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NITRATES CONCENTRATION IN PERCOLATING WATER IN RELATION TO DIFFERENT TYPES OF FERTLIZATION IN MOUNTAIN MEADOW

ZAWARTOŚĆ AZOTANÓW W WODZIE PRZESIĄKOWEJ W ZALEŻNOŚCI OD RODZAJU NAWOŻENIA ŁĄKI GÓRSKIEJ

Abstract: Specificity of highland agriculture is high contribution of natural fertilizers in feeding farm lands. This manner of fertilisation had been evaluated in terms of crop production effect. However, an evaluation of its influence on water environment was missing. This is the reason why the authors decided to assess an effect of folding on nitrogen content in water passing through the soil horizon of a highland meadow and NO_3-N loads leached away. The study took place in 2007–2009 in the mountain grassland by the type of red fescue and common bent-grass. Experimental objects involved a control and four fertilization treatments *eg* one with inorganic fertilizers, and three with manure from sheep folding. Each type of fertilization significantly changed the floristic composition of the sward. These changes increased the outflow of water from the soil profile. Inorganic nitrogen fertilization proved to be more safe for water environment, when set beside folding. Gross NO_3-N loads leached out by water for the whole experimental period amounted to 15–21 % share of nitrogen fertilization input for the folding objects, and 6 % for the inorganic fertilization one. Exceptionally heavy load left the high-density fold in the first year after treatment. This reached as much as 81 % of gross load for 3-year experimental period.

Keywords: mountain grassland, folding, percolation water, nitrates, losses

Introduction

Among all of major nutrients nitrogen is the one noted for greatest losses. They are caused by its remarkable ability to volatilize to the atmosphere and to be leached away from the soil. Amount of such loss depends on the level and type of fertilization as well as on the intensity of organic matter mineralization process in soil [1, 2]. On the basis of calculations done by Sapek [3] it is known that every year from the whole area of Poland about 1800 tons of this nutrient is transported by rivers to the Baltic Sea, while

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agriculture input to the whole nitrogen load is estimated at a rate of about 70 %. Chemical properties both of stream water and underground water are strongly influenced by a status of farming economy in highland regions, which are concerned to be a place, where water resources develop. Specificity of highland agriculture is high contribution of natural fertilizers in feeding farm lands, including fresh manure, and excreta of folded sheep in particular. This manner of fertilization had been evaluated in terms of its influence on crop production by several researchers [4–6]. However, there is no similar evaluation for its possible effect on water environment. This is the reason why the authors decided to assess an effect of folding on nitrogen content and load of NO_3-N leaving a mountain meadow with water passing through the soil horizon.

Material and methods

The study took place at Czarny Potok near Krynica (N 49°24′57″, E 20°55′32″) in a mountain meadow (640 m a.s.l.) by the type of red fescue (*Festuca rubra*) and common bent-grass (*Agrostis capillaris*) in years 2007 to 2009. The soil over an experimental field was brown, classified with texture as weak loamy sand, with acid reaction (pH_{KCl} = 4.3). The soil was fairly rich in potassium (70 mgK $\cdot$ kg^{-1}), however very poor in phosphorus (8.0 mgP $\cdot$ kg^{-1} soil). In order to determine plant effect on changes of NO_3-N content in soil a yearly research cycle was divided into two periods: summer (15 April to 15 October) and winter one (16 October to 14 April). Experimental objects included control and four fertilization treatments *eg* one with inorganic fertilizers, two manured by folded sheep and one fold-manured along with yearly application of inorganic nitrogen and phosphorus (10 kgP $\cdot$ ha^{-1} and 50 kgN $\cdot$ ha^{-1}). Sheep folding was performed in spring 2007. The two folding objects were differentiated according to stock density into a low-density fold and a high-density fold. In the former case an area assigned for 2 nights per 1 sheep was of 2 m^2, while in the latter it was 1 m^2. As regards the inorganic fertilization object minerals were applied yearly: phosphorus and potassium as a single dose in spring, while nitrogen dose was divided in two parts, 60 % in spring and 40 % for 2^{nd} regrowth. Every year the meadow was mowed twice. First cut at the beginning of the flowering stage and the second after approximately 8 weeks. The surface area of a field object was 50 m^2. Each object was fitted with 3 lysimeters dug into the ground at a 40 cm depth, because of soil horizon structure. Water from lysimeters was conveyed through hosepipes to plastic containers. The amounts of oozing water were measured several times as it appeared there, and samples containing 10 % of its volume were taken for chemical analysis. All specimens from each experimental period were collected together to make up a total sample; they were stored in a refrigerator. These total samples were subject to the estimation of NO_3-N content using microprocessor-controlled photometer LF205. As far as amount of precipitation is concerned, it was measured with a Hellman pluviometer placed in the experimental field. Nitrate nitrogen loads were calculated by multiplying nitrogen content by an amount of percolated water. Because of the changes that have occurred in the botanical composition of the sward, in the 2^{nd} year of research its assessment was performed by Klapp's technique. Obtained data on amounts of percolated water and

