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OPTIMIZATION OF LAWN FERTILIZATION WITH NITROGEN. PART II. NUTRIENT STATUS OF PLANTS

OPTYMALIZACJA NAWOŻENIA TRAWNIKÓW AZOTEM. CZ. II. STAN ODŻYWIENIA ROŚLIN

Abstract: The aim of the conducted investigations was to determine the effect of increasing nitrogen fertilization of lawns (at doses corresponding to 0, 50, 100, 150, 200 mg N · dm^{-3}) on the nutrient status of turf, nutrient uptake (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) and their quantitative proportions in aboveground parts of plants. A significant effect was found for fertilization with nitrogen on N, K and S nutrient status of plants, and a lack of such effect was recorded for P and Mg. A stimulating effect of nitrogen fertilization on nutrient uptake by aboveground parts of plants was observed. With an increase in the intensity of fertilization quantitative interrelations were recorded between nitrogen and the other macroelements (P, K, Ca, Mg and S). Nitrogen fertilization had a positive effect on the ornamental value of turf, which was most desirable when nutrient contents in aboveground parts of plants fell within the following ranges [%]: N 2.38–3.48, P 0.60–0.64, K 3.05–3.68, Ca 0.79–1.23, Mg 0.55–0.57 and S 0.45–0.55. These contents may be treated as temporary index nutrient contents for lawns.

Keywords: nitrogen fertilization, lawn, nutrient status, macroelements, nutrient uptake

Nitrogen, particularly its nitrate(V) form, belongs to nutrients which are relatively easily and rapidly leached from top soil layers deep into the soil profile. At the same time intensive fertilization with this nutrient is applied, among other things, in golf courses as well as football pitches. In turn, a lack of nitrogen fertilization is a major cause of the deteriorating appearance of lawns in green areas. It is commonly known that nitrogen fertilization has a significant effect on the appearance of plants, their yielding as well as uptake of the other nutrients [1–5].

The aim of the conducted investigations was to determine the effect of increasing nitrogen fertilization of lawns on the nutrient status of plants, nutrient uptake, as well as

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quantitative proportions of nutrients in aboveground parts of plants. Determination of temporary index nutrient contents in aboveground parts of plants, at which their ornamental value is most desirable, is an important parameter from the point of view of controlled nitrogen fertilization of the turf.

Material and methods

The vegetation experiment was conducted in the years 2007–2008 at the "Marcelin" Experimental Station of the Departments of the Faculty Horticulture, the Poznan University of Life Sciences. The analyses concerned the effect of increasing levels of nitrogen fertilization [mg N · dm^{-3}]: 0, 50, 100, 150, 200 (denoted as N-0 to N-200), corresponding to annual nitrogen doses of 0, 10, 20, 30 and 40 g N · m^2, on the macronutrient status of plants, as well as nutrient uptake and quantitative proportions of nutrients in aboveground parts of plants. Contents of the other macroelements in all analyzed combinations were supplemented to the standard levels [mg · dm^{-3}] of P 100, K 200, Mg 180 (2007) and 300 (2008) [6].

Experiment was conducted on a 2-year lawn, on which a lawn-seed mixture was sown at 25 g · m^{-2}, with the following composition: perennial ryegrass (*Lolium perenne* L.) 'Grasslands Nui' (45 %), tall fescue (*Festuca arundinacea* Schreb) 'Finelawn' (25 %), red fescue (*Festuca rubra* Hack.) 'Olivia' (10 %), red fescue (*Festuca rubra* Hack.) 'Boreal' (15 %), kentucky bluegrass (*Poa pratensis* L.) 'Balin' (5 %).

During the vegetation period samples of plant material, ie cut grass leaves, were collected for chemical analyses. Samples were collected individually, from each experimental plot (4 plots comprised 1 experimental combination) on the following dates: 26.07 and 03.09 (2007), 18.06, 23.07 and 25.08 (2008). Collected leaves were dried at 45–50 ^{o}C and next they were ground. In order to determine total N, P, K, Ca and Mg the plant material was mineralized in concentrated sulfuric acids, while for analyses of S content it was in a mixture of nitric(V) and chloric(VII) acids (3:1 v/v) [7]. After mineralization of plant material the following analyses were performed: N total – by distillation according to Kjeldahl in a Parnas–Wagner apparatus, P – by colorimetry with ammonium molybdate (according to Schillak), K, Ca, Mg – by AAS (in a Carl-Zeiss Jena apparatus), S – by nephelometry with $BaCl_2$. Results of chemical analyses of plants were analyzed statistically using the Duncan test (α = 0.05).

