Jan KAMIŃSKI[1], Jerzy BARSZCZEWSKI[2]
[1] Instytut Technologiczno-Przyrodniczy w Falentach, Zakład Doświadczalny w Biebrzy
[2] Instytut Technologiczno-Przyrodniczy w Falentach, Zakład Użytków Zielonych
Falenty, Al. Hrabska 3, 05-090 Raszyn, Poland
e-mail: j.kaminski@itp.edu.pl ; j.barszczewski@itp.edu.pl

THE EFFECT OF MINERAL FERTILISATION ON ECONOMIC AND BIOLOGICAL VALUE OF PERMANENT MEADOW ON PEAT-MUCK SOIL

Summary

The aim of this study was to analyse the effect of different ways of mineral fertilisation (0, K, PK, NPK) on yielding, botanical composition and utility value of sward and biological values of twice mown meadows on peat-muck soil. The paper contains final results of 50-year-long cycle of studies in experiment established in 1957 in Experimental Station in Biebrza. Water conditions of soil underwent marked changes during the experiment, periods with deep soil drainage prevailed. In the years 1997-2001 capillary irrigation was applied and in the years 2001-2010 drainage was moderate. A lack of fertilisation in many years caused very strong meadow degradation leading to the disappearance of the turf. Hay yields were only about 1.0 t·ha^{-1}. Fertilisation with potassium only slightly increased yields to 3.0 t·ha^{-1} at poor quality of the sward, facilitating the development of floristically rich communities with biologically valuable species characteristic for semi-natural wet, fresh and some bog meadows. Fertilisation with phosphorus and potassium (PK) increased the productive potential and good utility value of the sward. At deep soil drainage Bromus inermis Leyss was the dominant. Capillary irrigation increased the share of Poa pratensis L. s. str., Phalaris arundinacea L., Phleum pratense L. and Alopecurus pratensis L. NPK fertilisation did not significantly increase yields compared with PK fertilisation that enhanced mineralisation of organic matter.
Key words: *peat-muck soil, fertilisation meadows, mowing, economic and biological value*

WPŁYW NAWOŻENIA MINERALNEGO NA WARTOŚĆ GOSPODARCZĄ I WALORY PRZYRODNICZE WIELOLETNIEJ ŁĄKI 2-KOŚNEJ NA GLEBIE TORFOWO-MURSZOWEJ

Streszczenie

Badano wpływ różnych sposobów nawożenia mineralnego (0, K, PK, NPK) na plonowanie, skład botaniczny i wartość użytkową runi oraz walory przyrodnicze łąk 2-kośnych na glebie torfowe-murszowej. Praca zawiera wyniki kończące 50-letni cykl badań na doświadczeniu agrotechnicznym, założonym w 1957 roku w Zakładzie Doświadczalnym w Biebrzy. Warunki wodne gleb w trakcie realizacji doświadczenia ulegały znacznym zmianom, przeważały okresy z głębokim odwodnieniem gleb, w latach 1997-2001 stosowano nawodnienia podsiąkowe poprzez piętrzenie wody w pobliskim kanale, a w latach 2002-2010 odwodnienie było umiarkowane. Brak nawożenia w ciągu wielu lat powodował bardzo silną degradację łąki, prowadzącą aż do zanikania darni. Plony siana wynosiły zaledwie około 1,0 t·ha^{-1}. Nawożenie potasem (K) w niewielkim stopniu zwiększało wydajność użytku (3,0 t·ha^{-1}) przy miernej wartości użytkowej runi. Sprzyjało natomiast kształtowaniu bogatych florystycznie zbiorowisk, z udziałem cenniejszych przyrodniczo gatunków, charakterystycznych dla półnaturalnych łąk zmienno wilgotnych i świeżych oraz niektórych bagiennych. Natomiast fosforem i potasem (PK) decydowało o dużym potencjale produkcyjnym łąk (plony siana wynosiły 6–9 t·ha^{-1}) oraz dobrej wartości użytkowej runi. Nawożenie to sprzyjało też bogactwu gatunkowemu i dominacji w runi wartościowych gospodarczo traw. Przy głębokim odwodnieniu gleb dominowała stokłosa bezostna (Bromus inermis Leyss.), a w latach po wprowadzeniu nawodnień podsiąkowych zwiększył się udział wiechliny łąkowej (Poa pratensis L.), mozgi trzcinowatej (Phalaris arundinacea L.), tymotki łąkowej (Phleum pratense L.) i wyczyńca łąkowego (Alopecurus pratensis L.). Dodatek azotu nawozowego (NPK) nie powodował istotnych zwyżek plonów w porównaniu do obiektu PK w większości sezonów, ze względu na wzmożoną mineralizację substancji organicznej gleb. Nawożenie azotem sprzyjało jednak zachwaszczaniu runi nitrofilnymi gatunkami zielnymi, co nieznacznie zmniejszało walory przyrodnicze takich łąk.
Słowa kluczowe: *gleba torfowo-murszowa, nawożenie łąki, użytkowanie, wartość gospodarcza i przyrodnicza*

1. Introduction and aim of the study

Mineral fertilisation is one of the important measures affecting botanical composition [3] and productive potential of grasslands [6, 21]. The greatest role in shaping communities and productive potential of meadows on drained peatlands was attributed to potassium and phosphorus fertilisation because of low or medium content of these nutrients in peat-muck soils [13, 16]. The importance of nitrogen fertilisation is much smaller due to rather intensive mineralisation of soil organic substances, which liberates nitrogen compounds available for plants, in often large amounts [2, 10, 11, 12]. Its effects in terms of increasing yield are often visible already the year after application. The effect of fertilisation on species composition of plant communities is, however, much slower and long-lasting [1, 4, 5, 12].

