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INFLUENCE OF GROWTH REGULATORS AND PHOSPHORUS FERTILIZATION RATES ON NITROGEN BALANCE IN SPRING WHEAT

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Abstract

A pot experiment was carried out on cv. Jasna spring wheat grown on light loamy sand soil. The soil was slightly acidic in reaction and moderately abundant in available phosphorus, potassium and magnesium. Consistent NKMg fertilization rates (1.5 g N, 1.5 g K and 0.25 g Mg) were accompanied by increasingly high doses of phosphorus (0.0 to 1.02 g P per pot). In order to compare the effect produced by growth regulators, applied in conjunction with the growing phosphorus doses, the pots were split into four groups, depending on the sprays applied: distilled water (control), kinetin, gibberellin and auxin. The target was to determine the influence of plant hormones and phosphorus fertilization on nitrogen balance in spring wheat. The content of nitrogen in wheat grain depended mainly on the phosphorus fertilization level, the relationship which became particularly evident following auxin and kinetin application. The highest N concentration occurred when 0.85 g P per pot was used. The growth regulators, auxin and gibberellin in particular, depressed the concentration of nitrogen in grain. The level of nitrogen in glumes and stems was only slightly dependent on the level of phosphorus nutrition. In leaves, it was negatively correlated with the doses of phosphorus. The phytohormones depressed the concentration of nitrogen in stems, oldest leaves and in the flag leaf, raising it in the penultimate leaf. The uptake and accumulation of nitrogen in grain tended to increase up to the phosphorus rate of 0.68 g P per pot. The growth regulators inhibited the accumulation of nitrogen in aerial organs of wheat, especially in grain. Gibberellin, in turn, increased the accumulation of nitrogen in glumes and stems. The contribution of grain in nitrogen accumulation ranged from 62% (without P fertilization) to 68% when 0.68 g P per pot was applied. The growth regulators, especially gibberellin, decreased the ratio of nitrogen accumulated in grain. Protein yield per plant, except wheat sprayed with gibberellin, increased proportionately to the rate of phosphorus.

Key words: spring wheat, phosphorus fertilization, nitrogen, growth regulators.

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WPŁYW REGULATORÓW WZROSTU I POZIOMU NAWOŻENIA FOSFOREM NA GOSPODARKĘ AZOTEM W ROŚLINACH PSZENICY JAREJ

Abstrakt

W doświadczeniu wazonowym, na glebie o składzie granulometrycznym piasku gliniastego lekkiego, uprawiano pszenicę jarą odmiany Jasna. Gleba charakteryzowała się lekko kwaśnym odczynem i średnią zasobnością w przyswajalny fosfor, potas i magnez. Na tle stałego nawożenia NKMg (1,5 g N, 1,5 g K i 0,25 g Mg) zastosowano wzrastające fosforu (0,0-1,02 g P na wazon). W celu porównania działania regulatorów wzrostu, stosowanych w warunkach wzrastających dawek fosforu, wazony podzielono na 4 grupy, w zależności od stosowanych oprysków: woda destylowana (kontrola), kinetyna, giberelina i auksyna. Celem pracy było określenie wpływu regulatorów wzrostu i poziomu nawożenia fosforem na gospodarkę azotem w roślinach pszenicy jarej. Zawartość azotu w ziarnie zależała od poziomu nawożenia fosforem, zwłaszcza po oprysku auksyną i kinetyną. Najwyższą koncentrację N uzyskano po zastosowaniu 0,85 g P na wazon. Regulatory wzrostu, zwłaszcza auksyna i giberelina, zmniejszyły koncentrację azotu w ziarnie. Zawartość azotu w plewach i źdźble w niewielkim stopniu zależała od poziomu nawożenia fosforem, natomiast w liściach była ujemnie skorelowana z dawką P. Fitohormony zmniejszyły koncentrację azotu w źdźble, najstarszych liściach i liściu flagowym, a zwiększyły w podflagowym. Pobranie i akumulacja azotu w ziarnie wzrastały do dawki 0,68 g P na wazon. Regulatory wzrostu zmniejszyły akumulację azotu w nadziemnych organach pszenicy, szczególnie w ziarnie, a pod wpływem gibereliny zwiększyło się nagromadzenie tego składnika w plewach i źdźble. Udział ziarna w gromadzeniu azotu wahał się od 62% (bez nawożenia P) do 68% po zastosowaniu 0,68 g P na wazon. Regulatory wzrostu, zwłaszcza giberelina, zmniejszyły udział ziarna w gromadzeniu tego składnika. Plon białka z rośliny, z wyjątkiem pszenicy opryskiwanej gibereliną, wzrastał proporcjonalnie do dawki fosforu.

