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BALANCE OF NITROGEN IN GROWING GRASS UNDER FIELD CONDITIONS DEPENDING ON THE SPECIES AND NITROGEN FERTILIZATION

Summary

The field experiment with three species of grasses in different water conditions was carried out in 2005-2008 in the experimental fields in Złotniki near Poznań, a subsidiary of Experimental- Educational Laboratory for Soil and Plant Cultivation, University of Life Sciences in Poznań. The aim of the study was to elaborate a nitrogen balance, using common indicators of uptake and based on laboratory confirmed nitrogen content in plant material. On this basis, both developed balances were confronted. In conducted study it was found that the calculation of the amount of nitrogen taken with the use of generally accepted factors was understated in relation to the actual uptake. In the option with sprinkling irrigation, regardless of species, the applied dose of 180 kg of nitrogen was almost entirely used by plants, but in the option without sprinkling irrigation, nitrogen balance was obtained after the application of about 120 kg N ha^{-1}.
Key words*: nitrogen balance, grasses, sprinkling irrigation*

BILANS AZOTU W UPRAWIE TRAW W WARUNKACH POLOWYCH W ZALEŻNOŚCI OD GATUNKU I NAWOŻENIA AZOTEM

Streszczenie

Doświadczenie polowe, z trzema gatunkami traw w zróżnicowanych warunkach wodnych: w wariancie deszczowanym i niedeszczowanym, przeprowadzono w latach 2005-2008 na polach doświadczalnych w Złotnikach koło Poznania, filii Zakładu Doświadczalno-Dydaktycznego Uprawy Roli i Roślin Uniwersytetu Przyrodniczego w Poznaniu. Celem przeprowadzonych badań było opracowanie bilansu azotu, z wykorzystaniem powszechnie stosowanych wskaźników pobrania oraz na podstawie zawartości azotu w materiale roślinnym oznaczonej laboratoryjnie. Na tej podstawie skonfrontowano obydwa opracowywane bilanse. W przeprowadzonych badaniach stwierdzono, że obliczenie ilości pobranego azotu przy pomocy powszechnie przyjętych współczynników było zaniżone w stosunku do pobrania rzeczywistego. W wariancie deszczowanym, niezależnie od gatunku, zastosowana dawka 180 kg azotu, praktycznie w całości została wykorzystana przez rośliny, natomiast w niedeszczowanym, zbilansowanie azotu uzyskiwano po zastosowaniu około 120 kg N·ha^{-1}.
Słowa kluczowe*: bilans azotu, trawy, deszczowanie.*

1. Introduction

Intensification of agricultural technology and, in particular, mineral fertilization, affects the circulation of nutrients, and thus the soil environment.

In Poland, the majority of the soils are light, characterized by low content of humus and floating particles as well as high permeability. Under these conditions, balancing of nutrients is particularly difficult.

Among the elements brought into the soil, the biggest threat comes from nitrogen which is a serious danger to the environment, thus contributing, inter alia, to eutrophication [5]. Rational fertilization can limit this negative impact, reducing losses caused among others by washing.

Legal acts, which result in limiting the negative impact, include implemented in 1991 so-called The Nitrates Directive [4] and others [11, 12, 13, 14]. Poland, as a member of the OECD, is committed to an annual compilation of the balance of nitrogen, and since 2002 also to prepare the balance of phosphorus [9].

One of the methods for identification of potential risks to the environment from agricultural practice is to determine the balance of fertilizing components.

The aim of the study was to develop nitrogen balance, depending on nitrogen fertilization under different water conditions, which determine the yielding of grass. In addition, an attempt was made to confront the balance developed with the use of indicators of uptake provided by Łabętowicz [10] with the actual uptake calculated on the basis of performed laboratory analyses.

