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EFFECT OF IRRIGATION AND NITROGEN FERTILIZATION ON PHOSPHORUS CONTENT IN THREE GRASSES CULTIVATED IN FIELD CONDITIONS

Summary

In the years 2002-2005, a four-year long field experiment was conducted with three grass species in sole cropping. The study aimed at evaluating the effect of irrigation and differential nitrogen fertilization on phosphorus content in three swaths of grasses. The study was made in three-factor design test where experimental factors involved: (A) water treatment: objects both irrigated (D) and not-irrigated (ND) - representing natural soil moisture conditions; (B) grass species: Italian ryegrass (Lolium multiflorum L. Mitos); hybrid ryegrass (Lolium hybridum L., Trogres); orchard grass (Dactylis glomerata L., Krysta) and (C) differential nitrogen fertilization (0, 60, 120 and 180 kg N·ha^{-1}). The highest levels of phosphorus were determined in orchard grass. The content of phosphorus in all grass species increased in subsequently harvested swaths this trend resulted from decreasing yields. A significant increase in P content in the grass biomass was found in response to irrigation.
***Key words**: phosphorus content, grasses, irrigation, nitrogen fertilization*

WPŁYW NAWADNIANIA ORAZ NAWOŻENIA AZOTEM NA ZAWARTOŚĆ FOSFORU W TRZECH GATUNKACH TRAW W UPRAWIE POLOWEJ

Streszczenie

W latach 2002-2005 przeprowadzono czteroletnie doświadczenie polowe z trzema gatunkami traw w siewie czystym. Celem pracy było określenie wpływu deszczowania i zróżnicowanego nawożenia azotem na zawartość fosforu w trzech pokosach traw. Badania przeprowadzono w układzie trzyczynnikowym, w którym czynnikami doświadczalnymi były (A) wariant wodny: obiekt deszczowany (D) i niedeszczowany (ND) – naturalny układ warunków wilgotnościowych gleby; (B) gatunek trawy: życica wielokwiatowa (Lolium multiflorum L. Mitos); życica mieszańcowa (Lolium hybridum L., Trogres); kupkówka pospolita (Dactylis glomerata L., Krysta) i (C) nawożenie azotem (0, 60, 120, 180 kg N·ha^{-1}). Największe zawartości fosforu stwierdzono w przypadku kupkówki pospolitej. Zawartość P w przypadku wszystkich analizowanych traw wzrastała w kolejno zbieranych pokosach i tendencja ta była wynikiem zmniejszającego się poziomu plonów. Stwierdzono istotny wzrost zawartości P w biomasie traw pod wpływem zabiegu deszczowania.
***Słowa kluczowe**: zawartość fosforu, trawy, deszczowanie, nawożenie azotem*

1. Introduction

Mineral treatment is basically applied to grass in order to improve nutrient availability to plants as this assures the production of high quality forage [2]. Whereas ensuring a high and stable yield constitutes a secondary task. Chemical composition of grass species depends on many factors including, among others, site conditions, soil types and soil chemical properties as well as plant species and plant development stage [12, 18, 20]. Mineral nutrition of grasses is also significantly influenced by soil reaction [4, 16] which, for a majority grass species, shall be contained within the range of pH 5-6. Soil reaction controls the uptake of phosphorus which is an essential element for regular functioning of every plant [5]. It is phosphorus that dictates the quantity and quality of grass yield. Phosphorus uptake by plants depends upon the balance between numerous phosphorus containing compounds and the diversified abilities of plants to modify their rhizospheral environment [3]. Physiological functions of phosphorus have been widely discussed in the w literature [8-10, 14-15, 19]. The potential for creating high energy chemical bonds is one of the vital properties of phosphate ions taken up by plant. The process enables energy storage, flux and release within a plant. The energy released in the above process is periodically stored in high energy phosphate bonds, and later utilized for energy demanding reactions. A good phosphorus nutrition has beneficial effect on the physiological status e.g. by stimulating root growth thereby contributing to increased accumulation of plant nutrients. Phosphorus is a nutrient whose effect on plants is thought to be most important in the initial vegetation stages as it promotes root system development, and in the so-called generative phase [9]. High yields of grass cannot be achieved unless intensive mineral fertilization is applied. It goes beyond discussion that the higher nitrogen doses, the higher the biomass, however, the quality of technological parameters and the relationships between the contents of elements are still a matter of discussion. Nitrogen fertilization increases the thickness of sward and consequently ensures higher yield [2]. Plant chemical composition dictates not only the nutrition value of forage due to its mineral element content, but also its digestibility and availability.

