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EFFECT OF GROWTH REGULATORS ON THE MINERAL BALANCE IN SPRING TRITICALE

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Abstract

It is assumed that progress in cultivar breeding corresponds to over 50% of the increase in cereal yields. Among possible ways of improving the success of fertilisation and, consequently, increasing yields and enhancing the mineral balance in crops is the application of growth regulators.

The purpose of this study has been to assess the effect of growth regulators and their doses on the mineral balance in spring triticale. The research was based on a two-factor pot experiment, completed in four replicates. The experiment was carried out in Kick-Brauckmann pots filled with light soil of slightly acidic reaction and highly abundant in available forms of P, moderately abundant in K and poor in Mg. Mineral fertilisation per pot consisted of 1.5 g N, 2.0 g K and 0.25 g Mg. Nitrogen and potassium were applied in two rates – half the complete dose before sowing and the remaining amount as top dressing during the stem elongation phase. All the rate of magnesium was introduced to soil before sowing.

Prior to sowing the tested cereal, grain of cv. Migo spring triticale was soaked for 24 hours in water (control) or in aqueous solutions of growth regulators: IBA (indole butyric acid), NAA (α-naphthaleneacetic acid), BAP (benzyl adenine): 5, 10, 20 mg dm^{-3}; GA_3 (gibberellin acid): 20, 40, 80 mg dm^{-3} and Tria (triacontanol): 0.1, 0.2, 0.2 mg dm^{-3}. Spring triticale was harvested in the full maturity stage.

An increase in the total nitrogen concentration in grain ranged from 6% following an application of GA_3 to 15% after using NAA. Owing to its increased concentration and higher yield of triticale, the accumulation of nitrogen in grain increased by about 20% in plants treated with NAA and by 15-17% when the seed material was dressed with Tria, BAP or GA_3. IBA produced the weakest effect, increasing the accumulation of this nu-

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trient in grain by just 8%. This effect was obtained mainly by improved remobilisation and transport of N from vegetative parts to grain. The contribution of grain to nitrogen accumulation varied from 63% (control) to 71-73% after an application of the tested growth regulators. Under the influence of IBA, the concentration of potassium (by 14%) and the share of straw in potassium accumulation increased. In respect of the other macronutrients, the influence of growth regulators was less evident.

Key words: spring triticale, mineral balance, growth regulators.

WPŁYW REGULATORÓW WZROSTU NA GOSPODARKĘ MINERALNĄ PSZENŻYTA JAREGO

Abstrakt

Szacuje się, że o wzroście plonów zbóż w ponad 50% decyduje postęp odmianowy. Jedną z możliwości zwiększenia efektywności nawożenia, a tym samym zwiększenia plonowania i poprawienia gospodarki mineralnej roślin, jest stosowanie regulatorów wzrostu.

Celem pracy była ocena wpływu regulatorów wzrostu i ich dawek na gospodarkę mineralną pszenżyta jarego. Podstawę badań stanowiło dwuczynnikowe doświadczenie wazonowe, wykonane w 4 powtórzeniach. Badania prowadzono w wazonach typu Kick-Brauckmanna napełnionych glebą lekką o odczynie lekko kwaśnym oraz bardzo wysokiej zasobności w przyswajalne formy P, średniej w K oraz niskiej w Mg. Nawożenie mineralne na wazon wynosiło odpowiednio: 1,5 g N, 2,0 g K oraz 0,25 g Mg. Azot i potas zastosowano w 2 dawkach – połowę przedsiewnie, a resztę pogłównie w fazie strzelania w źdźbło, natomiast magnez w całości przedsiewnie.

Przed siewem ziarno pszenżyta jarego odmiany Migo moczono 24 h w wodzie (kontrola) lub w wodnych roztworach regulatorów wzrostu: IBA (kwas indolilomasłowy), NAA (kwas α-naftylooctowy), BAP (benzyloadenina) – 5; 10; 20 mg dm^{-3}; GA_3 (kwas giberelinowy) – 20; 40; 80 mg dm^{-3} oraz Tria (triacontanol) – 0,1; 0,2; 0,2 mg dm^{-3}. Pszenżyto jare zebrano w fazie dojrzałości pełnej.

Przyrost zawartości azotu ogółem w ziarnie wahał się od 6% do 15% po zastosowaniu odpowiednio GA_3 i NAA. Na skutek zwiększonej koncentracji i przyrostu plonu, akumulacja tego składnika w ziarnie wzrosła o ok. 20% na obiektach traktowanych NAA, a 15-17% po zaprawianiu materiału siewnego Tria, BAP lub GA_3. Najsłabiej działał IBA, bowiem przyrost akumulacji tego składnika w ziarnie wynosił tylko 8%, co uzyskano głównie dzięki zwiększonej remobilizacji i odprowadzaniu N z części wegetatywnych do ziarna. Udział ziarna w akumulowaniu azotu wahał się od 63% (kontrola) do 71-73% po zastosowaniu badanych regulatorów wzrostu. Pod wpływem IBA zwiększyła się zawartość potasu (o 14%) oraz udział słomy w jego gromadzeniu. W przypadku pozostałych makroskładników działanie regulatorów wzrostu było mniej widoczne.

Słowa kluczowe: pszenżyto jare, gospodarka mineralna, regulatory wzrostu.