NO_3-N loads leaving the soil underwent the analysis of variance, and mean values compared with the use of Student's t-test.

Results

Sward of control object was dominated by two species of grasses (Table 1).

Table 1

Floristic composition of mountain meadow sward (1st regrowth) in the 2nd year of the study [%]

Species	Fertilization				
	Control – 0	Inorganic $P_{25}K_{50}N_{120}$	Fold		
			Low density $P_{14}K_{147}N_{92}$	Low density + $P_{10}N_{50}$	High density $P_{28}K_{294}N_{184}$
Festuca rubra	28	15	19	13	14
Agrostis capillaris	23	9	12	8	6
Anthoxanthum odoratum	9	2	5	2	2
Festuca pratensis	5	24	15	22	25
Poa pratensis	3	12	8	10	10
Dactylis glomerata	+	5	2	2	3
Elytrigia repens	+	5	2	2	2
Phleum pratense	—	+	3	5	5
Trifolium repens	6	3	12	8	6
Plantago lanceolata	6	2	3	1	1
Taraxacum officinale	1	5	3	3	6
Rumex acetosa	+	3	1	3	4
Ranunculus repens	+	3	3	3	4
Others	17	12	12	18	12

+ – less than 0.5 %.

These dominated species were red fescue (*Festuca rubra* L.) and common bent grass (*Agrostis capillaris* L.) constituting more than 50 % yield of the sward. Next to them in smaller amounts were still sweet vernal grass (*Anthoxanthum odoratum* L.), meadow fescue (*Festuca pratensis* Huds.) and smooth-stalked bluegrass (*Poa pratensis* L.). White clover (*Trifolium repens* L.) was present in an amount of 6 % yield, and other dicotyledonous completed floristic composition – in largest amount occurred plantain (*Plantago lanceolata* L.) – 6 %.

Each type of fertilization negatively affected the number of species that dominated the control sward. The share of red fescue in the object of loose fold decreased by 1/3 and twice in case of other objects. At the same time, the loss of common bent grass in these objects was 2-fold and 3–4-fold, respectively. In contrast, species that have spread in large quantities under the influence of fertilization were among grasses meadow fescue and Kentucky bluegrass, and smaller quantities of orchard grass (*Dactylis* *glomerata* L.), quack grass (*Elytrigia repens* L.) and timothy (*Phleum pratense* L.). Among the dicotyledonous plants biggest gain in yield was found in the common dandelion (*Taraxacum officinale* L.), sorrel (*Rumex acetosa* L.) and buttercup (*Ranunculus repens* L).

The highest precipitation totals for vegetative seasons were characteristic of year 2007, and the lowest one of 2009 (Table 2).

