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# THE EFFECT OF VARIOUS WAYS OF FERTILISATION ON YIELDS AND POTASSIUM AND MAGNESIUM CONTENT IN MEADOW SWARD ON PEAT-MUCK SOIL

*Summary*

*Productive effects and potassium and magnesium cycling in relation to the ways of fertilisation of permanent meadow on peat-muck soil were tested in field experiment in the years 2006-2009. Due to progressing soil mineralization and nitrogen release, fertilisation with only phosphorus and potassium (P-30 and K-60 kg·ha$^{-1}$) was applied at the first level of fertilisation. Complete fertilisation (P-30, K-60 and N-60 kg ha$^{-1}$) was also applied at this level. Fertilisation at the second level included P-45, K-90 and N-90 kg·ha$^{-1}$. Apart from mineral fertilisation, two levels of manure and liquid manure fertilisation were applied considering the content of particular nutrients and equivalents of their utilisation. Phosphorus deficits were supplemented with mineral forms of the element. Potassium was introduced with fertilisers in large amounts and organic fertilisers contained substantial amounts of magnesium – from 27 to 41 kg ha$^{-1}$ delivered in manure and from 6 to 9 kg ha$^{-1}$ in liquid manure. Peat-muck soil gave relatively large yields exceeding 6 t ha$^{-1}$ of dry mass from PK variant. Complete NPK fertilisation, irrespective of the form, did not always increase the yields. Organic fertilisation usually increased the content of potassium in meadow sward. Despite high magnesium input with fertilisers, the content of this element did not always increase in meadow sward.*
***Key words**: peat-muck soil, fertilisation, meadow sward, potassium content, magnesium content*

# WPŁYW RÓŻNYCH SPOSOBÓW NAWOŻENIA NA PLONY ORAZ ZAWARTOŚCI POTASU I MAGNEZU W RUNI ŁĄKOWEJ W WARUNKACH GLEBY TORFOWO-MURSZOWEJ

*Streszczenie*

*Na łące trwałej w warunkach gleby torfowo-murszowej w badaniach z okresu 2006-2009 na doświadczeniu łanowym porównano efekty produkcyjne oraz gospodarkę potasem i magnezem w stosowanych sposobach jej nawożenia. Ze względu na postępującą mineralizację tej gleby i uwalnianie azotu, stosowano nawożenie wyłącznie fosforowo-potasowe na poziomie P-30 i K-60 kg·ha$^{-1}$. Na bazie takiego nawożenia (P i K) również nawożono azotem na jego pierwszym poziomie N-60 kg·ha$^{-1}$. Na drugim poziomie nawożenia azotem odpowiednio stosowano P-45, K-90 oraz N-90 kg·ha$^{-1}$. Tak jak w nawożeniu mineralnym stosowano również dwa poziomy nawożenia obornikiem i gnojowicą bydlęcą uwzględniając zawartości w nich poszczególnych składników oraz równoważniki wykorzystania z nich azotu, fosforu i potasu, niedobory zwłaszcza fosforu uzupełniano formami mineralnymi. Wraz z nawożeniem wnoszono duże ilości potasu a nawozy naturalne wnosiły również znaczne ilości magnezu od około 27 do 41 kg·ha$^{-1}$ w oborniku a w gnojowicy odpowiednio od 6 do 9 kg·ha$^{-1}$. W warunkach gleby torfowo-murszowej uzyskiwano dość wysokie plony na poziomie powyżej 6 t·ha$^{-1}$ s.m. na obiekcie fosforowo-potasowym (PK), kompleksowe nawożenie NPK niezależnie od formy nawozów nie zawsze wykazywało wyraźny ich wzrost. Nawozy naturalne w znacznej większości powodowały wzrost zawartości potasu w runi łąkowej, lecz mimo znacznego wnoszenia magnezu nie zawsze notowano wyraźny wzrost tego składnika.*
***Słowa kluczowe**: gleba torfowo-murszowa, nawożenie, ruń łąkowa, zawartość potasu, zawartość magnezu*

