąty and in Kodeń, the utility value increased from good to very good. In Dymnik, however, due to precipitation deficits and droughts in 2012 and 2013, undersowing did not bring expected results. Utility value of the sward remained good for the whole study period. Complete cultivation markedly improved the utility value of pasture sward which was assessed as very good (9.14 to 9.60 per 10.0 maximally possible).

4.2. Yielding

Grasslands in Dymnik

The improvement and enrichment of floristic composition of the sward in Dymnik was performed with direct undersowing and complete cultivation methods. Statistical analysis showed significant differences between the ways of grassland sward renovation (fig. 1). Three basic groups were distinguished. Group „a" consisted of yields obtained from the control object, significantly smaller compared with the yields from grassland subjected to renovation by direct undersowing (group "b"). Complete cultivation (group "c") enabled obtaining the highest yields significantly higher than those from undersowing and control.

Renovation by complete cultivation provided good yielding already in the year of sowing. Apart from the first regrowth (mown and intended for ensilage), other regrowths were fed to cows with calves. The height of sward grazed by animals markedly exceeded that recommended at the beginning of grazing permanent pastures (20-30 cm).

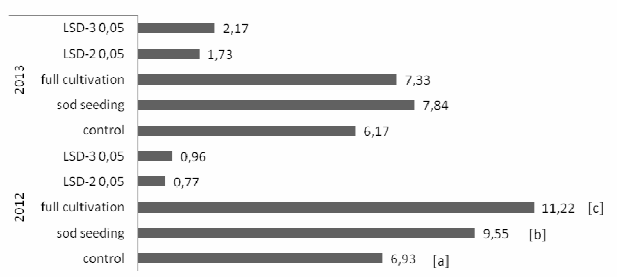

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Fig. 1. Yielding of sward after sod seeding and full cultivation in Dymnik [t DM · ha^{-1}]

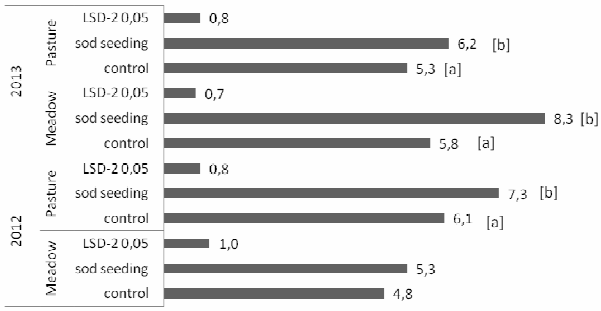

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Fig. 2. Yielding of sward after sod seeding in Kąty [t DM · ha^{-1}]

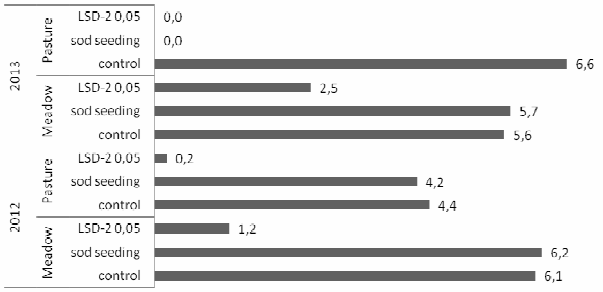

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Fig. 3. Yielding of sward after sod seeding in Kodeń [t DM · ha^{-1}]

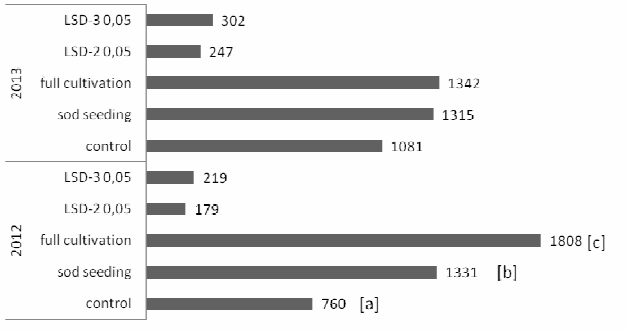

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Fig. 4. Yield of crude protein in Dymnik [kg · ha^{-1}]

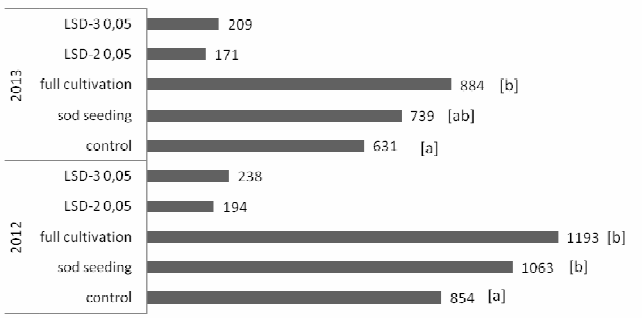

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Fig. 5. Yield of carbohydrates in Dymnik [kg · ha^{-1}]