Słowa kluczowe: pszenica jara, nawożenie fosforem, azot, regulatory wzrostu.

INTRODUCTION

Spring wheat constitutes about 5% of all sown cereals. The nutritional value of spring wheat grain is often superior to that of winter wheat grain (KACZYŃSKI 2002). Quality cultivars of spring wheat should produce grain containing at least 12.5% protein and over 26% gluten, which guarantees good baking quality of wheat flour. Fertilization is one of the major factors which determine the volume and quality of yields. In order to obtain high, good quality grain yield, it is necessary to provide wheat with all essential nutrient throughout the whole growing season. It is crucial that wheat plants receive good nitrogen fertilization, which stimulates high yields, but it is of equal importance that wheat is well supplied with phosphorus, potassium and magnesium. Wheat plants which receive enough phosphorus form larger grains and mature earlier. Phosphorus has beneficial influence on the synthesis and quality of proteins and carbohydrates. It can also alleviate negative effects of excessive nitrogen fertilization. In cereal crops, phosphorus conditions proper root system growth and tillering (VALIZADEH et al. 2002, SANDER et al. 1991).

Biologically active substances which act as growth regulators can modify metabolic responses of plants in a way that is economically and agriculturally profitable, but without producing a reproducible effect. Growth regulators can indirectly affect the uptake of nutrients by plants, their further transport and remobilization during the formation of grains. This indirect effect is a consequence of the root system, particularly root hairs, being better developed, which means that the plants absorb mineral components from soil and fertilizers more effectively. The response of plants to phytohormones is highly diverse and depends on the age and physiological state of a plant, environmental conditions as well as synergic or antagonistic reactions between endogenous and exogenous phytohormones.

The aim of the present study has been to determine the effect of growth regulators and phosphorus fertilization doses on the nitrogen balance in spring wheat.

METHODS

The experiment, with four replications, was established in Mitscherlich pots filled with 6.5 kg of light loamy sand, whose reaction was 6.4 pH in 1mol $KCL \cdot dm^{-3}$ and which was moderately abundant in available phosphorus, potassium and magnesium. The following mineral fertilization regime was applied: 1.5 g N [NH_4NO_3]; 0.0 – 1.02 g P[$Ca(H_2PO_4O_2 \cdot H_2)$], 1.5 g K [KCl and K_2SO_4 at a 1 : 1 ratio], 0.25 g Mg [$MgSO_4 \cdot 7H_2O$] per pot. All of the P and Mg rates and half the doses of N and K were added to soil before sowing wheat. The remaining portions of the nitrogen and potassium fertilizers were applied in 2 equal doses – at the early inflorescence and the ear shooting stages. Twenty cv. Jasna wheat plants were grown in each pot. In order to compare the results produced by growth regulators under the effect of increasing phosphorus fertilization rates, the pots were divided into 4 groups (Table 1). Each spraying treatment consisted of an application of 0.5 dm^3 of a liquid containing 50 $mg \cdot dm^{-3}$ of a growth regulator.

Wheat was harvested at the full maturity stage. Following the biometrical measurements, wheat plants were dissected into organs: grains, glumes including rachises, stems, flag leaf, penultimate leaf and other leaves. The plant material was ground and digested with concentrated sulphuric acid supplemented with hydrogen dioxide as an oxidizer. Finally, nitrogen was determined with Kjeldahl method.