## 1. Introduction and aim of the study

Large animal stock in many farms specialising in cattle breeding raises the interest in fertilisation of permanent grasslands, including those on peat-muck soils, with organic fertilisers. Many authors: [3, 8, 10, 13] underline good points of these fertilisers, which consist in improving species composition of meadow sward, increasing yields or enriching soils in macro- and microelements. Fertilisation with organic fertilisers, especially with manure, of meadows on peat-muck soils, usually deficient in phosphorus and potassium [11], may substantially supplement deficits and increase yields [7, 11, 13]. Turnover of magnesium and potassium in soil and sward depends largely on soil richness [7] and fertilisation [2, 12, 16]. Fertilisation with manure [9] or liquid manure [3], apart from other nutrients, delivers magnesium and supplements its deficits in soils. Improper fertilisation [10] especially with potassium-rich organic fertilisers may result in exceeding the optimum content of potassium in fodder [15] limiting thus the availability of magnesium to plants [2]. Optimum magnesium concentration in fodder should vary between 2 and 3 g kg$^{-1}$ [5, 6, 14, 15]. It is the concentration of potassium and its changes that govern the K:Mg ratio [12, 14], whose optimum according to Czuba and Mazur [4] is 6 but other authors [5, 12, 14] report the value of 8.3.

The aim of this study was to analyse the effect of various types and intensity of fertilisation on meadow yielding, soil richness in potassium and magnesium and the content of these elements in meadow sward.

## 2. Material and methods

Studies were carried out in the years 2006–2009 in the Experimental Farm Biebrza on permanent meadow situated on peat-muck soil. The effects of fertilisation with mineral

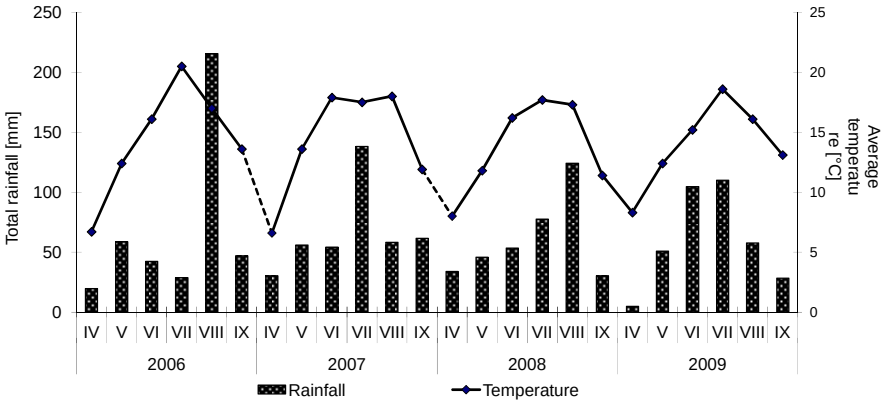
(PK and NPK) and organic (manure and liquid manure) fertilisers were compared. The following fertilisation variants were applied: PK – 30 kg P and 60 kg K·ha$^{-1}$, NPK/I – 60 kg N·ha$^{-1}$ and P and K in the same amounts as above, NPK/II – 90 kg N, 45 kg P and 90 kg K·ha$^{-1}$, O/I – manure 15–20 t·ha$^{-1}$ (the amount of nutrients comparable with the NPK/I variant), O/II – manure 22.5–30.0 t·ha$^{-1}$ (the amount of nutrients comparable with the NPK/II variant), G/I – liquid manure 25–35 m$^3$·ha$^{-1}$, G/II – liquid manure 37.5–52.5 m$^3$·ha$^{-1}$ (the amount of nutrients comparable with NPK/I and NPK/II, respectively). Mineral fertilisation was applied in a form of ammonium saltpetre at 1/3 of the annual dose under each cut, phosphorite flour applied in spring and potassium sulphate in three equal doses in spring and after the 1st and 2nd cut. Manure was spread once in autumn using manure spreader. Liquid manure was applied by splashing in two equal doses in spring and after the 1st cut. Doses of manure and liquid manure were estimated based on their nitrogen concentration and on respective equivalents of its use (0.5 for manure and 0.7 for liquid manure). The equivalent for phosphorus was 1 in both organic fertilisers and that for potassium was 0.7 in manure and 0.8 in liquid manure. Phosphorus deficits in liquid manure were supplemented with phosphorite flour. Five 25 m$^2$ plots were established on meadows of an area of 0.3 ha to assess the yields and to take samples of soil and vegetation. Meadows were mown three times a year and samples of sward were mineralized in sulphuric acid and hydrogen peroxide. Analyses were made in a through-flow analyser. Results of the dry mass yields and concentrations of nitrogen, magnesium and potassium in meadow sward were statistically processed with the Statistica software using the least significant difference at $\alpha = 0.05$.