2. Material and methods

The field experiment was carried out in 2002-2005 in the experimental fields in Złotniki near Poznan, a subsidiary of Experimental- Educational Laboratory for Soil and Plant Cultivation, University of Life Sciences in Poznań. They were implemented in a static four-field crop rotation: maize, barley, grass, grass. It was a three-factor experiment, in a "split-split-plot" arrangement in which two water variants (with and without sprinkling irrigation) were the first row factor and the second row - three species of grasses (ryegrass hybrid - variety 'Trogres', Italian ryegrass - variety' Mitos ', orchard grass - variety' Krysta "). Third row factor refers to nitrogen fertilization; the doses were 0, 60, 120 and 180 kg kg N·ha^{-1}. As a nitrogen fertilizer, ammonium nitrate was used. It was used in three periods: spring, after the start of vegetation and post-harvest, after the second and third cut. Each time one third of the dose was used which means respectively 0, 20, 40 and 60 kg N·ha^{-1}. Before sowing triple superphosphate and potassium salt were applied. Used fertilizers gave the following amounts of pure ingredients: 34.9 kg P and 83.0 kg K.

The experimental field was characterized by a high abundance of available forms of phosphorus, average source of potassium and high magnesium content. The soil is classified as an experimental field for quality class IVb, and in terms of agricultural suitability to good rye complex.

Nutrient uptake was calculated based on the obtained yields and the average content of this component in the dry matter [10] and based on the laboratory determined nitrogen content for each combination. Nitrogen balance was calculated by deducting from the amount of nitrogen brought in mineral fertilizers the nitrogen taken in the yield from the field.

The years of research were characterized by high volatility of hydrothermal conditions (Table. 1). The system of weather conditions in the years of research was very diverse. In all the years of research during the growing season there were generally higher air temperatures in relation to the average temperature of the multi-year period. The year 2004 was especially dry, the rainfall in April and May amounted only to 9.0 and 4.9 mm, and in the period of April-August its sum was only 93.7 mm, comparing with a long-term average for this period amounting to 265.8 mm. Significant rainfall shortages occurred also in 2003. Water shortages were supplemented by using sprinkling irrigation. Irrigation was not used during the first regrowth. During this period, there were adequate supplies of winter water. Each year, three swaths were collected, and the results are based on the synthesis of four years of research.

3. Results

In the four-year study period, the examined grass species were characterized by different yielding potential. Under conditions without nitrogen fertilization, tested grass species yielded similarly. Increase in nitrogen fertilization resulted in significant growth in the yield of green matter, which was the greatest in the case of hybrid ryegrass. In both variants of aquatic conditions, this species had the best yields. The yields of other species were smaller and did not differ from each other. The impact of sprinkling irrigation on the yield of grasses and nitrogen uptake was presented in Fig. 1, and corresponding regression equation in Table 2. Yield-forming influence of sprinkling irrigation on grass yielding used to grow with increasing nitrogen fertilization is presented in the Fig. 1.

Single uptake of nitrogen, regardless of species, was higher in the variant without sprinkling irrigation and the tested varieties did not differ from one another in this regard. The nitrogen content in dry matter, regardless of the species, grew up with increasing fertilization. The amount of taken nitrogen is thus the result of the interaction of the water variant and nitrogen fertilization. The amount of taken nitrogen, regardless of the method of calculation, was the biggest in hybrid ryegrass and the smallest in Italian ryegrass. The amount of nitrogen calculated on the basis of the results of laboratory analysis, as compared to the calculation on the basis of individual tabulated uptake, was always higher. These differences deepened with increasing nitrogen fertilization (Fig. 1).