Table 1

Design of the application of the plant growth regulators

Experiment variant	Spraying time and plant growth applied	
	beginning of tillering	beginning of flowering
I – control (C)	aqua destillata	aqua destillata
II – kinetin (K)	BAP (benzylaminopurine)	FAP (phurphurilaminopurine)
III – gibberellin (G)	GA_3 (gibberellic acid)	GA_3 (gibberellic acid)
IV – auxine (A)	IAA (indole-3-acetic acid)	NAA (naphthaleneacetic acid)

RESULTS

The up-to-date results of experiments indicate that plant hormones can raise concentration of nitrogen in grains (Wierzbowska et al. 2006, Wierzbowska et al. 2002, Wierzbowska, Nowak 1999). Harms and Nowak (1990a, b) suggest that this effect is an outcome of inhibited aging of plants, particularly the flag leaf, and induced activity of enzymes responsible for remobilization of nitrogen compounds in vegetative organs of plants. As a result, the content of proteins in grains rises at the cost of decreasing amounts of nitrogen in straw.

However, the present research has revealed contrary effects. The growth regulators tested depressed the content of nitrogen in wheat grain compared to the control (Table 2). Auxin and gibberellin in particular proved to produce adverse influence, depressing the concentration of nitrogen in grain by 21.6 and 15.6%, respectively. The content of nitrogen in wheat grain depended on the phosphorus fertilization doses, especially in the case of wheat sprayed with auxin (r=0.94) and kinetin (r=0.68), but also – to a somewhat lesser degree – the control plants (r=0.50). On average, the highest nitrogen concentration was obtained using 0.85 g P per pot. The highest phosphorus dose depressed the concentration of nitrogen in grain of all wheat plants except these treated with kinetin. Application of gibberellin caused an unprecedented decline in grain concentration of nitrogen, below that found in the grain of wheat not fertilized with phosphorus.

Gibberellin and auxin raised the concentration of nitrogen in glumes by 13.4 ad 6.7%, respectively. The growth regulators, and auxin in particular (a 26.4% decrease) depressed the content of nitrogen in wheat stems. Both in wheat glumes and stems, the content of nitrogen was only weakly dependent on the level of phosphorus nutrition. Gibberellin and auxin depressed the content of nitrogen in the flag leaf by about 17%, while raising it, along with kinetin, in the penultimate leaf. The concentration of nitrogen in the flag and penultimate leaves was largely dependent on the phosphorus dose, typically decreasing as the rate of phosphorus went up, except

Table 2

Nitrogen content (g N · kg^{-1} d.m.)