In recent papers little attention has been paid to the role of mineral fertilisation in creating floristic species richness and diversity and biological values of meadows on reclaimed peatlands. Fertilisation of twice mown meadows with moderate doses of fertilisers is particularly desired in environment-friendly and sustainable economy. Small doses of fertilisers are also allowable on biologically valuable semi-natural meadows qualified to biological packages (variants) of agro-environmental programme [20].

The aim of this study was to assess the effect of long-term mineral fertilisation on yielding, floristic composition and utility value of sward and on biological values of twice mown meadows on peat-muck soil. Results of long-term experiment pertaining to the effect of fertilisation on yielding and botanical composition of sward were the subject of earlier papers both for the period of deep soil drainage [8] and for the period of intensive capillary irrigation [10]. This paper contains results, which summarise 50-year-long cycle of studies carried out in this experiment.

2. Material and methods

Studies were carried out in the first and second series of a long-term agro-technical experiment in six repetitions. The experiment was set up in 1958 with a random block method in Experimental Farm Biebrza on reclaimed lowland peatland. The study variants included the following ways of fertilisation of permanent meadow mown twice:

- 0 – without fertilisation,
- K - 100 kg $K_2O \cdot ha^{-1}$ (applied in two doses),
- PK - 100 kg $K_2O \cdot ha^{-1}$ and 50 kg $P_2O_5 \cdot ha^{-1}$ (potassium applied in two doses, phosphorus in one),
- NPK - 100 kg $K_2O \cdot ha^{-1}$, 50 kg $P_2O_5 \cdot ha^{-1}$ and 60 kg $N \cdot ha^{-1}$ (nitrogen and potassium applied in two doses, phosphorus in one).

The first cut was harvested at the break of June and July, the second – in the middle of September.

Meadow in the first experimental series was sown with a mixture of grasses and legumes at doses given in kg ha^{-1}: the awnless brome (*Bromus inermis* Leyss.), red fescue (*Festuca rubra* L. s. str.) – 3, timothy grass (*Phleum pratense* L.) – 3, cock's foot (*Dactylis glomerata* L.) – 3, redtop bent (*Agrostis gigantea* L.) – 1, common meadow-grass (*Poa pratensis* L. s. str.) – 1, fowl bluegrass (*Poa palustris* L.) – 2, meadow fescue (*Festuca pratensis* Huds.) – 6, white clover (*Trifolium repens* L.) – 2 and bird's-foot trefoil (*Lotus corniculatus* L.) – 2. In the second experimental series the awnless brome was replaced with the tall fescue (*Festuca arundinacea* Schreb.) – 6, the white clover was replaced with the alsike clover (*Trifolium hybridum* L.) – 2, and the bird's-foot trefoil – with the marsh bird's-foot trefoil (*Lotus uliginosus* L.) – 2.

Floristic studies were carried out in 2009, hence 50 years after the experiment set up.

- floristic relevés were made with the Braun-Blanquet method. Separate relevés were made on each 50 m^2 plot and results were presented in a table. The following parameters were estimated based on phytosociological relevés:
- combined share of species characteristic for particular phytosociological classes (G) in percent of occurrence acc. to Pawłowski's [19] equation G (%) = $\frac{g}{t}$ 100,

where:

g = the sum of occurrences in phytosociological table of species of a given group/class calculated by summing the numerators of the constancy degrees of particular species expressed as a fraction (each numerator = the number of relevés with the present species)

t = the sum of occurrences of all species in phytosociological table.

- Shannon-Wiener H' indices of floristic diversity used by the formula: H' = -∑ (pi x log pi),

where:

H'- Shannon-Wiener H' indices,

Σ - total number of species,

pi - number of occurrences of the species in pictures;

- mean moisture indices of phytocoenoses determined after Oświt [18]. The method is based on the assumption that plant community reflects moisture conditions prevailing in several-year-long period. Phytoindication of habitat moisture was based on the calculation of mean moisture indices for habitat patches (phytosociological relevés) knowing water demands of particular plant species. The demands were expressed in a 10-grade scale, where 1 meant that the species was least demanding with respect to water and 10 meant the greatest demands for water. Specific category of habitat moisture was estimated using the defined threshold numerical values of the mean moisture index;
- indices of biological valorisation acc. to Oświt's [17] method applicable to wetlands including reclaimed peatlands. The assessment was based on calculation of these indices for phytosociological relevés. They were calculated from the quotient of sums of biological values attributed to particular plant species (on a 10-grade scale) divided by the number of species present in a given relevé. The lowest value of 1 was attributed to accidental, not endangered species alien to hydrogenic sites and the highest value of 10 – to most biologically valuable and endangered species. Then, using the established threshold values of the index, biological values of communities were assigned to a given valorisation class (1 to 10);
- utility value of the sward acc. to the method proposed by Filipek [7]. The value was calculated on a 10-grade scale based on percent share of particular species and on their fodder value.