Results

A significant effect of nitrogen fertilization on the nutrient status of plants in terms of this nutrient was observed (Table 1). Total nitrogen content in aboveground parts of plants, in case of the N-0, N-50 and N-100 combinations, did not differ significantly (2.43, 2.25, 2.38 % N, respectively). In case of the N-50 combination a trend was found, although not proven statistically, for nitrogen content to decrease in leaves, probably caused by the so-called Steenbjerg effect. The most advantageous nutrient status of plants in case of nitrogen was recorded in case of the N-200 combination (3.48 % N).

Table 1

The effect of nitrogen fertilization on contents of nitrogen, phosphorus and potassiu min aboveground parts of plants [% d.m.]

N level (A)	N			P			K		
	Year								
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
N-0	2.57a	2.29a	2.43a	0.65a	0.57a	0.61a	3.43a	2.68a	3.06a
N-50	2.39a	2.11a	2.25a	0.60a	0.57a	0.59a	3.27a	2.67a	2.97a
N-100	2.45a	2.31a	2.38a	0.66a	0.54a	0.60a	3.29a	2.81a	3.05a
N-150	2.77b	2.85b	2.81b	0.71a	0.56a	0.64a	3.64b	3.07b	3.36b
N-200	3.50c	3.45c	3.48c	0.67a	0.54a	0.61a	4.01c	3.34c	3.68c
Mean	2.73a	2.60a		0.66a	0.56a		3.53b	2.91a	

* Values designated with the same letters within columns do not significantly differ at p = 0.05.

In contrast to nitrogen, no significant effect was shown of increasing fertilization on the nutrient status of aboveground parts of plants in case of phosphorus. Contents of this nutrient ranged from 0.59 % (in the N-50 combination) to 0.64 % P (in the N-150 combination). Nutrient status of plants for phosphorus in successive years of the study was similar (0.67 and 0.54 % P, respectively).

Increasing nitrogen fertilization significantly differentiated nutrient status of plants for potassium. As in case of total nitrogen, a similar nutrient status for this nutrient was found in case of combinations N-0, N-50 and N-100 (3.06, 2.97 and 3.05 % K, respectively). The best nutrition with potassium was observed for plants in case of combination N-200 (3.68 % K). The year of the study significantly modified the content of this nutrient in aboveground parts of plants. It was significantly higher in the first year of the study (3.53 % K) in comparison with the second year (2.91 % K).

A significant variation in calcium status of plants was found, depending on the level of nitrogen fertilization. The lowest calcium content was determined for combination N-200 (0.79 % Ca), while the highest (1.23 % Ca) in combination N-100. Nutrient status for this element was similar in successive years of the study (1.07 and 0.94 % Ca, respectively).

Nitrogen fertilization did not modify the nutrient status of plants in case of magnesium. Contents of this element in aboveground parts of plants ranged from 0.52 % (for N-0) to 0.57 % Mg (for N-200). A significant improvement was found in the nutrient status of plants for magnesium in 2008 (0.59 % Mg) in comparison to that of 2007 (0.50 % Mg).

Nitrogen fertilization had a positive effect on sulfur status of plants (Table 2). The biggest amount of this nutrient was determined in case of combination N-200 (0.55 % S). The other combinations did not differ significantly, falling within the range from 0.44 % (for N-50) to 0.47 % S (for N-0). Probably the best nutrient status of plants for sulfur in case of combination N-200 was caused by the application of the highest doses of sulfur as ions accompanying in magnesium fertilization (magnesium sulfate) and potassium fertilization (potassium sulfate).

Table 2

The effect of nitrogen fertilization on contents of calcium, magnesium and sulphur in aboveground parts of plants [% d.m.]