Plant growth regulators	Dose P (g per pot)							Mean	*r*
	0.00	0.17	0.34	0.51	0.68	0.85	1.02		
Grain									
C	28.00	30.60	29.80	28.90	29.80	30.60	28.90	29.51	0.50
K	26.80	27.10	28.00	28.90	31.50	32.40	28.40	29.01	0.68
G	24.50	21.90	25.40	26.30	26.30	26.30	23.60	24.90	0.32
A	21.90	21.90	21.90	23.60	23.60	24.50	24.50	23.13	0.94
Mean	25.30	25.38	26.28	26.93	27.80	28.45	26.35	-	0.25
Glume									
C	8.80	10.50	12.20	12.20	8.80	7.00	12.20	10.24	-0.14
K	14.00	8.80	7.00	8.80	10.50	9.60	12.20	10.13	-0.01
G	10.50	12.20	12.20	10.50	14.00	10.50	11.40	11.61	-0.30
A	10.50	14.00	12.30	7.90	12.30	9.00	10.50	10.93	-0.36
Mean	10.95	11.38	10.93	9.85	11.40	9.03	11.58	-	0.13
Stem									
C	5.30	3.50	6.10	6.10	5.30	3.50	3.50	4.76	-0.39
K	5.00	3.50	3.50	5.30	3.50	3.50	5.30	4.22	0.00
G	5.30	3.50	5.30	5.30	3.50	5.30	3.50	4.53	-0.29
A	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	0.00
Mean	4.78	3.50	4.60	5.05	3.95	3.95	3.95	-	-0.21
Flag leaf									
C	17.50	17.50	15.80	19.30	14.00	15.80	13.70	16.22	-0.85
K	15.80	22.80	19.30	17.50	15.80	12.30	10.50	16.29	-0.75
G	15.80	17.50	12.30	12.30	10.50	15.80	10.50	13.53	-0.58
A	12.30	15.80	12.30	16.60	15.80	10.50	10.50	13.40	-0.37
Mean	15.35	18.40	14.93	16.43	14.03	13.60	11.30	-	-0.65
Penultimate leaf									
C	19.30	17.50	15.80	15.80	21.00	15.80	15.80	17.29	-0.32
K	22.80	22.80	22.80	20.10	15.70	15.70	17.50	19.63	-0.87
G	19.30	21.00	22.80	21.00	17.50	19.30	17.50	19.77	-0.56
A	14.00	12.30	20.50	22.80	17.50	19.30	17.50	17.70	0.46
Mean	18.85	18.40	20.48	19.93	17.93	17.53	17.08	-	-0.32
Remaining leaves									
C	10.50	12.30	12.30	10.50	8.80	8.80	8.80	10.29	-0.77
K	8.80	7.00	8.80	12.30	8.80	7.00	7.00	8.53	-0.22
G	5.30	7.00	7.00	10.50	7.00	7.00	10.50	7.76	0.61
A	7.00	5.30	7.00	5.30	7.30	7.00	10.50	7.06	0.64
Mean	7.90	7.90	8.78	9.65	7.98	7.45	9.20	-	0.08

C – control, K – kinetin, G – gibberellin, A – auxine, *r* – correlation coefficient when wheat was treated with auxin. In the other leaves, the plant hormones considerably depressed (16-31%) the content of nitrogen. In the oldest leaves of the control plants (r=-0.77) and plants sprayed with kinetin, the concentration of nitrogen decreased; in plants treated with gibberellin (r=-0.61) and auxin (r=-0.64), the nitrogen concentration in the oldest leaves increased in proportion to the doses of phosphorus.

The uptake of nitrogen by wheat plants and accumulation of this nutrient in grain tended to be larger up to the rate of 0.68 g P per pot, and the nitrogen increment obtained versus the wheat plants not fertilized with phosphorus was 38 and 24%, respectively (Figure 1). The growth regulators, due to depressed yields and lower N concentrations, had a negative effect on the uptake and accumulation of nitrogen in wheat grain. Gibberellin and auxin sprays depressed the nitrogen uptake by plant by about 18%; the accumulation of nitrogen in wheat plants was about 25% lower versus the control.