The aim of the study was to evaluate the effect of irrigation and differentiated fertilization with nitrogen upon the content of phosphorus in three subsequent swaths of grasses cultivated in sole cropping.

2. Materials and methods

The study was carried out in the years 2002-2005 at Gorzyń Experimental–Educational Laboratory, Branch of Złotniki, which belongs to the University of Life Sciences in Poznań; 52º28' N, 16º50'E. The study is based on the three-factor experiment with field cultivated grasses in sole cropping. The experiment was set up using a random block method in the „split split plot" design in four replications. The factors examined in the experiment included: (A) water treatment: objects both irrigated (D) and not-irrigated (ND) - representing natural soil moisture conditions; (B) grass species: Italian ryegrass (*Lolium multiflorum* L. *Mitos*); hybrid ryegrass (*Lolium hybridum* L., *Trogres)*; orchard grass (*Dactylis glomerata* L., *Krysta*) and (C) differential nitrogen fertilization (0, 60, 120 and 180 kg $N \cdot ha^{-1}$).

The experiment was set up on lessive soil developed from light clayey sands underlain by clays; the soil was classified as *Haplic Luvisol* according to the international soil classification (FAO). The soil was of medium phosphorus and potassium availability to plants, with levels in range of 57.5 mg P $\cdot$kg of $soil^{-1}$ and 152 mg $K \cdot kg\ soil^{-1}$, respectively. The soil was slightly acidic (pH 5.6). To all treatment types phosphorus and potassium were added in stable doses which attained 34.5 kg $P \cdot ha^{-1}$and 83 kg $K \cdot ha^{-1}$, respectively. Phosphorus was added as triple superphosphate following the forecrop harvest, while potassium in the form of potassium salt (60% KCl). Mineral nitrogen was applied as ammonium sulphate (34% N) in doses divided in accordance with the experimental design. The first dose (60 kg $N \cdot ha^{-1}$) was added after vegetation started. The subsequent N doses (60 + 60 $kg \cdot ha^{-1}$) were applied after harvesting I and II swath, respectively. Based on the soil moisture level the needs for irrigation were determined and wetting level in irrigated objects was maintained at 70% field water capacity. Irrigation frequency was assessed based on the decrease of soil water content below the adopted reference value of field water capacity. Spring barley was the forecrop for grasses in all years of cultivation. Grasses in the amount of 40 $kg \cdot ha^{-1}$ were sown in August, using a mechanical drill. Dates of grass mowing varied between the years of observation. Taking into account 10-day intervals the mowing dates were as follows: I swath – beginning of the last third of May; II swath – the last third of June; III swath – end of the second third of July.

In the appropriately pretreated plant material, following dry mineralization at the temperature of 550ºC, the ash was dissolved in diluted nitric acid (concentrated 65% nitric acid diluted 1: 1 with distilled water). The concentration of phosphorus in the resulting solution was determined colorimetrically with vanado-molybdate. The results of study were statistically analyzed by MANOWA. When synthesizing the results of the four-year long study, the subsequent years were accounted for as replications. The significance of differences between means was tested using Tukey test at significance level $\alpha < 0.05$. All computations were performed using Microsoft Excel© 2007 and Statistica© 10.