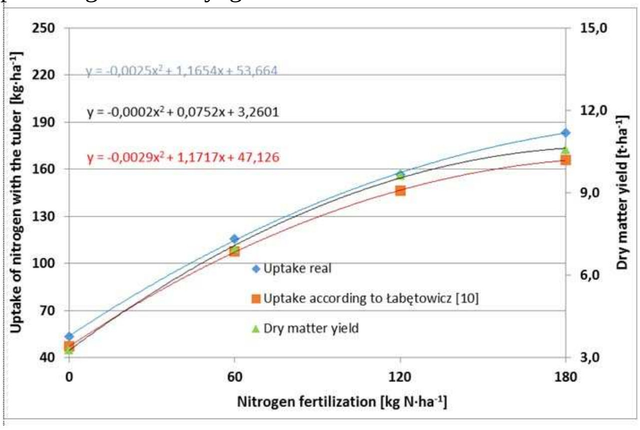
In a variant with sprinkling irrigation, the use of even the largest doses of nitrogen was safe for the environment and irrespective of the method of calculating nitrogen uptake, balance at 180 kg N·ha^{-1} was close to zero (Italian ryegrass and orchard grass) or a negative in hybrid ryegrass. In a variant without sprinkling irrigation, regardless of the species, nitrogen balance in growing Italian ryegrass and orchard grass was obtained on the objects fertilized with a dose of about 120 kg N·ha^{-1}, and in the case of hybrid ryegrass at the highest dose - 180 kg N·ha^{-1}. Increasing nitrogen fertilization in the case of Italian ryegrass and orchard grass up to 180 kg N·ha^{-1}resulted in a positive net balance, however, this surplus in extreme cases did not exceed 60 kg N·ha^{-1}. Differences in nitrogen balance made with comparable methods of calculation, in the variant without sprinkling irrigation compared to the option including irrigation, were lower (Fig. 2).

Table 1. Average temperatures and sum of rainfall in Experimental Station at Złotniki
Tab. 1. Średnie temperatury oraz sumy opadów w Stacji Doświadczalnej w Złotnikach

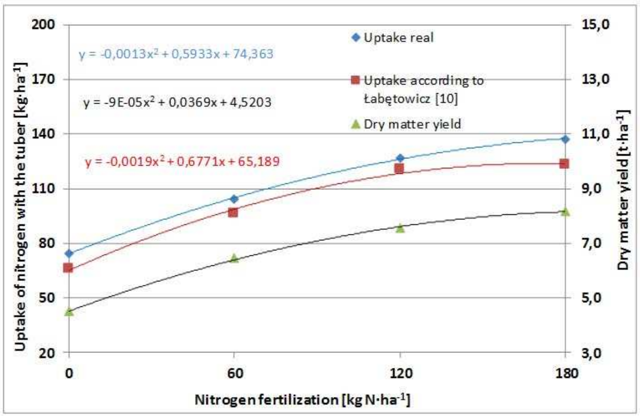
Month	Air temperature (^{o}C)					Rainfall (mm)				
	average of month					average of month				
	2002	2003	2004	2005	**1951-2005**	2002	2003	2004	2005	**1951-2005**
I	1,5	-1,4	-3,2	2,3	**-1,4**	34,2	48,0	5,2	33,9	**28,9**
II	5,1	-2,1	2,3	-0,9	**-0,4**	67,2	7,0	1,5	51,1	**27,2**
III	3,8	4,9	5,7	2,6	**3,3**	57,0	12,0	12,4	36,7	**30,0**
IV	10,7	10,2	11,4	11,6	**8,5**	37,0	24,0	9,0	20,5	**31,3**
V	19,2	18,0	14,1	14,7	**14,2**	69,0	20,0	4,9	71,3	**48,0**
VI	19,8	21,1	17,5	18,5	**17,4**	48,0	27,0	28,2	14,2	**57,8**
VII	22,2	21,7	19,6	21,3	**19,1**	26,0	85,0	11,2	88,2	**74,5**
VIII	23,7	22,0	21,2	19,1	**18,4**	70,0	8,9	40,4	49,7	**54,2**
IX	15,9	16,5	15,9	17,8	**13,8**	45,0	21,8	24,5	27,8	**45,8**
X	7,3	6,5	11,1	12,0	**9,1**	91,0	30,4	14,7	6,7	**34,8**
XI	4,1	6,1	4,7	4,0	**3,7**	46,0	18,5	20,8	13,3	**34,7**
XII	-2,7	2,0	2,2	0,7	**0,1**	23,0	35,0	21,0	71,5	**39,0**