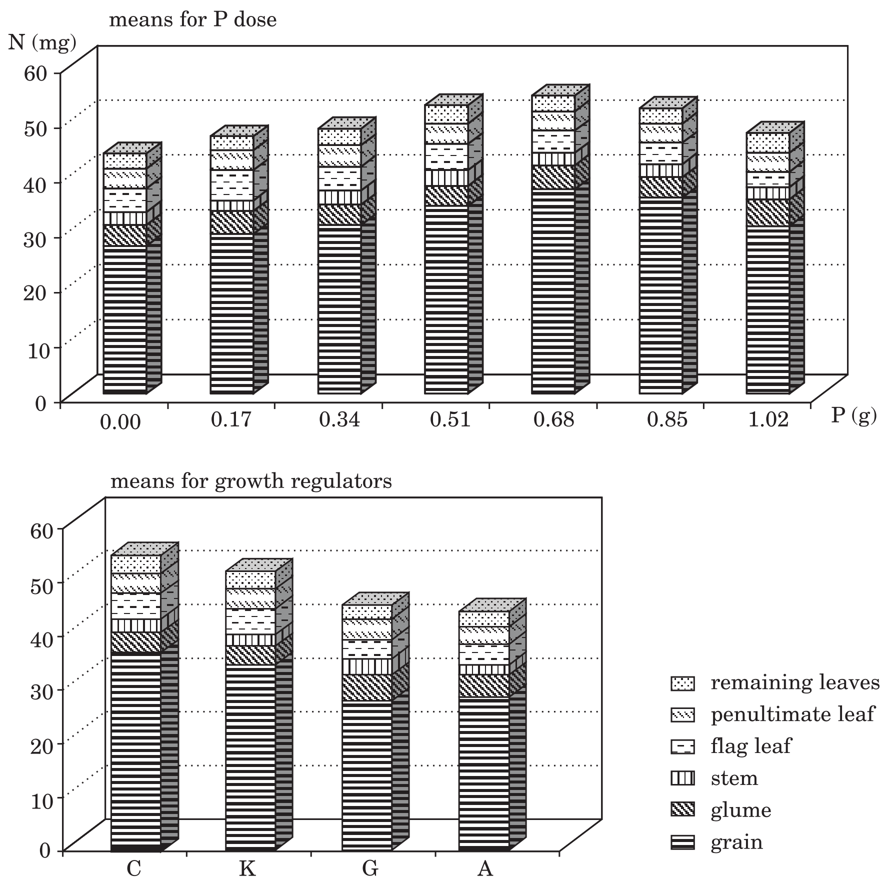

Fig. 1. Nitrogen accumulation (designations as in Table 2)

Kinetin produced the weakest effect, as it depressed the nitrogen uptake and accumulation in grain by just about 6%.

Increasing phosphorus fertilization from 0 to 0.68 g P per pot resulted in a larger participation of wheat grain in nitrogen accumulation (from 61.6 to 68.2%, Figure 2). The highest P doses depressed the contribution of grain to the total nitrogen accumulation while the percentage of nitrogen accumulated in glumes rose. Out of the three tested plant hormones, gibberellin produced the least desirable effect. Under the influence of gibberellin, compared to the control, the percentage of nitrogen accumulated in grain declined by 6% while its concentration in glumes and stems increased.

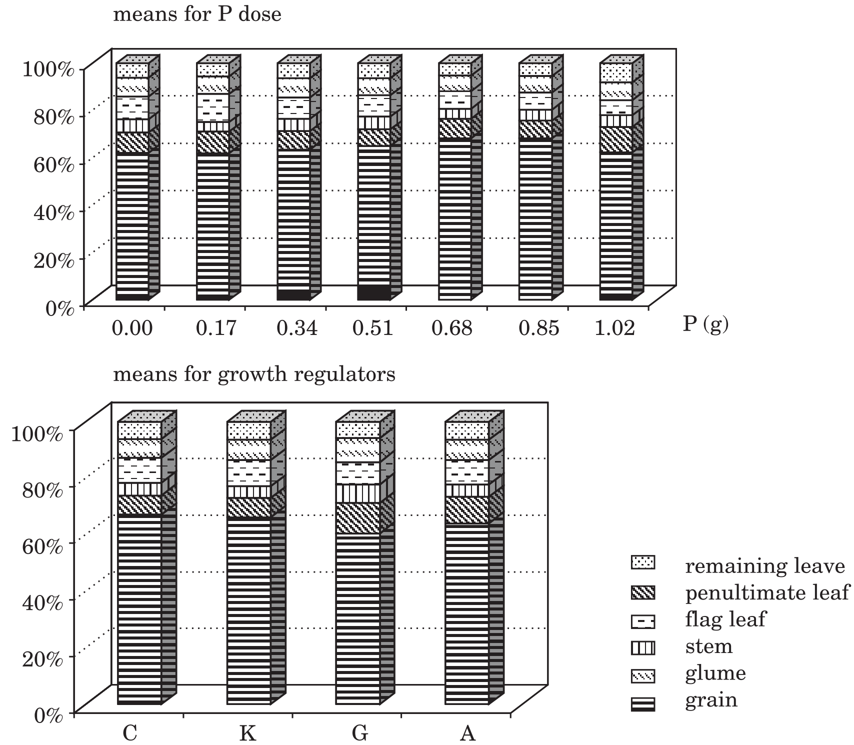

Fig. 2. Nitrogen distribution (designations as in Table 2)