N level (A)	Ca			Mg			S		
	Year								
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
N-0	0.91b	0.99a	0.95ab	0.48a	0.55a	0.52a	0.40a	0.54a	0.47a
N-50	1.25c	0.93a	1.09b	0.51a	0.59bc	0.55a	0.37a	0.51a	0.44a
N-100	1.41c	1.05a	1.23b	0.51a	0.58b	0.55a	0.38a	0.53a	0.45a
N-150	1.05b	0.88a	0.97ab	0.49a	0.62cd	0.56a	0.35a	0.58a	0.46a
N-200	0.75a	0.83a	0.79a	0.50a	0.63d	0.57a	0.53a	0.57a	0.55b
Mean	1.07a	0.94a		0.50a	0.59b		0.40a	0.55b	

* Values designated with the same letters within columns do not significantly differ at p = 0.05.

Concluding remarks. A significant effect was found of increasing nitrogen fertilization in doses ranging from 0 to 40 g N · m^{-2} (corresponding to 0–200 mg N · dm^{-3}) on nutrient status of the lawn in case of nitrogen, potassium and sulfur. Such an effect was not shown for phosphorus and magnesium. In case of sulfur no marked trend was observed for changes in its contents. The most desirable ornamental value of the lawn was found at the following nutrient contents in aboveground parts of plants [% d.m.]: N 2.38–3.48, P 0.60–0.64, K 3.05–3.68, Ca 0.79–1.23, Mg 0.55–0.57 and S 0.45–0.55.

Nutrient uptake. A significant effect of increasing nitrogen fertilization on nutrient uptake by aboveground parts of plants was observed (Table 3). The lowest net uptake was determined in case of the control combination (N-0), with no nitrogen fertilization. The biggest nutrient uptake was found for the combination with the most intensive nitrogen fertilization (N-200), which stimulated – in comparison with combination N-0 – an increase in uptake by [%]: N (+330.7), P (+202.6), K (+263.0), Ca (+150.0), Mg(+227.3) and S (+251.0).

Table 3

The effect of nitrogen fertilization on nutrient uptake by aboveground parts of plants [g m^2] (total for years 2007+2008)

Nutrient	N level					
	N-0	N-50	N-100	N-150	N-200	Mean
N	15.3a	20.4a	28.1b	42.9b	65.9c	34.5
P	3.8a	5.3a	7.1b	9.8bc	11.5c	7.5
K	19.2a	26.9a	36.0a	51.3b	69.7c	40.6
Ca	6.0a	9.9a	14.5b	14.8b	15.0b	12.0
Mg	3.3a	5.0a	6.5b	8.6b	10.8c	6.8
S	2.9a	4.0a	5.4b	7.1b	10.4c	6.0

* Values designated with the same letters within rows do not significantly differ at p = 0.05.

Relations between nutrients. A modifying effect of nitrogen fertilization on quantitative relationships between nutrients in aboveground parts of plants was observed in this study (Table 4). With an increase in nitrogen fertilization the following ratios were observed to decrease: the N : P ratio (from 1.00 : 0.25 to 1.00 : 0.18), N : K (from 1.00 : 1.26 to 1.00 : 1.06), N : Ca (from 1.00 : 0.39 to 1.00 : 0.23), N : Mg (from 1.00 : 0.21 to 1.00 : 0.16) and N : S (from 1.00 : 0.19 to 1.00 : 0.16).

Table 4

The effect of nitrogen fertilization on relations between components in aboveground parts of plants (means for 2007–2008)

Nutrient	N level				
	N-0	N-50	N-100	N-150	N-200
N	1.00	1.00	1.00	1.00	1.00
P	0.25	0.26	0.25	0.23	0.18
K	1.26	1.32	1.28	1.20	1.06
Ca	0.39	0.48	0.52	0.35	0.23
Mg	0.21	0.24	0.23	0.20	0.16
S	0.19	0.19	0.19	0.16	0.16

Discussion

In this study, depending on the level of nitrogen fertilization, nutrient contents in aboveground parts of plants were found to be [% d.m.]: N 2.25–3.48, P 0.59–0.64, K 2.97–3.68, Ca 0.79–1.23, Mg 0.52–0.57 and S 0.44–0.55. Similar contents of nitrogen, potassium, magnesium and markedly lower contents of phosphorus and calcium were recorded in case of perennial ryegrass in pure sowing [8].