3. Results of study and discussion

At a time of intensification of plant production it is important to evaluate the content of elements in subsequently harvested grass yields from the viewpoint of nutritive and forage values. The chemical composition of grasses is vital for the assessment of their biological value. A normal content of mineral elements in plant biomass constitutes a basic problem agrotechnically and it is also an important qualitative feature which may be used as a criterion for forage assessment. Owing to the well developed root systems, grass species are able to intensively take up phosphorus from soils. Numerous works provide evidence that grass root systems are several times more robust than those of grain crops or of other cultivated plants. Additionally, root system surface that adsorbs phosphorus is considerably enlarged by root hairs. The capacity to absorb phosphorus and the rate of P uptake depends largely not only on the species of plant but also, in cases of some grasses, such as e.g. the bentgrass, on its variety [2].

The content of phosphorus in the examined grass species varied due to experimental factors and timing of respective harvests. The species of grass and level of nitrogen fertilization were among factors that influenced the content of phosphorus in the first swath (Table 1). From among the three species examined, the highest contents of the element were found in orchard grass, whereas the lowest P contents were determined in hybrid ryegrass. Regardless the species of grass, the content of phosphorus in the first swath fluctuated below the normative value (3 $g \cdot kg^{-1}$), even thought the grasses were grown under conditions of good supply of available phosphorus. Nitrogen fertilization resulted in a significant increase in the phosphorus content in plant biomass. The between-treatment variation came down to the significance of contrast: plots without nitrogen addition versus all other fertilized plots. The mechanism of cooperation between nitrogen and phosphorus is well documented in the literature [8]. The status of nitrogen plant nutrition dictates the uptake of phosphorus by plants. No significant interaction was found between the water factor, the species of grass and nitrogen fertilization, however there was noted an increasing trend in phosphorus content on irrigated plots. The above relationship emphasizes the importance of water for the uptake of phosphorus. Whereas, water stress considerably decreases the rate of phosphorus uptake by plants to the point that the process is reduced under conditions of water deficit even in soils rich in P [6]. Periodically occurring symptoms of P deficit in plants may result from its lowered mobility in the soil. Phosphorus transportation towards roots is ruled by diffusion process [17]. These occur more rapidly in moist environments. Additionally, water deficit leads to acceleration of processes of precipitation and crystallization of amorphic bonds created by phosphorus with aluminum and calcium [11]. The mobility of phosphorus in the soil is very limited as compared to that of other mineral elements as P compounds are strongly bound by the soil [1].

The content of phosphorus in grass biomass in the second swath varied significantly due to both the water factor and grass species as well as to a level of nitrogen fertilization. Regardless of the species of grass, an increase in phosphorus content was noted as compared to the first swath. The highest levels of P were found in the case of orchard grass, likewise swath. Differentiated nitrogen fertilization led to differences in the content of P between the treatments without nitrogen addition and those treated with fertilizers (Table 2). Even thought that no significant interaction was found between the water factor and nitrogen fertilization, the trend of rising P content was observed in grass biomass due to irrigation and increased N fertilization levels. When comparing the contents of P in the three swaths, the highest levels of P content were determined in the third swath. The levels fluctuated, depending upon the variant, within the range from 3.3 to 4 g·kg^{-1} (Table 3). The increase in P content in grass biomass of the third swath is strongly related to the level of grass yields, which were lowest for the III swath (data may be provided by the authors).

Table 1. Effect of irrigation and nitrogen fertilization on phosphorus content in grasses harvested in 1st cut, g·kg^{-1}

Water variant (A)	Grass species (B)	Nitrogen fertilization (C) kg N·ha^{-1}			
		0	60	120	180
Irrigated	Italian ryegrass *Lolium multiflorum*	2.25	2.30	2.36	2.30
	Hybrid ryegrass *Lolium hybridum*	2.28	2.54	2.52	2.74
	Orchard grass *Dactylis glomerata*	2.50	2.17	2.73	2.73
Non- irrigated	Italian ryegrass *Lolium multiflorum*	2.15	2.33	2.22	2.23
	Hybrid ryegrass *Lolium hybridum*	2.24	2.53	2.48	2.61
	Orchard grass *Dactylis glomerata*	2.53	2.46	2.50	2.56
LSD $_{\alpha= 0.05}$	A – r.n; B – 0.135; C – 0.156; AxB – r.n.; AxC – r.n.; BxC – r.n.; AxBx C – r.n.				