Species of vascular plants were determined acc. to Szafer et al. [22], nomenclature was adopted after Mirek et al. [15]. Syntaxonomic classification of species was determined based on Matuszkiewicz [14].

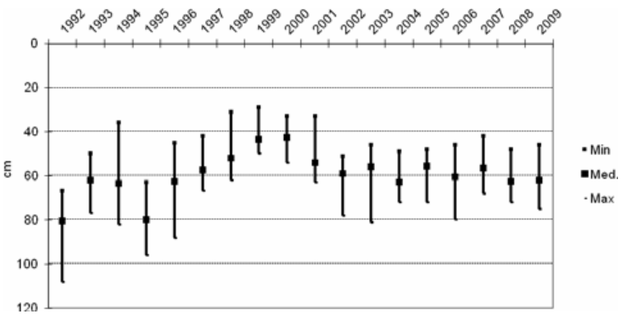
Yielding of meadow sward was given for vegetation seasons 2000, 2005 and 2009 in the end of the study period. Ground water table depth was determined in 10-day periods for vegetation seasons 1992-2009. One-way analysis of variance with Student-Neuwman-Keuls test was performed for selected parameters characterising plant patches of particular fertilisation variants (dependent variable) and for the yield assessment.

3. Results and discussion

3.1. Habitat conditions

Studies were performed on moderately transformed peat-much soil formed on highly decomposed alder peat (MtIIcc1) underlined by medium-grained sand. This soil of poor capillary raising was attributed to the drying (C) (in some places to dry CD) soil-moisture prognostic complex. During 50 years of experiment substantial changes took place in the soil, which consisted in shallowing of peat deposits due to mineralisation of organic matter. After the year 2000 medium deep and locally shallow peat deposits of a thickness not exceeding 130 cm were present in experimental area.

Moisture conditions of soils varied during the experiment (fig. 1). Relatively deep drainage was noted in the years 1958-1992. Ground water table depth was most often between 60 and 110 cm below ground. Sometimes, the depths exceeding 110 cm were observed [9]. Later on, particularly since 1996 the depth of ground water was smaller due to water lifting in Kuwasy Canal (main water recipient from Kuwasy area, which served also as a source of water for irrigations). The highest, periodically near-surface, ground water table was noted in the years 1998-2000. In the next vegetation seasons it was usually at a depth of 40 to 80 cm being thus within the optimum limits for highly productive grassland communities.



Source: own study / *Źródło:* opracowanie własne

Fig. 1. Variability of monthly mean ground water table depths in the vegetation seasons 1992-2009

Rys. 1. Wahania poziomu zalegania wód gruntowych według średnich miesięcznych w sezonach wegetacyjnych 1992-2009

3.2. Yielding

Statistical analysis showed significant effect of fertilisation with potassium (K) and potassium and phosphorus (PK) on meadow yielding compared with variants without fertilisation (0). This was also demonstrated for previous years [10] (tab. 1). Fertilisation with potassium and phosphorus gave also higher yielding compared with fertilisation with potassium alone. The effect of fertilisation with nitrogen (NPK), when compared with PK fertilisation was significant only in 2000, when intensive capillary irrigation was performed. A lack of clear effect of nitrogen fertilisation in most seasons of moderate to deep meadow drainage resulted from intensive mineralisation of soil organic matter [2, 10, 11, 12]. Nitrogen compounds released during decomposition covered the demands of plants for this element.

Table 1. Mean hay yields in relation to fertilisation of permanent meadow ($t{\cdot}ha^{-1}$)

Tab. 1. Średnie plony siana w zależności od nawożenia łąki wieloletniej, $t{\cdot}ha^{-1}$

Fertilisation	Yields				
	Mean in years 1991–1998*	2000	2005	2009	Mean in years 2000-2009
0	1,1	0,9 a	1,1 a	1,0 a	1,0
K	3,0	3,1 b	2,8 b	3,2 b	3,0
PK	9,0	6,5 c	8,3 c	9,2 c	8,0
NPK	9,5	8,7 d	8,6 c	9,7 c	9,0

* [10] *Source:* own study / *Źródło:* opracowanie własne

Explanations: a, b, c, d – means in columns marked with the same letter do not differ significantly acc. to Student-Neuwman-Keuls test

Objaśnienia: a, b, c, d – średnie w kolumnach oznaczone tymi samymi literami nie różnią się istotnie między sobą wg testu Studenta-Neuwmana-Keulsa