Source: own work / Źródło: opracowanie własne

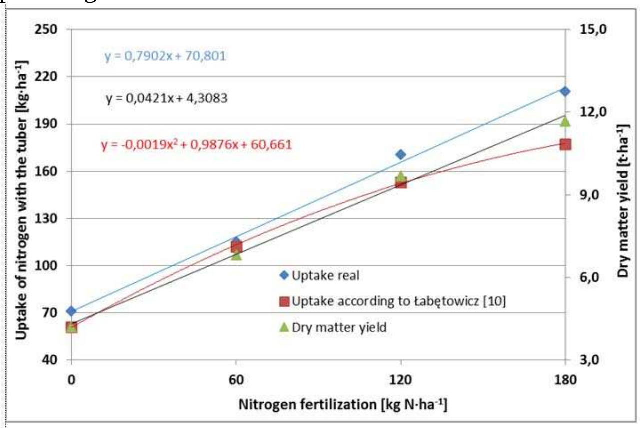
Sprinkling - Italian ryegrass



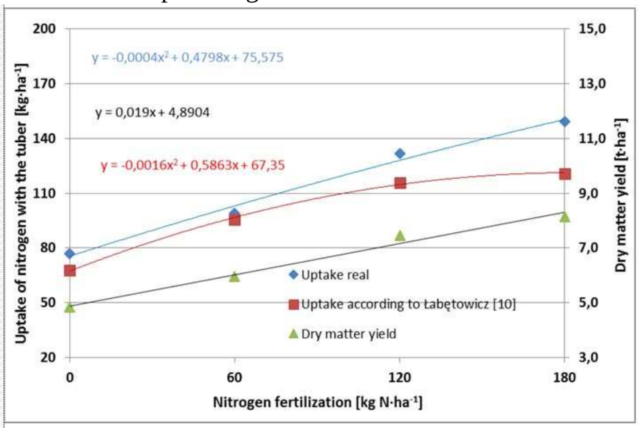
Non sprinkling - Italian ryegrass



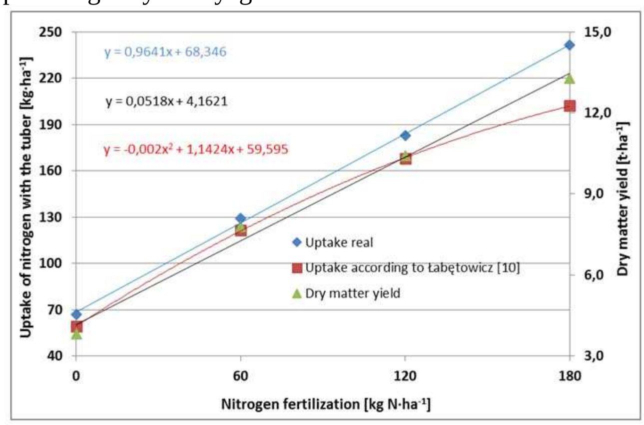
Sprinkling - Cocksfoot



Non sprinkling - Cocksfoot



Sprinkling - Hybrid ryegrass



Non sprinkling - Hybrid ryegrass

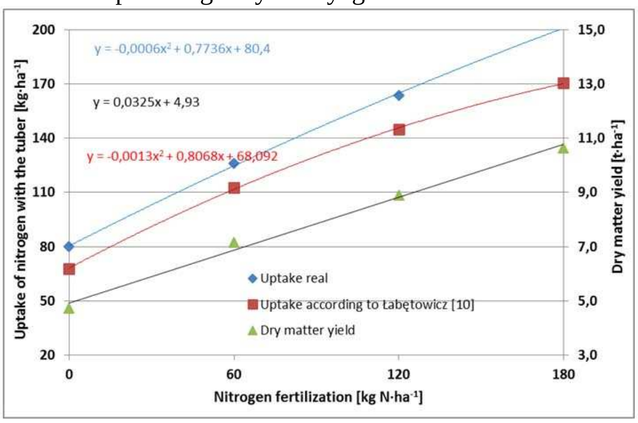


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Fig. 1. Influence of sprinkling irrigation and nitrogen fertilization on dry matter yielding and nitrogen uptake
Rys. 1. Wpływ deszczowania i nawożenia azotem na plony suchej masy i pobranie azotu