Protein yield produced by the control (r=0.91) and auxin- (r=0.97) or kinetin-treated (r=0.62) wheat plants depended on the level of phosphorus fertilization. According to Ragastis et al. (1999), high rates of nitrogen and phosphorus improve wheat grain quality parameters, especially the content of gluten and farinogram properties. The major criterion used for assessment of baking quality of flour is how much good quality protein it contains (Cygankiewicz 1997). The effect of phosphorus fertilization on total protein

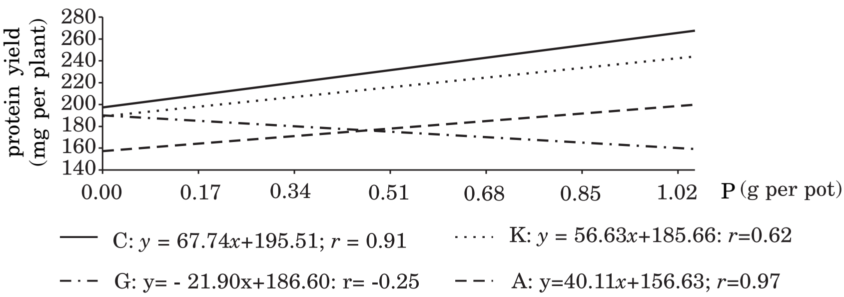

Fig. 3. Protein yield (designations as in Table 2)

and gluten concentration in wheat grain and, consequently, on the baking value of flour produced from this grain is not unilateral. It is often claimed that good baking quality of wheat flour can be obtained by using high nitrogen fertilization rates in combination with proper phosphorus and potassium nutrition. Others claim that on soils which are rich in phosphorus and potassium it is possible to reduce fertilization with these nutrients without any negative effect on yield and baking quality of wheat flour (KLUPCZYŃSKI et al. 2000), whereas increasing phosphorus and potassium rates applied together with constant nitrogen fertilization does not improve the baking quality of flour (KLUPCZYŃSKI et al. 2001). Likewise, studies on other cereal crops suggest that phosphorus nutrition produces a rather weak effect on nitrogen concentration in plants. CIEĆKO et al. (2006) found out that only high NK fertilization rates could slightly improve the total nitrogen and protein nitrogen concentration. On the other hand, as the doses of phosphorus went up, the content of exogenous amino acids declined. Increasing phosphorus fertilization had a very weak and variable effect on the concentration of total and protein nitrogen in grain (WIERZBOWSKA 2006).

CONCLUSIONS

1. The growth regulators, especially auxin and gibberellin, reduced the concentration of nitrogen in wheat grain. The content of nitrogen in wheat grain depended on the level of phosphorus fertilization, particularly in wheat plants treated with auxin and kinetin. The highest content of nitrogen was determined in the plants which received 0.85 g P per pot.

2. The phytohormones depressed the concentration of nitrogen in wheat stems, oldest leaves and in the flag leaf, while raising it in the penultimate leaf. The content of nitrogen in glumes and stems was only very weakly correlated with the rate of phosphorus nutrition. In leaves, the correlation between nitrogen concentration and P fertilization was negative.

3. The uptake and accumulation of nitrogen in wheat grain continued to rise up to 0.68 g P per pot. The plant hormones depressed the accumulation of nitrogen in aerial organs of wheat, especially in wheat grains. Gibberellin, however, favoured the accumulation of nitrogen in wheat glumes and stems.

4. The percentage of nitrogen accumulated in grain versus the whole wheat plant varied from 62% (no phosphorus fertilization) to 68% (0.68 g P per pot). The growth regulators, especially gibberellin, depressed the percentage of nitrogen accumulated in grains.

5. Yields of protein in the control, kinetin and auxin treated wheat plants increased proportionately to phosphorus rates.

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