A, B, C –experimental factors
n.s. – non significant differences

Source: Own work

Table 2. Effect of irrigation and nitrogen fertilization on phosphorus content in grasses harvested in 2nd cut, g·kg^{-1}

Water variant (A)	Grass species (B)	Nitrogen fertilization (C) kg N·ha^{-1}			
		0	60	120	180
Irrigated	Italian ryegrass *Lolium multiflorum*	2.85	3.07	3.17	3.04
	Hybrid ryegrass *Lolium hybridum*	2.96	3.03	3.45	3.48
	Orchard grass *Dactylis glomerata*	3.29	3.07	3.43	3.60
Non- irrigated	Italian ryegrass *Lolium multiflorum*	2.69	2.71	2.86	2.88
	Hybrid ryegrass *Lolium hybridum*	2.88	2.86	2.98	3.07
	Orchard grass *Dactylis glomerata*	3.14	3.08	2.97	3.08
LSD $_{\alpha= 0.05}$	A – 0.129; B – 0.158; C – 0.183 AxB – n.i.; AxC – n.i.; BxC – n.i.; AxBxC – n.i.				

Explanation of abbreviations under the Table 1.

Source: Own work

Table 3. Effect of irrigation and nitrogen fertilization on phosphorus content in grasses harvested in 3rd cut, g·kg^{-1}

Water variant (A)	Grass species (B)	Nitrogen fertilization (C) kg N·ha^{-1}			
		0	60	120	180
Irrigated	Italian ryegrass *Lolium multiflorum*	3.91	4.06	3.87	4.06
	Hybrid ryegrass *Lolium hybridum*	3.71	3.76	3.79	3.87
	Orchard grass *Dactylis glomerata*	3.65	3.91	3.82	3.57
Non- irrigated	Italian ryegrass *Lolium multiflorum*	3.30	3.45	3.45	3.74
	Hybrid ryegrass *Lolium hybridum*	3.46	3.23	3.26	3.29
	Orchard grass *Dactylis glomerata*	3.39	3.46	3.40	3.23
LSD $_{\alpha= 0.05}$	A – 0.146; B – r.n.; C – r.n. AxB – r.n.; AxC – r.n.; BxC – r.n.; AxBxC – r.n.				

Source: Own work

From among the experimental factors examined, only the water factor was found to have a significant effect on the content of phosphorus in the third swath. The average P content in irrigated treatments attained 3.83 $g \cdot kg^{-1}$ and was by 13% higher than in not irrigated treatments. The results of analysis of P contents in the three swaths show that P contents in grass significantly depended upon the course of meteorological conditions. During the experiment years, the distribution of precipitation and temperatures showed a great year to year variability. The most favourable course of weather conditions was noted in the first year, while the year 2003 was especially unfavourable since precipitation deficit extended over the entire vegetation season, in addition to high air temperatures. The deficit of water in not irrigated variants resulted in accelerated vegetation and earlier maturation and drying of plants. The irrigation is of basic importance in order to counteract negative effects of unfavourable distribution of precipitation [13, 21], however, for economic reasons this measure is mainly applied in special cultivation such as potatoes and vegetables as well as under conditions of field experiments.

4. Conclusions

1. From among the three grass species examined it was orchard grass that accumulated the highest contents of phosphorus, regardless the timing of mowing.
2. Nitrogen fertilization was found to favor the increase of phosphorus content in grasses, however, the dose of N was of secondary importance as there were no significant differences between the treatments fertilized with differentiated nitrogen rates.
3. Water availability was found to significantly influence of phosphorus in grass notwithstanding harvest.

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