Table 2. The regression equation for dry matter yields and nitrogen uptake
Tab. 2. Równania regresji dla plonów suchej masy i pobrania azotu

Species	Uptake real	Uptake according to Łabętowicz [10]	Dry matter yield
		Sprinkling	
Italian ryegrass	$y = -0{,}0025x^2 + 1{,}1654x + 53{,}664$	$y = -0{,}0002x^2 + 0{,}0752x + 3{,}2601$	$y = -0{,}0029x^2 + 1{,}1717x + 47{,}126$
Cocksfoot	$y = 0{,}7902x + 70{,}801$	$y = 0{,}0421x + 4{,}3083$	$y = -0{,}0019x^2 + 0{,}9876x + 60{,}661$
Hybrid ryegrass	$y = 0{,}9641x + 68{,}346$	$y = 0{,}0518x + 4{,}1621$	$y = -0{,}002x^2 + 1{,}1424x + 59{,}595$
		Non sprinkling	
Italian ryegrass	$y = -0{,}0013x^2 + 0{,}5933x + 74{,}363$	$y = -9E\text{-}05x^2 + 0{,}0369x + 4{,}5203$	$y = -0{,}0019x^2 + 0{,}6771x + 65{,}189$
Cocksfoot	$y = -0{,}0004x^2 + 0{,}4798x + 75{,}575$	$y = 0{,}019x + 4{,}8904$	$y = -0{,}0016x^2 + 0{,}5863x + 67{,}35$
Hybrid ryegrass	$y = -0{,}0006x^2 + 0{,}7736x + 80{,}4$	$y = 0{,}0325x + 4{,}93$	$y = -0{,}0013x^2 + 0{,}8068x + 68{,}092$

4. Discussion

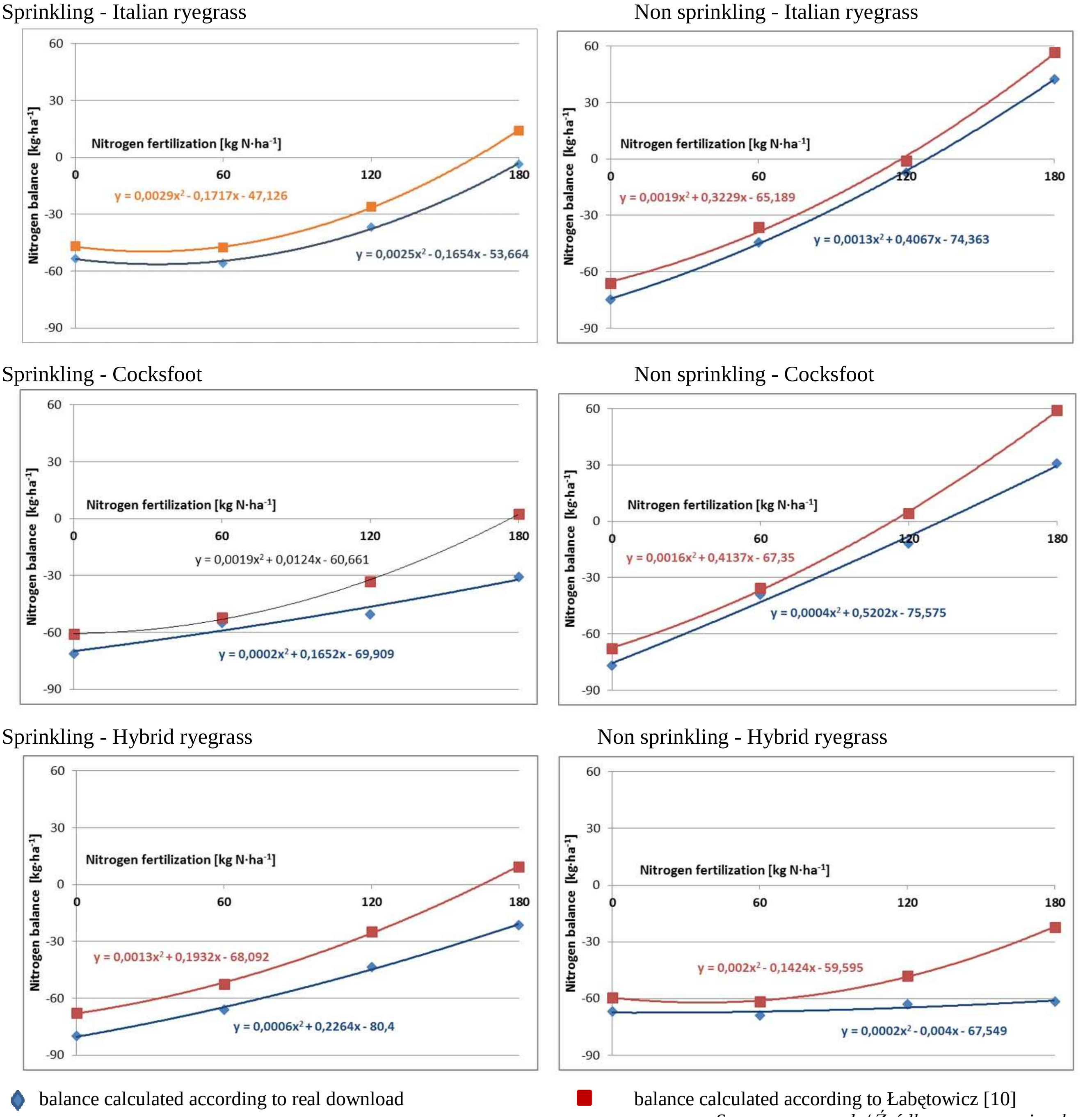
In the holdings located in the danger zone of water pollution by nitrates from agricultural sources, there must be a plan of fertilization and nitrogen balance on the farm drawn up in accordance with applicable laws and regulations [14] A positive nitrogen balance should not exceed 30 kg N ha^{-1} considered to be even safer value for the environment [11].