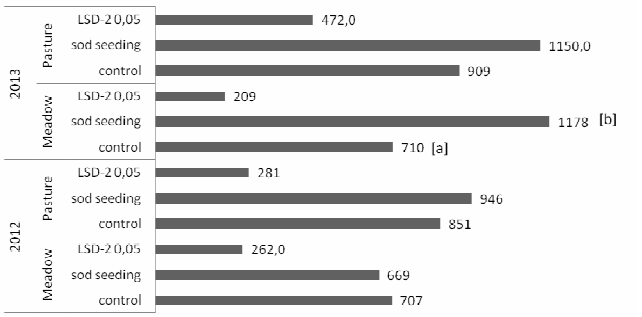

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Fig. 6. Yield of crude protein in Kąty [kg · ha^{-1}]

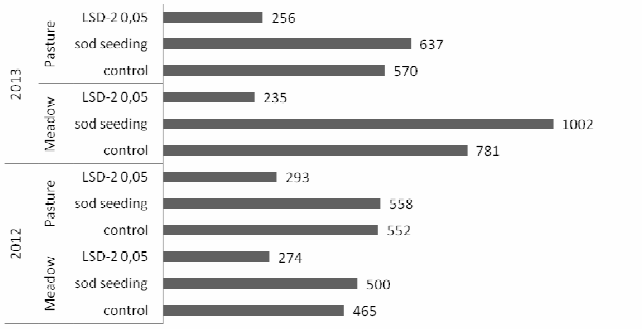

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Fig. 7. Yield of soluble carbohydrates in Kąty [kg · ha^{-1}]

Nevertheless, grazing was accurate and leftovers after grazing the quarter were about 5-10%. Hence, one may see clear advantage in yielding of the renovation by complete cultivation over the renovation by direct undersowing (fig. 1), which is more risky and brings positive effects with a time delay. However, the use of special grass and legume varieties in undersowing permanent meadows and pastures may contribute to the improvement of yielding and the quality of produced bulk fodder in favourable meteorological conditions.

In the year 2013 long summer drought limited yielding on both control and renovated objects.

Grasslands in Kąty

Yielding of meadow and pasture in 2012 is presented in fig. 2. Undersown meadow yielded 5.3 t DM · ha^{-1} while the control object 4.8 t DM · ha^{-1} (fig. 2). The yield from undersown pasture was 7.3 t per ha. Direct undersowing significantly increased yields. In pasture, positive effect was obtained already in the year of undersowing. In the next year (2013) significantly higher yields were obtained from undersowing both meadow and pasture (fig. 2). Positive effect of undersowing was obtained in Kąty thanks to favourable weather conditions (table 1).

Grasslands in Kodeń

Dry mass yields of both meadows and pastures did not differ significantly between the control and undersown sward (fig. 3). Poor effects of yielding after undersowing were caused by long periods of drought and by the distribution of precipitation unfavourable for biomass increments in vegetation seasons (table 1).

4.3. Assessment of meadow and pasture sward quality

The yields of total protein and soluble carbohydrates were assessed in the sward of meadows and pastures renovated with undersowing or complete cultivation in studied farms.

4.3.1. Assessment of the yields of total protein and soluble carbohydrates in Dymnik

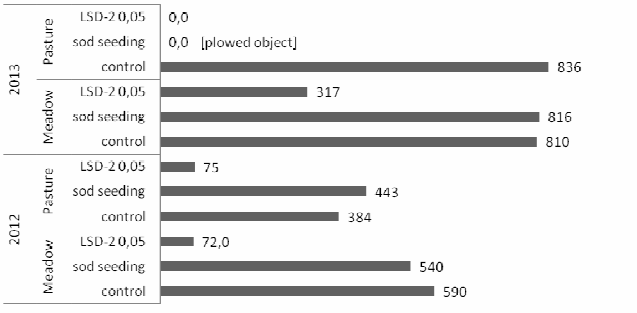
Based on chemical analysis of sward and on obtained dry mass yields, the yields of total protein and soluble carbohydrates were calculated for undersown sward and that renovated by complete cultivation (tables 4 and 5). Both methods significantly increased total protein and carbohydrate yields compared with the control object. Particularly high yield increment was obtained after renovation by complete cultivation. However, due to unfavourable weather conditions, the yields of total protein in sward renovated by complete cultivation varied greatly compared with that from undersown sward. The yield of soluble carbohydrates in the undersown sward and in the sward after complete cultivation was significantly higher than that from the control object. This was a result of the introduction - by both renovation methods – of special grass varieties richer in soluble carbohydrates.