## 3. Results and discussion

Weather conditions, i.e. monthly mean air temperature and rainfall in compared vegetation seasons (fig. 1) did not vary much. The lowest temperature of about 7°C was noted in April and raised to about 20°C in July or August. Monthly sums of precipitation varied from 20 mm to slightly more than 50 mm. The largest rainfalls were recorded in August 2006 and 2008, in July 2007 and in June and July 2009.

Soils were rich in available forms of magnesium (tab. 1) in the beginning of the experiment (in 2006). A higher richness of this element, especially in the upper soil layer (0-10 cm), was found in plots NPK/I, O/I and O/II. Lower soil layer tended to be richer in magnesium in plots NPK/I oraz O/I.

After four years of experiment, soil richness in magnesium decreased in most variants, especially in the 0-10 cm soil layer.




*Source:* own work / *Źródło:* opracowanie własne

Fig. 1. Temperature and rainfall in vegetation seasons of the study years
*Rys. 1. Przebieg temperatury oraz opadów w sezonach wegetacyjnych w latach badań*

Table 1. The content of available forms of magnesium and potassium in soils determined in 0.5 M HCl solution (g·ha$^{-1}$)
*Tab. 1. Zasobności przyswajalnych form magnezu oraz potasu w glebie oznaczanych w 0,5 M HCl (g·ka$^{-1}$)*

| Component | Years | Layer | PK | NPK/I | O/I | G/I | NPK/II | O/II | G/II |
|---|---|---|---|---|---|---|---|---|---|
| Magnesium | 2006 | 0-10 | 0,87 | 1,30 | 1,20 | 0,97 | 0,68 | 1,15 | 0,73 |
| | | 10-20 | 0,56 | 1,05 | 0,80 | 0,72 | 0,60 | 0,71 | 0,61 |
| | 2009 | 0-10 | 0,82a | 1,18b | 1,13ab | 0,92a | 0,74a | 1,06ab | 0,71a |
| | | 10-20 | 0,68ab | 1,14b | 0,82ab | 0,72ab | 0,59a | 0,67a | 0,53a |
| Potassium | 2006 | 0-10 | 0,20 | 0,18 | 0,29 | 0,21 | 0,24 | 0,25 | 0,28 |
| | | 10-20 | 0,09 | 0,17 | 0,21 | 0,09 | 0,14 | 0,12 | 0,14 |
| | 2009 | 0-10 | 0,18 | 0,17 | 0,24 | 0,19 | 0,018 | 0,21 | 0,14 |
| | | 10-20 | 0,14 | 0,11 | 0,13 | 0,10 | 0,08 | 0,11 | 0,10 |

*Source:* own work / *Źródło:* opracowanie własne

Distinct increase in magnesium in soil was found in variants fertilised with manure. Despite clear trend of decreasing magnesium content in soils, its highest concentration in both upper and lower soil layer was noted in variant NPK/I compared with other variants.

Soil richness in potassium in the upper soil layer differed from very low in PK, NPK/I, G/I and NPK/II variants to low in other variants with a distinct tendency of increasing potassium concentration. In the lower soil layer, much smaller richness in potassium was noted in all variants with slightly higher potassium concentration in variant O/I. Four-year period of diverse fertilisation and harvesting did not increase soil richness in potassium but resulted rather in its decrease in the upper soil layer of all variants and in lower soil layer of most variants. Fertilisation with organic fertilisers of those potassium-deficient soils only slightly decreased the dynamics of decreasing potassium content in soils, which was also reported in the literature [1, 7, 11].