3.3. Botanical composition

Yield-forming potential of studied meadows depended on turf cover and on botanical composition (tab. 2) [3]. Non-fertilised meadows supported phytocoenoses characteristic for poorly covered meadows with the red fescue (*Festuca rubra*) of very low yield-forming potential about 1 $t\ ha^{-1}$ of dry weight. After intensive capillary irrigation the sward cover slightly improved because of increasing share of the red fescue. Herb plants were mainly represented by low rosette species like: the sand rock cress (*Cardaminopsis arenosa* (L.) Hayek), autumn hawkbit *(Leontodon autumnalis* L.), mouse ear chickweed (*Cerastium holosteoides* Fr. emend. Hyl.) and common sorrel (*Rumex acetosa* L.). The common sedge *(Carex nigra* Reichard) and field woodrush (*Luzula campestris* L.) were small admixtures.

Table 2. Botanical composition of variably fertilised meadows [3]

Tab. 2. Skład botaniczny różnie nawożonych łąk [3]

Fertilisation	0		K		PK		NPK	
Number of phytosociological relevés	12		12		12		12	
Number of species in community	44		54		41		43	
Coverage of the plant layer, %	75		90		100		100	
S – stability, D – cover factor	S	D	S	D	S	D	S	D
ChCl. *Molinio-Arrhenatheretea*								
Festuca rubra L. s. str.	V	4187	V	1083	IV	258	IV	150
Poa pratensis L. s. str.	V	383	II	29	V	2646	V	3417
Rumex acetosa L.	V	546	III	25	V	633	V	858
Plantago lanceolata L.	IV	429	V	1292	III	54	III	142
Ranunculus acris L.	IV	87	III	96	III	58	I	21
Cerastium holosteoides Fr. emend. Hyl.	III	233	III	62	V	158	V	112
Vicia cracca L.	III	54	I	4	III	108	III	87
Holcus lanatus L.	II	154	III	37	V	762	IV	242
Phleum pretense L.	I	4	IV	171	IV	467	II	150
Poa trivia lis L.	I	4	-	-	V	504	V	833
Agrostis gigantea Roth	-	-	III	87	I	21	III	54
Prunella vulgaris L.	-	-	III	312	-	-	-	-
Trifolium pratense L.	-	-	II	12	-	-	-	-
Alopecurus pratensis L.	-	-	-	-	IV	362	V	629

cont. tab. 2 / cd tab. 2

ChO. ***Arrhenatheretalia***								
Galium mollugo L. s. str.	V	546	V	979	V	1396	V	1292
Leontodon autumnalis L.	V	979	V	233	II	50	III	37
Taraxacum officinale F. H. Wigg.	III	46	V	946	V	787	V	367
Arrhenatherum elatius (L.) P. Beauv. ex Presl	II	29	I	4	V	596	V	979
Trifolium repens L.	II	12	II	17	I	25	-	-
Dactylis glomerata L.	-	-	V	229	V	392	V	387
Achillea millefolium L. s. str.	-	-	V	233	III	54	I	25
Lotus corniculatus L.	-	-	II	50	-	-	-	-
Heracleum sphondylium L. s. str.	-	-	-	-	III	92	II	67
ChO. ***Molinietalia***								
Carex panicea L.	III	92	V	2687	-	-	-	-
Deschampsia caespitosa (L.) P. Beauv.	III	71	III	58	I	21	-	-
Lythrum salicaria L.	-	-	III	75	I	4	I	4
Lysimachia vulgaris L.	-	-	II	50	-	-	-	-
ChO. ***Trifolio fragiferae-Agrostietalia stoloniferae***								
Potentilla anserina L.	IV	217	V	942	I	25	II	12
Ranunculus repens L.	III	46	II	29	V	504	V	400
Festuca arundinacea Schreb.	-	-	V	354	III	104	II	12
ChCl. ***Nardo-Callunetea,*** **ChCl** ***Koelerio glaucae-Corynephoretea canescentis***								
Luzula campestris (L.) DC.	V	1250	V	875	I	42	I	21
Viola canina L.	IV	187	V	1667	-	-	-	-
Rumex acetosella L.	III	108	III	46	-	-	-	-
Hieracium pilosella L.	II	29	I	125	-	-	-	-
Hypochoeris radicata L. Commons	-	-	II	83	-	-	-	-
ChCl. ***Scheuchzerio-Caricetea nigrae***								
Carex nigra Reichard	V	875	II	83	-	-	-	-
Carex flava L.	-	-	III	104	-	-	-	-
ChCl. ***Phragmitetea***								
Phalaris arundinacea L.	I	4	III	54	III	646	IV	833
Poa palustris L.	-	-	-	-	IV	137	V	271
ChCl. ***Agropyretea***								
Bromus inermis Leyss.	I	4	V	729	V	2833	V	2729
Agropyron repens (L.) P.B.	-	-	I	42	II	29	-	-
ChCl. ***Artemisietea vulgaris***								
Linaria vulgaris (L.) Mill	III	58	-	-	-	-	-	-
Cirsium arvense (L.) Scop.	-	-	I	25	I	21	-	-
Urtica dioica L.	-	-	-	-	V	646	V	958
Anthriscus sylvestris L.	-	-	-	-	IV	187	V	642
ChCl. ***Stellarietea mediae***								
Viola arvense Murr.	I	4	-	-	I	4	IV	116
Spergula arvensis L.	I	62	-	-	-	-	-	-
Stellaria media (L.) Vill.	-	-	-	-	I	25	III	42
Capsella bursa pastoris (L.) Medik.	-	-	-	-	I	25	II	33
Lamium purpureum L.	-	-	-	-	-	-	II	67
Others								
Cardaminopsis arenosa (L.) Hayek	V	650	III	46	IV	137	V	146
Potentilla norvegica L.	V	92	-	-	-	-	-	-
Veronica chamaedrys L.	II	67	I	8	III	179	II	171
Stellaria graminea L.	I	8	III	58	I	4	I	4
Anthoxanthum odoratum L.	I	42	II	292	-	-	-	-
Veronica arvensis L.	I	8	I	4	III	96	V	142
Fragaria vesca L.	-	-	III	71	-	-	-	-