Table 2

Total precipitation and amounts of water passing through soil horizon

Type of fertilization	Summer period			Winter period	
	2007	2008	2009	2007/2008	2008/2009
	Total precipitation [mm]				
	732	664	619	431	468
	Amount of water soaking through soil horizon [mm]				
Control – 0	170	190	62	346	280
Inorganic $P_{25}K_{50}N_{120}$	217	258	177	350	282
Low-density fold $P_{14}K_{147}N_{92}$	177	186	165	351	297
Low-density fold + $P_{10}N_{50}$	185	232	179	346	292
High-density fold $P_{28}K_{294}N_{184}$	213	212	190	356	294
$LSD_{\alpha = 0.05}$	18	26	22	40	33

The difference in whole summer rainfall between these years equals 113 mm. Precipitation totals for winter periods were similar to each other and evidently lower to those for vegetative seasons. Any summer period had a share of about 60 % of yearly precipitation. The greatest amounts of water passing through a soil horizon in a vegetative season were noted for 2008 while the least in 2009, which was characterized by less rain. In this year water outflow coefficients (the ratios of percolating water outflow to precipitation inflow) ranged from 28 % to 39 %, while in the other years they were found either 23–30 % or 10–31 %. As regards winter periods water outflow coefficients were significantly higher when compared to those in summer periods. They amounted to about 81 % for the first winter period, and 62 % for the second one, being similar among objects. With regard to summer periods the lowest water outflow coefficients were characteristic of the control object (average water outflow coefficient for the period of study was approximately 20 %), while the highest ones were noted for both inorganic fertilization and high-density folding object, where their values were half as great as the control.

For each experimental period percolating water from the control object had the lowest NO_3-N concentration (Table 3). This water was 2–7 times poorer in nitrates than water from the object fertilized with minerals alone.

Table 3

NO_3-N levels in percolated water [mg · dm^{-3}]

Type of fertilization	Summer period			Winter period	
	2007	2008	2009	2007/2008	2008/2009
Control – 0	0.96	0.53	0.32	0.30	0.38
Inorganic $P_{25}K_{50}N_{120}$	2.19	1.41	1.16	2.27	1.07
Low-density fold $P_{14}K_{147}N_{92}$	3.09	0.74	0.61	1.56	0.60
Low-density fold + $P_{10}N_{50}$	5.72	1.72	1.25	4.98	0.67
High-density fold $P_{28}K_{294}N_{184}$	5.92	1.30	1.04	5.22	0.88

In the first year after spring folding seepage water from each folded object contained high amounts of such nitrogen form, both in vegetative and winter periods. For the high-density fold and the low-density one supplied with minerals their NO_3-N levels were 2.5 times higher than in the case of inorganic fertilization object. In the succeeding years water from them had similar NO_3-N content as the inorganic fertilization object. As regards water from the low-density fold, it contained 2 times less of NO_3-N than those two, although this measure was twice as much as in the control.

Loads of NO_3-N leached out by percolating water are shown in Table 4.

Table 4

NO_3-N loads transported by percolating water [kg · ha^{-1}]

Treatment	Summer period			Winter period		Total
	2007	2008	2009	2007/08	2008/09	
Control – 0	1.63	1.01	1.98	1.04	1.06	6.72
Inorganic $P_{25}K_{50}N_{120}$	4.75	3.64	2.05	7.94	3.02	21.40
Low-density fold $P_{14}K_{147}N_{92}$	5.47	1.38	1.01	5.48	1.78	15.12
Low-density fold + $P_{10}N_{50}$	10.58	3.99	2.24	17.23	1.96	36.00
High-density fold $P_{28}K_{294}N_{184}$	12.61	2.76	1.98	18.58	2.59	38.52
$LSD_{\alpha = 0.05}$	1.20	0.41	0.29	1.40	0.32	3.62

For the whole experimental period such value amounted to 6.71 kg · ha^{-1} from the control, which was more than 3-fold lower when compared to the inorganic one, and as much as 6 times lower than for low-density fold combined with minerals and high density fold. Especially high loads were transported from these two objects in the first year after folding. Their respective shares in gross loads leached out during the study were 77 % and 81 %, whereas for winter period alone this portion amounted to 48% in both objects. It is worth noting that in the two periods of the winter elevated load of NO_3-N in the fertilized objects ranged from 48 % to 55 % of the total load, which was greater than the total load in the three summer periods, which amounted to 45–52 %.