Annual yields of dry mass from particular variants in 2006 differed markedly (tab. 2). Compared with other variants, the highest yield was obtained in variant NPK/II. Significantly higher yields were obtained in variants G/I and O/II than in PK and G/II. In 2007 significantly higher yields were obtained in both variants fertilised with mineral fertilisers (NPK/I and NPK/II) and manure (O/I) than in variant PK. Yield from both variants fertilised with liquid manure (G/I and G/II) were significantly higher compared with other variants. In 2008 meadow yields were more uniform than before and significantly higher yields were found in variants O/I, O/II and G/I than in PK. In 2009, variants NPK/II, O/I, O/II and G/II gave significantly higher yields than the PK variant. Yields of plots fertilised with organic fertilisers (O/I and O/II) were higher than those obtained from the NPK/II variant. Higher yields of dry mass obtained from most plots fertilised with organic fertilisers confirm the conclusions of many authors [7, 8, 10, 11, 13], who underlined doubtless advantages of these fertilisers.

Magnesium concentration in meadow sward of particular plots (tab. 3) in the first study year (2006) fell within the optimum range and did not differ among each other. In the next year magnesium concentration increased in sward from all study variants. The lowest concentration of magnesium was found in sward from variant PK and significantly higher in NPK/I. The highest concentration was found in sward from variant O/II, which was higher than in sward from variants PK and G/II. In the third study year further increase in magnesium concentration of meadow sward was noted in variants O/II, O/I and NPK/II. As in the year before, the lowest concentration of magnesium was found in sward from variant PK and significantly higher – in variant G/I. Significantly highest magnesium concentrations were found in sward from variants NPK/II and O/I. This increasing trend of magnesium concentration in sward repeated in some variants in the last study year. The lowest concentrations of magnesium were noted in variants NPK/I and G/I, slightly higher in sward from variant PK and NPK/II and significantly highest in variant O/II. Organic fertilisers, especially manure, caused marked increase of magnesium concentration in dry mass of meadow sward as it was also demonstrated in many other studies [3, 9, 15, 16].

Potassium concentrations in meadow sward in particular variants in 2006 (tab. 4) were within the optimum limits. The lowest concentration of potassium was noted in sward from variant NPK/II, higher in variants NPK/I, O/I, G/I and significantly highest in O/II, G/II. In the second study year (2007) an increase of potassium concentration was noted in all variants, especially in those fertilised with organic fertilisers. As before, the lowest concentration of potassium was found in sward from variant NPK/II and significantly higher in variants O/I, G/I, O/II and G/II. In both variants of more intense fertilisation (O/II and G/II), potassium concentration in sward was higher than in O/I. In 2008 potassium concentration was lowest in variants NPK/II and PK and slightly higher in NPK/I. Compared with the two former variants, potassium concentration in sward was higher in variants O/I, G/I, O/II and G/II. As before, sward from variants O/II and G/II contained more potassium than that from variant O/I. In the fourth study year, potassium concentration in sward from variants NPK/II and PK was lowest. Significant increase of potassium concentration in meadow sward was noted in variants O/I and O/II compared with other variants. Potassium concentration in O/II was higher than that in O/I.

Table 2. Annual dry mass yields from particular variants ($t \cdot ha^{-1}$)
*Tab. 2. Roczne plony suchej masy z poszczególnych obiektów ($t \cdot ha^{-1}$)*

| Years | PK | NPK/I | O/I | G/I | NPK/II | O/II | G/II |
|---|---|---|---|---|---|---|---|
| 2006 | 6,56a | 7,52ab | 7,55ab | 8,18b | 9,88c | 8,39b | 6,58a |
| 2007 | 5,87a | 7,18b | 7,24b | 8,68cd | 7,06b | 7,58bc | 9,74d |
| 2008 | 7,21a | 8,14ab | 8,72b | 8,60b | 8,16ab | 8,70b | 8,16ab |
| 2009 | 6,17a | 6,12a | 9,02cd | 6,97ab | 7,81bc | 10,02d | 8,05bc |