4.3.2. Assessment of the yields of total protein and soluble carbohydrates in Kąty Milewskie

No significant improvement in the yield of total protein was observed after undersowing sward in relation to the control object in the year 2012. Next year, significant increment of total protein yield was obtained only after undersowing the meadow. No significant effect of undersowing either meadow or pasture on the yield of soluble carbohydrates was observed. Noteworthy, meteorological conditions in Kąty were most favourable for the growth and development of undersown sward among all studied farms.

4.3.3. Assessment of the yields of total protein and soluble carbohydrates in Kodeń

Obtained yields of total protein and carbohydrates (fig. 8 and 9) were lowest in comparison with other farms.



Source: own work / Źródło: opracowanie własne

Fig. 6. Yield of crude protein in Kodeń [kg · ha^{-1}]

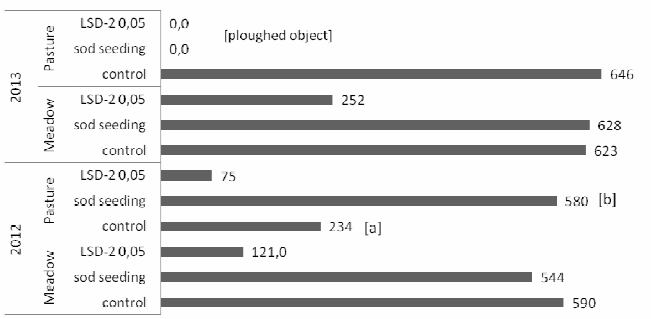


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Fig. 9. Yield of soluble carbohydrates in Kodeń [kg · ha^{-1}]

Apart from rather random significantly higher yield of soluble carbohydrates obtained after undersowing pasture in 2012, no significant impact of undersowing on protein or carbohydrate yield was noted. Noteworthy, grasslands in the farm are located on mineral light soils which in combination with unfavourable meteorological conditions (long-lasting droughts) may pose a risk of failure in meadow and pasture sward enrichment by undersowing.

5. Conclusions

Grasslands in farms selected for programme realization were situated on mineral soils. In every farm, cows with calves before separation were fed by pasture grazing. Bulls were fed in stalls.

In the year of grassland renovation the best yielding was achieved in Dymnik after complete cultivation. Best yielding of both meadow and pasture due to undersowing with a slot seeder were obtained in the farm in Kąty. The worst effects of sward improvement by undersowing were obtained in Kodeń. Long summer droughts and light, permeable soils under grasslands of this farm were the reason.

The success of sward enrichment by direct undersowing depends on meteorological conditions after renovation i.e. on the amount and distribution of atmospheric precipitation during sprouting and in the rest of the vegetation season, on mean daily temperatures and on the competition with older species in the sward. Soil conditions were another important factor. Better results of undersowing were noted in grasslands situated on light and medium soils made of sandy loams and much worse – on light sandy soils.

Undersowing brought diverse effect of the enrichment of floristic composition:

- positive results of undersowing were observed in grasslands located on soils made of light and medium loam in favourable weather conditions (Kąty Milewskie and Dymnik),
- worse effect was noted in Kodeń, with grasslands located on light sandy soils, during long-lasting droughts.

An improvement of floristic composition as a result of undersowing or complete cultivation were noted in farms in Dymnik and Kąty.

The enrichment of species composition significantly increased the yield of biomass, of total protein and soluble carbohydrates. Utility value of the sward was also improved.

As a result of direct undersowing the following (mean) increments were obtained:

- total protein yield – by 300 kg ·ha^{-1} (on average)
  from pastures by 250 kg ·ha^{-1}
  from meadows by 400 kg ·ha^{-1}
- soluble carbohydrate yield – by 150 kg ·ha^{-1} (on average)
  from pastures by 100 kg (ha-1
  from meadows by 200 kg (ha-1.

Assuming that the sward of meadows and pastures is enriched by undersowing with special grass and legume mixtures on 20% of Polish grasslands (0.7 million ha) annually, the yields of total protein would increase by about 210 thousand tons and the yields of soluble carbohydrates – by about 105 thousand tons.

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