In the assessment of the impact of agriculture on the environment, two methods can be used: direct and indirect. An indirect method of assessing the impact of agriculture with biogenic components includes their total consumption in mineral and natural fertilizers and their balance. The direct method relates, among others, to changes in the content of mineral nitrogen in the soil profile [6].

In this study an indirect method was applied. The positive balance may lead to a movement of the component to the groundwater and the negative balance indicates very small doses of fertilizer in relation to the nutritional requirements of plants [7].

The results of this study indicate that regardless of the water variant, the use of even the highest dose of nitrogen - 180 kg N ha^{-1} was insufficient to achieve maximum yields. In contrast, nitrogen balance results varied depending on the water variant and the grass species.

In the variant without sprinkling irrigation, in respect to Italian ryegrass and orchard grass, regardless of the method of preparing the balance sheet (the real uptake or calculated by tabular Indicators), the application of 180 kg of nitrogen per 1 ha dose was too large, and especially if you also take into account the atmospheric nitrogen fixation that is on average 10 to 24 kg N ha^{-1} [1].



Source: own work / Źródło: opracowanie własn

Fig. 2. Nitrogen balance depending on the species and the water variant
Rys. 2. Bilans azotu w zależności od gatunku i wariantu wodnego

Balancing of this component was obtained at doses close to 120 kg N ha^{-1}. However, for hybrid ryegrass, a dose of 180 kg N ha^{-1} was safe even after taking into account atmospheric nitrogen fixation.

In a variant of sprinkling irrigation, the application of even the highest dose of nitrogen resulted in virtually offset of this component when it is calculated using indicators, or its negative balance, if it is made based on actual uptake. Similar results in conditions without irrigation were also obtained by [8], who, in addition to mineral fertilization, used also the manure. The research of Borówczak et al. [2, 3] shows that grasslands are not a threat to the environment arising from the use of nitrogen fertilizers. Nitrogen balance developed based on tabulated indicators, regardless of the water variant, was more restrictive than it appeared from the actual uptake.