Discussion

Great soil water outflow in winter periods was due to lack of water uptake by plants and reduced evaporation from soil. However, a considerable difference observed between both the analyzed winter periods despite similar levels of precipitation must be attributed to different degrees of soil freezing decisive for the amount of percolated liquid. In the winter period 2008/2009 mean temperature was by 1 ^{o}C lower when compared to the 2007/2008 one, nevertheless for January and February temperature in 2009 occurred to be even 3–4 times lower. This was the reason for more intense freezing of the soil, then reduced percolation of water, while surface runoff was greater, especially due to water from melting. On the other hand the differences in the amount of percolating water between the objects should be combined with the floristic composition of the sward. The control object, characterized by the smallest amount of water that outflow from the soil profile, was dominated by species forming very good sod – with whom is positively related water retention. However, in other objects the loss of these species in favour of others, forming rather loose turf, was the cause of the movement of large quantities of water through the soil profile. This is confirmed, among others by Merz et al [7] and Sulas et al [8]. From the data reported by Sapek [9] it appeared that the origin of nitrogen leached out of the soil by percolating water is not only in fertilization, but also in mineralization of organic matter, and the latter process is stimulated by fertilizers. According to that author the amount of nitrogen released from the soil due to mineralization of organic matter on mineral soils richer in organic matter without plant cover reaches up to 430 kgN $\cdot$ ha^{-1} $\cdot$ y^{-1}. This supposition may explain the elevated levels of NO_3-N in percolated water found for the inorganic object in the first year after treatment, where the soil had been accumulated certain amount of organic matter prior to fertilization.

High concentration of NO_3-N in percolating water as well as immense nitrogen loads leached from the soil of folded objects for both periods in the first experimental year would cause some trouble, because folding is considered as environmentally friendly manner of fertilization. In fact, first-year leached nitrogen, as NO_3-N alone, amounted to 20 % of total nitrogen delivered by fertilization for both the high-density fold and the low-density fold supplied with minerals. As regards the inorganic fertilization object the respective proportion was almost half the size of the previous one. The amounts of NO_3-N transported out of the soil by seeping water stay within the limits specified by Sapek [11]. In her opinion this kind of loss depends on various factors (nitrogen dose, type of fertilizer, time of application, site conditions) and may vary from 5 to 20 % of nitrogen supplied by fertilization. The reason why the first-year nitrogen loss for each folded object was so heavy is, apart from the ample supply of easily leachable nitrogen from urine, because sheep, especially the dense-fold ones, caused a lot of damage to the turf, which in turn encouraged nitrogen escape. Remarkable nitrogen loss during the first year after folding must be ascribed to its relatively low efficiency rate of uptake from natural fertilizers. According to Mazur [11] the rate of nitrogen uptake from barnyard manure reaches approximately 50 %.

Significant nitrogen loss due to the surface-spreading of natural fertilizers can be assumed given the results reported by Svensson [12]. As the author stated, to postpone ploughing land-spread manure for 4 hours instead of performing it immediately would increase nitrogen loss even 6 times.

Conclusions

Based on the experimental data we came to the following conclusions:

1. Each type of fertilization clearly changed the floristic composition of meadow sward, leading to loosening of sod and a larger outflow of water from the soil profile.

2. In winter periods coefficients of water outflow from a soil horizon were 2–3 times higher than in summer ones. Moreover, in winter periods neither a type of fertilization nor its level affected the volume of water leaving the soil horizon. As regards summer periods the lowest amounts of water soaked through the control object, while the highest through the objects with intensive fertilization.