Source: own study / *Źródło:* opracowanie własne

Sporadically; 0: *Geum riale* L., *Sagina nodosa* L., *Inula britannica* L., *Artemisia vulgaris* L., *Ranunculus flam mula* L., *Carex ovalis* L. Common, *Betula pubescens* Ehrh. (c), *Polygonum persicaria* L., *Rhamnus cathartica* L. (c), K: *Leucanthemum vulgare* Lam., *Trifolium hybridum* L., *Juncus effusus* L., *Equisetum palustre* L., *Filipendula ulmaria* (L.) Abundant, *Onopordum acanthium* L., *Sonchus arvensis* L., *Carex pallescens* L., *Salix cinerea* L. (c), *Polygonum persicaria* L., PK: *Rumex crispus* L., NPK: *Campanula patula* L., *Poa annua* L., *Rumex crispus* L., *Melandrium album* (Mill.) Garcke, *Onopordum acanthium* L., *Rumex obtusifolius* L.

Sporadycznie; 0: Geum riale L., Sagina nodosa L., Inula britannica L., Artemisia vulgaris L., Ranunculus flam mula L., Carex ovalis L. Commons, Betula pubescens Ehrh. (c), Polygonum persicaria L., Rhamnus cathartica L. (c), K: Leucanthemum vulgare Lam., Trifolium hybridum L., Juncus effusus L., Equisetum palustre L., Filipendula ulmaria (L.) Maxim., Onopordum acanthium L., Sonchus arvensis L., Carex pallescens L., Salix cinerea L. (c), Polygonum persicaria L., PK: Rumex crispus L., NPK: Campanula patula L., Poa annua L., Rumex crispus L., Melandrium album (Mill.) Garcke, Onopordum acanthium L., Rumex obtusifolius L.

3.4. Fertilisation

Fertilisation with potassium alone appeared insufficient to maintain productive sward due to a small share of grasses composed mainly of the red fescue (*Festuca rubra* L. s. str.) with less frequent awnless brome (*Bromus inermis* Leyss.). Dicotyledon community was, however, more numerous there than in the variant without fertilisation. Clearly increasing abundance of such species as: the common dandelion (*Taraxacum officinale* F. H. Wigg.), small plantain (*Plantago lanceolata* L.), autumn hawkbit (*Leontodon autumnalis* L.) and common yarrow (*Achillea millefolium* L. s. str.) was noted. Species characteristic for impoverished habitats like: the field wood-rush *(Luzula campestris* (L.) DC.), heath dog-violet (*Viola canina* L.) and carnation sedge (*Carex panicea* L.) – the latter characteristic for semi-natural moist Molinia meadows – had substantial share in species composition. The share of the carnation sedge increased largely after the year 2000.

Grasses dominated on meadows fertilised with phosphorus and potassium (PK) and with nitrogen, phosphorus and potassium (NPK). Yields in NPK variant were largest (7–10 $t{\cdot}ha^{-1}$). The awnless brome (*Bromus inermis* Leyss.) was the dominating species for many years. In the first series of the experiment it was a component of sown mixture; in the second series it appeared spontaneously invading plots since 1981 [8]. The share of the awnless brome in meadow sward before irrigation reached as much as 80% to decrease markedly after soil irrigation in favour of the meadow grass (*Poa pratensis* L. s. str.), which is considered as one of most common grasses on reclaimed peatlands [5, 12]. The raise of ground water table facilitated hydrophytic grass species such as: the reed canary grass (*Phalaris arundinacea* L.), rough blue-grass (*Poa trivialis* L.) and meadow foxtail (*Alopecurus pratensis* L.). Starting from 2000 the encroachment of the tufted grass (*Holcus lanatus* L.) was observed. The species has recently become expansive, especially on extensively used meadows 24]. Other tall and medium size grasses present invariably for many years in communities constituted a small admixture to meadow sward of variants fertilised with PK and NPK. These species included: the tall oat-grass (*Arrhenatherum elatius* (L.) P. Beauv. ex Presl), cock's foot (*Dactylis glomerata* L.), fowl bluegrass (*Poa palustris* L.) and tall fescue (*Festuca arundinacea* Schreb.). From among herb dicotyledons of more common share in meadow sward worth mentioning are: the hedge bedstraw (*Galium mollugo* L. s. str.), common dandelion (*Taraxacum officinale* F. H. Wigg.), common sorrel (*Rumex acetosa* L.) and nitrophilous stinging nettle (*Urtica dioica* L.). The amount of the latter has recently decreased more that twofold compared with previous periods with deeper soil drainage.