5. Conclusions

1. In the option using sprinkling irrigation, regardless of the species, the dose of 180 kg of nitrogen was almost entirely used by the plants, which meant that the balance of this component was close to 0.
2. In orchard grass and Italian ryegrass cultivation, in the option without sprinkling irrigation, nitrogen balance was obtained after the application of about 120 kg N ha^{-1}, while in case of ryegrass hybrid nitrogen balance remained negative also at 180 kg $N \cdot ha^{-1}$.
3. Calculation of the amount of nitrogen uptake with factors used in the elaboration of the element's balance was understated in relation to the uptake calculated on the basis of its content in the yield. Actual uptake was higher regardless of the grass species or water option.
4. Irrespective of the water variant and the species of grass, the use of even the highest dose of nitrogen – 180 kg N ha^{-1}, was insufficient to achieve maximum dry matter yields.

6. References

[1] Barszczewski J., Jankowska-Huflejt H., Wolicka M.: Analiza bilansu azotu, fosforu i potasu w łąkarskich gospodarstwach ekologicznych, Woda-Środowisko-Obszary Wiejskie 2007, t. 7, z. 2b(21): 7-19.

[2] Borówczak F., Alaszkiewicz M., Miłkowska A.: Bilans azotu w wybranych gospodarstwach rolnych gminy Święciechowa. Journal of Research and Applications in Agricultural Engineering, 2007, Vol. 52(3): 15-18.

[3] Borówczak F., Majewska A., Przykłota S., Śmietana B.: Bilans azotu w wybranych gospodarstach rolnych gmin Góra, Krzemieniewo i Osieczna. Journal of Research and Applications in Agicultural Engineering, 2009. 54(3), 25-29.

[4] Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal L. 375, 31.12.1991.

[5] Csatho P., Radimszky L.: Two worlds within EU27: Sharp contrasts in organic and mineral nitrogen-phosphorus use, nitrogen-phosphorus balance, and soil phosphorus status, widening and depending gap between Western and Central Europe. Comm. Soil Sci. Plant Analysis, 2009, 40, 999-1019; http://www.informaworld.com.

[6] Fotyma, M.; Igras, J.; Kopiński, J.; Podyma, W.: Ocena zagrożeń nadmiarem azotu pochodzenia rolniczego w Polsce na tle innych krajów europejskich. Studia i Raporty IUNG-PIB, 2010, 21, 53-75.

[7] Gosek, S.: Wapnowanie i nawożenie mineralne a żyzność gleby i plony roślin. Biul. Inf. IUNG, 1997, 5, 6-7.

[8] Konieczna A., Roman K.: Wpływ wielkości nawożenia na bilans NPK i próchnicy w glebie w wybranych technologiach produkcji roślinnej. Inżynieria rolnicza. 2013: Z. 3(145) T.1: 139-148.

[9] Kopiński J.: Regionalne zróżnicowanie bilansu azotu, fosforu i potasu w rolnictwie polskim w latach 1999-2003. Nawozy i Nawożenie, 2005, 2(23), 84-93.

[10] Łabętowicz J.: Podstawy zasady opracowania planu nawozowego w gospodarstwie specjalizującym się w chowie zwierząt. Warszawa: SGGW, 1999.

[11] Rozporządzenie Ministra Środowiska z dnia 23 grudnia 2002 r. w sprawie kryteriów wyznaczania wód wrażliwych na zanieczyszczenie związkami azotu ze źródeł rolniczych. Dz. U. z 2002 r. Nr 241, poz. 2093.

[12] Ustawa z dnia 18 lipca 2001 r. Prawo wodne. Dz. U. z 2001 r. Nr 115, poz. 1229.

[13] Ustawa z dnia 2 kwietnia 2004 r. o zmianie ustawy o nawozach i nawożeniu. Dz. U. z 2004 r. Nr 91, poz.876.

[14] Ustawa z dnia 10 lipca 2007 r. o nawozach i nawożeniu. Dz. U. Nr 147, poz. 1033.