A positive and stimulating effect of nitrogen fertilization was found on the uptake of this nutrient by aboveground parts of plants, which confirms earlier studies [1] for doses ranging from 0 to 500 kg N · ha^{-1}. Moreover, a significant effect on nitrogen uptake by ryegrass as well as its yielding was found for lower doses, up to 200 kg N · ha^{-1} [5]. A strong response of ryegrass to nitrogen fertilization was observed [2]. This is evident particularly in the initial stage of plant development, which affects the formation and development of inflorescences – and which is used in seed plantations of this species [9]. A positive effect of nitrogen fertilization on nutrient status of grasses for this nutrient was confirmed in earlier studies [10]. At the same time the authors determined a reduction in the contents of the other macroelements in plants, ie phosphorus, potassium, calcium, magnesium and sulfur.

The effect of nitrogen fertilization on nutrient status was also investigated in case of other horticultural species. High levels of nitrogen fertilization had a negative effect on potassium uptake by *Geranium sylvaticum* [11]. Moreover, increased contents of nitrogen, calcium, magnesium, sulfur and sodium in biomass of Virginia fanpetals were recorded under the influence of increasing doses of nitrogen (ranging from 0 to 150 kg N · ha^{-1}), at a constant fertilization with phosphorus (80 kg P_2O_5) and potassium (120

kg K_2O) [3, 4]. In turn, high contents of nitrogen in the substrate (100–200 mg $N \cdot dm^{-3}$) in case of pelargonium (*Pelargonium xhortorum*) caused an increase in contents of soluble forms of nitrogen, calcium and magnesium in some parts of plants [12]. Earlier studies showed [13] that increasing nitrogen fertilization (at doses ranging from 0 to 200 kg $N \cdot ha^{-1}$) had a significant effect on an increase in nitrogen content in dry matter of tubers in sunflower (*Helianthus tuberosus*); moreover, it significantly modified contents of calcium and sodium.

Conclusions

1. A significant effect of nitrogen fertilization on nutrient status of aboveground parts of the lawn was found in case of nitrogen, potassium and sulfur. Nitrogen fertilization did not modify phosphorus and magnesium status of plants.

2. A positive and stimulating effect of nitrogen fertilization was shown for nutrient uptake by aboveground parts of plants. The lowest uptake was determined in case of the control combination (N-0), while the highest in the combination with the most intensive nitrogen fertilization (N-200).

3. Nitrogen fertilization modified quantitative proportions between nutrients in aboveground parts of plants. With an increase in fertilization with this nutrient the N:P, N:K, N:Ca, N:Mg and N:S ratios decreased.

4. The most desirable ornamental value was found for the turf, containing in aboveground parts of plants the following amounts of nutrients [% d.m. aboveground parts of plants]: N 2.38–3.48, P 0.60–0.64, K 3.05–3.68, Ca 0.79–1.23, Mg 0.55–0.57 and S 0.45–0.55.

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Abstrakt: Celem przeprowadzonych badań było określenie wpływu wzrastającego nawożenia azotem trawnika (w dawkach odpowiadających 0, 50, 100, 150, 200 mg $N \cdot dm^{-3}$) na stan odżywienia murawy, pobranie składników pokarmowych (azotu, fosforu, potasu, wapnia, magnezu i siarki) oraz wzajemne relacje ilościowe między nimi w częściach nadziemnych roślin. Stwierdzono znaczny wpływ nawożenia azotem (w formie NH_4NO_3) na stan odżywienia roślin N, K i S, a brak takiego wpływu w przypadku P i Mg. Zaznaczył się stymulujący wpływ nawożenia azotem na pobranie składników pokarmowych przez części nadziemne roślin. Wraz ze wzrostem intensywności nawożenia osłabieniu ulegały wzajemne relacje ilościowe między azotem a pozostałymi makroelementami (P, K, Ca, Mg, S). Nawożenie azotowe wpływało pozytywnie na walory dekoracyjne murawy, które były najkorzystniejsze, gdy zawartości składników pokarmowych w częściach nadziemnych roślin kształtowały się w zakresie [%]: N 2,38–3,48; P 0,60–0,64; K 3,05–3,68; Ca 0,79–1,23; Mg 0,55–0,57 oraz S 0,45–0,55. Zawartości te można traktować jako tymczasowe zawartości wskaźnikowe składników pokarmowych dla trawników.

Słowa kluczowe: nawożenie azotem, trawnik, stan odżywienia, makroelementy, pobranie składników