3. Fertilization by means of folding, with the high-density fold or the low-density fold supplied with inorganic fertilizers was a source of significant nitrate-nitrogen loads entering water environment, particularly in the first year after treatment. The amount of NO_3-N leached out of those folds made almost 20 % of nitrogen delivered in fertilizers, in contrast to the inorganic fertilization, where it was 10 %.

4. Because of easy leaching NO_3-N out of the soil in fertilization of mountain grasslands by means of folding one should use a low-density fold. This way of fertilization need to be repeated every 2–3 years depending on sheep stocking rate and alternated with inorganic fertilization.

5. Feeding with inorganic nitrogen, when compared with folding, occurred to be more safe for water environment. Gross N-NO_3 loads leached out for the whole experimental period amounted to 15–21 % of nitrogen delivered from fertilization for the folding objects and 6 % for the inorganic fertilization one.

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Zakład Łąkarstwa
Uniwersytet Rolniczy im. Hugona Kołłątaja w Krakowie

Abstrakt: Celem badań była ocena wpływu nawożenia łąki górskiej z wykorzystaniem koszaru przy udziale owiec na zawartość azotanów (N-NO_3) w wodzie przemieszczającej się przez profil glebowy. Badania przeprowadzono w latach 2007–2009. Uwzględniono w nich 5 obiektów: kontrolę i 4 obiekty nawożone. Jeden z tych obiektów był nawożony wyłącznie nawozami mineralnymi ($P_{25}K_{50}N_{120}$), dwa obiekty nawożono tylko przez koszarzenie (koszar luźny $P_{14}K_{147}N_{92}$ i koszar ciasny $P_{28}K_{294}N_{184}$), jeden obiekt obejmował nawożenie kombinowane, w którym koszar luźny uzupełniono nawożeniem mineralnym ($P_{10}N_{50}$).

Koszarzenie przeprowadzono wiosną 2007 r., a przed jego wykonaniem wyceniono skład florystyczny runi. W przypadku koszaru luźnego przez okres 2 nocy dla jednej owcy przydzielono 2 m^2 powierzchni pastwiska, a w koszarze ciasnym 1 m^2. W obiektach z nawożeniem mineralnym nawozy stosowano corocznie. Na każdym obiekcie o powierzchni 50 m^2 były wkopane po 3 lizymetry głębokość 40 cm (z racji takiej miąższości gleby) celem określenia ilości wody przesiąkowej. Łąkę koszono 2 razy w roku. Ilość wody przesiąkającej przez profil glebowy mierzono w miarę jej pojawienia się w odbieralnikach, zaś ilość opadów atmosferycznych mierzono wykorzystując deszczomierz Hellmana.

Każdy rodzaj nawożenia wyraźnie zmienił skład florystyczny runi łąkowej, doprowadzając do rozluźnienia darni i większego odpływu wody z profilu glebowego. Nawożenie z wykorzystaniem koszaru ciasnego lub luźnego w połączeniu z nawozami mineralnymi, zwłaszcza w pierwszym roku po zastosowaniu, było zabiegiem istotnie obciążającym środowisko wodne azotem azotanowym. Ładunek N-NO_3 wynoszony z gleby w tych obiektach stanowił prawie 20 % ilości azotu dostarczonego w nawozach, wobec 10 % ilości tego składnika traconego w obiekcie nawożonym nawozami mineralnymi. Do nawożenia górskich użytków zielonych metodą koszarzenia z racji podatności na wymywanie N-NO_3 z gleby należy stosować koszar luźny. Nawożenie azotem mineralnym w porównaniu z koszarzeniem okazało się bezpieczniejsze dla środowiska wodnego. Za cały okres badawczy z obiektów koszarzonych ładunek N-NO_3 wyniesiony z wodą stanowił 15–21 % ilości azotu dostarczonego w nawożeniu wobec 6 % w przypadku stosowania azotu mineralnego.

Słowa kluczowe: łąka górska, koszarzenie, wody przesiąkająca, azotany, straty