3.5. Utility value

Indices of utility value of meadow sward (*Lwu*) differed markedly depending on the type of fertilisation (tab. 3). The lowest values indicating poor utility class were typical for non-fertilised sward (0) and for that fertilised only with potassium (K). Low value of this parameter was evidently affected by substantial share of low sedges and the field wood rush. Exceptional abundance of dicotyledon species (herbs) in sward fertilised with potassium only did not compensate its utility value. For the improvement of palatability and the dietary and health values of animal fodder, 10% share of beneficial herbs is sufficient [25]. Significantly higher numbers of utility value were attributed to sward fertilised with phosphorus and potassium (PK) or with all nutrients (NPK). Good utility class of these meadows, despite minor contribution of legumes, was determined by dominating and co-dominating grass species commonly considered as economically beneficial. Fertilisation with nitrogen under these habitat conditions appeared insignificant for creating utility value of meadow sward.

3.6. Species richness and diversity

Flora of meadows in the fiftieth year of experiment included 80 species of vascular plants. In particular fertilisation variants there were from 41 (PK) to 54 (K) species. The greatest richness and floristic diversity was provided by fertilisation with potassium alone.

Species characteristic for fresh and moist meadows of the class *Molinio-Arrhenatheretea* predominated in the composition of plant communities. Irrespective of fertilisation, they constituted the core of phytocoenoses as in most meadows on reclaimed peatlands [5]. Within the class, more numerous and diverse were the species characteristic for fresh habitats of the order *Arrhenatheretalia* than those characteristic for wet habitats of the order *Molinietalia*. This is evidence that periods of soil drainage prevailed in the long-lasting history of this habitat.

Table 3. Values of selected indices characterising meadow sward
Tab. 3. Wartości wybranych wskaźników charakteryzujące ruń łąkową

Indicator	Fertlisation			
	0	K	PK	NPK
Lwu factor acc. to Filipek	3,8 a	3,6 a	6,5 b	6,7 b
Class of utility value of sward	poor	poor	good	good
Shannon-Wiener diversity index *H'*	2,44	2,90	2,82	2,77
Mean moisture indices (*Lw*)	5,4	5,6	5,5	5,5
Moisture habitat	fresh	fresh	fresh	fresh
Average number of plants per plot	19,2 a	24,9 b	22,2 b	22,9 b
Indices of biological valorisation (*Wwp*):				
- mean for phytosociological relevés	2,2 a	2,1 ab	2,0 b	2,0 b
- for habitats acc. to summary table	2,1	2,2	2,0	1,9
Valorisation class	III	III	III	III

Explanations: a, b – means in rows marked with the same letter do not differ significantly
Objaśnienia: a, b – średnie oznaczone tymi samymi literami nie różnią się istotnie między sobą w wierszach

Source: own study / Źródło: opracowanie własne

Table 4. Share of species characteristic for phytosociological classes in sward of variably fertilised meadows, % of occurrence
Tab. 4. Udział gatunków charakterystycznych dla klas fitosocjologicznych w runi różnie nawożonych łąk, % wystąpień

Phytosociological class	Fertilisation			
	0	K	PK	NPK
Molinio-Arrhenatheretea, including:	59,7	68,3	69,2	61,5
order *Molinietalia*	5,7	11,0	0,8	0,4
order *Arrhenatheretalia*	16,2	23,1	24,1	20,7
order *Trifolio-Agrostietalia*	7,4	9,0	6,7	6,2
Nardo-Callunetea, *Koelerio-Corynephoretea canescentis*	12,7	12,0	0,8	0,4
Scheuchzerio-Caricetea nigrae	5,7	3,0	0	0
Phragmitetea	0,4	1,7	6,0	7,2
Artemisietea	3,1	1,0	7,9	9,1
Stellarietea mediae	0,4	0,3	1,9	8,0
Agropyretea-intermedio repentis	0,5	4,3	5,6	4,4
Other species	17,5	9,4	8,6	9,4
Total	100,0	100,0	100,0	100,0

Source: own study / Źródło: opracowanie własne

Drainage facilitated mineralisation of organic matter, losses of peat mass and led in the long run to drying of these post-bog habitats. These processes were reflected by the increased importance of species characteristic for fresh meadows of the order *Arrhenatheretalia* in meadow sward [11]. The type of fresh habitats is also confirmed by mean moisture indices calculated from phytosociological relevés (tab. 3). Values of these indices were exceptionally equal (5.4 to 5.6 in a 10-grade scale) and did not differ among variably fertilised meadows.