*Source:* own work / *Źródło:* opracowanie własne

Table 3. Mean magnesium concentration in meadow sward in the study period ($g \cdot kg^{-1}$)
*Tab. 3. Średnie zawartości magnezu w runi łąkowej w okresie badań ($g \cdot kg^{-1}$)*

| Years | PK | NPK/I | O/I | G/I | NPK/II | O/II | G/II |
|---|---|---|---|---|---|---|---|
| 2006 | 2,54 | 2,47 | 2,27 | 2,56 | 2,70 | 2,30 | 2,48 |
| | insignificant | insignificant | insignificant | insignificant | insignificant | insignificant | insignificant |
| 2007 | 2,89 | 3,49 | 3,30 | 3,37 | 3,30 | 3,71 | 3,10 |
| | a | bc | abc | abc | abc | c | ab |
| 2008 | 2,87 | 2,97 | 3,51 | 3,30 | 3,75 | 4,08 | 3,00 |
| | a | ab | cd | bc | de | e | ab |
| 2009 | 3,22 | 3,07 | 4,17 | 3,07 | 3,57 | 4,88 | 4,07 |
| | a | a | ab | ab | a | b | ab |

*Source:* own work / *Źródło:* opracowanie własne

Table 4. Mean concentrations of potassium in meadow sward in the study period ($g \cdot kg^{-1}$)
*Tab. 4. Średnie zawartości potasu w runi łąkowej w okresie badań ($g \cdot kg^{-1}$)*

| Years | PK | NPK/I | O/I | G/I | NPK/II | O/II | G/II |
|---|---|---|---|---|---|---|---|
| 2006 | 16,62 | 17,79 | 17,72 | 19,23 | 13,34 | 20,19 | 20,36 |
| | ab | bc | bc | bc | a | c | c |
| 2007 | 18,87 | 21,18 | 22,73 | 27,4 | 17,61 | 31,21 | 27,90 |
| | ab | ab | bc | cd | a | d | d |
| 2008 | 15,62 | 16,03 | 18,46 | 20,93 | 14,82 | 25,58 | 24,37 |
| | a | ab | bc | cd | a | d | d |
| 2009 | 15,45 | 16,94 | 25,00 | 18,35 | 15,36 | 35,15 | 22,07 |
| | a | ab | b | ab | a | c | ab |

*Source:* own work / *Źródło:* opracowanie własne

Table 5. K:Mg ratios in meadow sward during the study period
*Tab. 5. Stosunki jonowe K:Mg w runi łąkowej w okresie badań*

| Years | PK | NPK/I | O/I | G/I | NPK/II | O/II | G/II |
|---|---|---|---|---|---|---|---|
| 2006 | 6,54 | 7,20 | 7,81 | 7,51 | 4,94 | 8,78 | 8,21 |
| 2007 | 6,53 | 6,07 | 6,89 | 8,13 | 5,34 | 8,41 | 9,00 |
| 2008 | 5,44 | 5,40 | 5,26 | 6,34 | 3,95 | 6,27 | 8,12 |
| 2009 | 4,80 | 5,52 | 6,00 | 5,98 | 4,30 | 7,20 | 5,42 |

*Source:* own work / *Źródło:* opracowanie własne

Potassium concentrations in meadow sward at the first level of fertilisation with organic fertilisers did not exceed optimum thresholds [1, 4, 12], which was, however, possible at the second level of fertilisation.

K:Mg ratios in meadow sward (tab. 5) noted in most meadow swards in the first study year exceeded 6 adopted as the optimum by Czuba and Mazur [4] and in some variants, particularly those fertilised with organic fertilisers, were close to 8.3 adopted as the optimum by other authors [5, 12]. Clear narrowing of the range of ionic ratios below the optimum was noted in the first and the next study years in variant NPK/II. In 2007 distinct broadening of the ionic ratio was found in variant G/II. In the third and fourth study year a remarkable increase in magnesium in meadow sward significantly narrowed K:Mg ionic ratios. As seen from performed studies, ionic ratios are determined not only by potassium concentration [12, 16] but they may also be narrowed by higher magnesium in sward due to high magnesium and low potassium concentrations in soil.

## 4. Conclusions

1. Fertilisation with organic fertilisers markedly affecting yields indicates better use of nutrients than that with mineral fertilisers.
2. Fertilisation with organic fertilisers, especially with manure, of magnesium-rich peat-muck soil resulted in the increase of magnesium content in meadow sward above its optimum level.
3. Optimum potassium content in meadow sward maintained in subsequent study years at increasing magnesium concentrations resulted in the narrowing of ionic ratios K:Mg below the optimum.

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