The type of fertilisation modified phytosociological relationships of communities, which manifested itself in the appearance of species characteristic for several other units of the Braun-Blanquet system (tab. 4). Long-lasting lack of fertilisation caused the depletion of nutrients from soil. In the case of potassium fertilisation phosphorus resources were depleted, which favoured less competitive species typical of impoverished habitats. Enough numerous admixtures in sward of these meadows were the species characteristic for species-rich Nardus meadows of the class *Nardo-Callunetea*. Less numerous were species characteristic for xeric sand meadows of the class *Koelerio glaucae-Corynephoretea canescentis.* Despite soil drainage, some bog species characteristic for low sedge communities of the class *Scheuchzerio-Caricetea nigrae* were also present.

Systematic fertilisation with PK and NPK favoured species of fertile habitats. Such species include the reed canary grass (*Phalaris arundinacea* L.) and the fowl bluegrass (*Poa palustris* L.) characteristic for rush communities of the class *Phragmitetea*. Phytocoenoses of these fertilisation variants were distinguished by the admixture of nitrophilous herbs characteristic for ruderal communities of the class *Artemisietea* and annual species characteristic for weed communities of the class *Stellarietea mediae*. Fertilisation with nitrogen, even at small doses, increased synanthropisation of meadow communities.

3.7. Natural values of meadows

Indices of biological valorisation (*Wwp*) calculated for both phytosociological relevés and for plant communities differed slightly among study variants (tab. 3). Slightly higher values of these indices were noted for non-fertilised meadow and for meadow fertilised with potassium alone and smaller for PK and NPK fertilisation. However, according to established limits [17], all indices, despite great floristic diversity, fell within the third class of valorisation, which means low biological value. The evaluation reflected rather poor set of species representing natural flora and a lack of protected and endangered species. More biologically valuable plant species are more frequent in semi-natural meadow communities e.g. in wet meadows of the alliance *Calthion palustris* than in reclaimed peatlands [23].

4. Conclusions

1. Mowing twice meadows on peat-muck soils MtIIc for many years brings about the formation of multi-species plant communities of complex phytosociological relationships. Botanical composition, yield-forming properties and biological values of such meadows depend in principle on the type of applied fertilisation.
2. Several-year-long changes in soil moisture modify botanical composition of meadows but do not affect their economic and biological value.
3. Complete lack of fertilisation for many years results in meadow degradation including the decline of meadow turf. Such grasslands are unsuitable for agricultural purposes and have low biological value.
4. Fertilisation with potassium is insufficient for providing satisfactory productive values but increases species richness and diversity of meadows through their enrichment in species typical of semi-natural communities.
5. Under the conditions of peat-muck soils, a phosphorus-potassium fertilization is an important factor in improving the economic value of meadows, productive potential of such meadows is high, utility value of sward is good which does not interfere with their biological values.
6. Fertilisation of meadows situated on peat-muck soils (MtIIc) with nitrogen is justified only at a high level of ground water and aimless at deep drainage.
7. Nitrogen from fertilisers at variable soil moisture conditions slightly increases the productive potential but facilitates synanthropisation of plant communities and decreases biological values of grasslands.

5. References

[1] Barszczewski J., Sapek B.: Changes in botanical composition of sward of permanent meadow due to liming and ammonium and calcium nitra te fertilisation. Journal of mountain agriculture on the Balkans, 2010, Vol. 13, No 1, 236-243.

[2] Barszczewski J., Szatyłowicz M.: Gospodarka azotem w warunkach zróżnicowanego nawożenia łąki na glebie torfowo-murszowej. Woda Środowisko Obszary Wiejskie, 2011, T. 11, Z. 3 (35), 7-19.
[3] Barszczewski J., Wolicka M., Burs W.: Dynamic of chan ges in botanical composition of meadow sward in conditions of differentiated fertilisation and optima moisture. Permanent and Temporary Grassland Plant, Environment and Economy, 2007, Vol. 12, 114-117.
[4] Baryła R.: Zmienność plonowania łąk na glebach organicznych w warunkach zróżnicowanego wieloletniego nawożenia azotem. Wiadomości IMUZ, 1992, t. 17 z. 2, 297-308.
[5] Baryła R., Kulik M.: Zmiany składu gatunkowego runi w warunkach wieloletniego użytkowania łąk pobagiennych w rejonie kanału Wieprz-Krzna. Woda Środowisko Obszary Wiejskie, 2011, T. 11 z. 4 (36), 7-18.
[6] Doboszyński L.: Nawożenie użytków zielonych w świetle prac polskich. Bibl. Wiad. IMUZ, 1996, Nr 88.
[7] Filipek J.: Projekt klasyfikacji roślin łąkowych i pastwiskowych na podstawie liczb wartości użytkowej. Postępy Nauk Rolniczych, 1973, 4/141, 59-68.
[8] Gotkiewicz J., Gotkiewicz M.: Dynamika plonowania oraz jakość plonów z łąk wieloletnich doświadczeń. W: Wyniki 25-letniego stałego doświadczenia nad porównaniem wpływu sposobu użytkowania i nawożenia na glebę torfową w Zakładzie Doświadczalnym Biebrza. Bibl. Wiad. IMUZ, 1987, Nr 68, 155-177.
[9] Gotkiewicz J., Szuniewicz J.: Kształtowanie się stosunków powietrzno-wodnych w wierzchniej warstwie gleb torfowo-murszowych wieloletnich doświadczeń. Bibl. Wiad. IMUZ, 1987, Nr 68.
[10] Kamiński J., Szymanowski M.: Wpływ nawożenia mineralnego na plonowanie, skład florystyczny i walory przyrodnicze łąk na glebie torfowo-murszowej w świetle wyników wieloletniego doświadczenia. Woda Środowisko Obszary Wiejskie, 2007, T. 7, Z. 2a (20), 191-208.
[11] Kiryluk A.: Proces grądowienia w pobagiennych ekosystemach łąkowych. Woda Środowisko Obszary Wiejskie, 2009, T. 9. Z. 4(28), 59-69.
[12] Łękawska I:. Wpływ zróżnicowanych dawek nawożenia azotem na skład gatunkowy runi łąk położonych na różnych glebach torfowo-murszowych. Wiadomości IMUZ, 1989, t. 16, z. 2, 43-56.
[13] Łękawska I., Szuniewicz K.: Wpływ nawożenia potasem i sodem łąk na glebach torfowo-murszowych na plony i skład botaniczny runi. Roczniki Nauk Rolniczych, 1988, S. F T. 80, Z. 2-4, 353-372.
[14] Matuszkiewicz W.: Przewodnik do oznaczania zbiorowisk roślinnych Polski, Warszawa: Wydaw. Nauk. PWN, 2005. ISBN 83-01-14439-4.
[15] Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M.: Flowering plants and pteridophytes of Poland. A checklist, 2002, Kraków, W. Szafer Institute of Botany PAS. ISBN 83-85444-83-1.
[16] Okruszko H., Sapek B.: Zasobność gleb torfowych składniki mineralne w aspekcie zasad nawożenia. W: Gospodarowanie na glebach torfowych w świetle 40-letniej działalności Zakładu Doświadczalnego Biebrza. Bibl. Wiad. IMUZ, 1991, Nr 77, 79-86.
[17] Oświt J.: Metoda przyrodniczej waloryzacji mokradeł i wyniki jej zastosowania na wybranych obiektach. Materiały Informacyjne, Falenty: Wydaw. IMUZ, 2000, Nr 35. ISSN 08060-1410.
[18] Oświt J.: Identyfikacja warunków wilgotnościowych w siedliskach łąkowych za pomocą wskaźników roślinnych. W: Hydrogeniczne siedliska wilgotnościowe. Bibl. Wiad. IMUZ, 1992, Nr 79, 39-67.
[19] Pawłowski B.: Skład i budowa zbiorowisk roślinnych oraz metody ich badania. W: Szata roślinna Polski. T. 1. Red. W. Szafer, K. Zarzycki, Warszawa: PWN, 1977, 237-269.
[20] Rozporządzenie MRiRW z dnia 26 lutego 2009 r. w sprawie szczegółowych warunków i trybu przyznawania pomocy finansowej w ramach działania ,,Programu rolnośrodowiskowego objętego Programem Rozwoju Obszarów Wiejskich na lata 2007-2013". Dz. U. 2009, Nr 33 poz. 262 z późn. zm.
[21] Sapek B., Barszczewski J.: Characteristic of long-term meadow experiments in Janki and Laszczki; a description of the sites, soils, treatment and some results. W: Effects of liming and nitrogen fertilizers application on soil acidity and gaseous nitrogen oxide emissions in grassland system. Wydaw. IMUZ, 2000, 14-24.
[22] Szafer W., Kulczyński S., Pawłowski B.: Rośliny polskie. T. 1 i 2. Warszawa: PWN, 1988. ISBN 83-01-05287-2.
[23] Trąba Cz., Wolański P.: Zróżnicowanie florystyczne łąk związków *Calthion* i *Alopecurion* w Polsce – zagrożenia i ochrona. Woda Środowisko Obszary Wiejskie, 2011, T. 11, z. 1 (33), 299-313.
[24] Wolański P., Trąba Cz.: Skład florystyczny i wartość pokarmowa runi ekstensywnych łąk kosówkowych na pogórzu Dynowskim. Fragmenta Agronomia, 2010, vol. 27 No 4, 161-168.
[25] Wolański P., Trąba Cz., Rogut K.: Występowanie oraz wartość paszowa ziół i runi łąkowej z ich udziałem na pogórzu Dynowskim. Woda Środowisko Obszary Wiejskie, 2015, T. 15, z. 3 (51), 127-144.