INTRODUCTION

The economic importance of spring triticale, compared to other cereals, is small. Observations made for many years have demonstrated that on poorer soils, triticale can produce higher yields than spring wheat. Grain of spring triticale, like that of winter forms, is considered as one of the most valuable fodder cereals owing to its high protein concentration and metabolic enegry, comparable to, and sometimes even higher than that in wheat grain (SOBKOWICZ, PODGÓRSKA 2006). The fact that triticale contains less of anti-nutritive substances creates many possibilities of using its grain for feeding purposes (KONDRACKI 2000). Moreover, triticale is the cereal whose grain can be used for human conslumtiopn (HABER, LEWCZUK 1990, SOBCZYK et al. 2009). The soil and climatic conditions as well as agronomic practice are the factors which condition the yield and amino acid composition of proteins, which in turn shape the fodder and nutritional values of triticale grain (SPYCHAJ-FABISIAK et al. 2005, STANKIEWICZ 2005). Spring cultivars of triticale are characterised by a higher concentration of proteins than winter forms (SPYCHAJ-FABISIAK et al. 2005, GIL 1995, GIL, NARKIEWICZ-JODKO 1997).

Application of growth regulators is one of the ways of improving yields and mineral balance of crops. The effect of using such substances depends on many factors, e.g. a crop species or even its cultivar, environmental conditions or fertilisation (CZAPLA et al. 2007, CZAPLA, NOGALSKA 2000a,b, WIERZBOWSKA 2006a,b, WIERZBOWSKA, BOWSZYS 2008a,b, WIERZBOWSKA et al. 2007).

The objective of this study has been to evaluate the influence of growth regulators on mineral balance in spring triticale.

MATERIAL AND METHODS

The study was based on a two-factor pot experiment, performed in four replicates. The trials were set up in Kick-Brauckmann pots, filled with 9.5 kg of light soil, slightly acidic in reaction (pH 6.4 in 1 mol KCl dm^{-3}) and very highly abundant in the available form of P (92.6 mg kg^{-1}), moderately abundant in K (104.2 mg kg^{-1}) and poor in Mg (30 mg kg^{-1}). Mineral fertilisation per pot consisted of 1.5 g N in the form of urea, 2.0 g K in the form of KCl and 0.25 g Mg as $MgSO_4 \cdot H_2O$. Nitrogen and potassium were applied in two rates: 50% before sowing and the remaining amount as top dressing during the stem elongation phase; in contrast, all magnesium was introduced to soil before sowing.

In each pot, 25 plants of cv. Migo spring triticale were grown. Before sowing, seeds of spring triticale were soaked for 24 hours in water (control) or in aqeous solutions of growth regulators (Table 1). Triticale was harvested in the full maturity phase. The plant material, having been mineralised in concentrated sulphuric (VI) acid with an addition of hydrogen peroxide, was assayed to determine the concentration of nitrogen (spectrophotometrically with the hypochlorite method), phosphorus (with the vanadium-molybdene method), potassium and calcium (with the flame photometric method, ASA) and magnesium (with the atomic absorption method, AAS).

Table 1

Design of the experiment

Variant	Dose of growth regulators (mg dm^{-3})		
	I	II	III
Control (aqua destillata)			
IBA	5	10	20
NAA	5	10	20
GA3	20	40	80
BAP	5	10	20
Tria	0.1	0.2	0.4

The results of the chemical analyses underwent analysis of variance. Tukey's test at the level of significance α=0.01 wads performed in order to verify the data.

DISCUSSION OF THE RESULTS

The concentration of macronutrients in cereal grains changes depending on the weather conditions, soil abundance and agronomic practice. Growth regulators had a significant effect on the total nitrogen concentration in spring triticale grain (Table 2). The highest increase (by 14.8% in the concentration of this nutrient was obtained when the seed material had been treated with synthetic auxin NAA). The other phytohormones raised the concentration of nitrogen by 6.2-7.8% versus the control. Triacontanol increased the concentration of phosphorus and potassium in grain by *ca* 7% and that of magnesium by over 18%. Compared to the control, the concentration of nitrogen in husks decreased under the influence of phytohormones by 56-61%. Moreover, the auxins (IBA and NAA) and gibberillin depressed the concentration of phosphorus by about 25% while NAA and BAP significantly decreased the concentration of P in straw. In turn, the concentration of potassium in straw rose significantly after treating the seed material with the growth regulators.

BRZOZOWSKA (2006) points to the fact that some herbicides can cause an increase in the concentration of total nitrogen in winter triticale grain but do not have any effect on the concentration of other macronutrients. CZAPLA et al. (2007) concluded that growth regulators and their mixtures with magnesium sulphate VI differentiated the concentration of nitrogen and magnesium in spring triticale. Triticale grain was characterised by a higher concentration of these nutrients after an application of any of the growth regulators (except Tria); however, when the growth regulators were applied together with magnesium sulphate (VI), the concentration of nitrogen gen-

Table 2

Concentration of macronutrients (g kg^{-1})

Growth regulator (pgr)	Concentration (mg dm^{-3})	Grain					Husk					Straw				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Control		25.60	3.80	3.60	0.20	1.10	13.70	1.40	8.50	1.10	0.70	11.40	0.80	18.70	3.80	1.10
IBA	5	27.20	3.80	3.60	0.30	1.20	4.00	1.00	8.30	1.10	0.60	8.80	0.60	20.70	4.00	1.20
	10	27.40	3.80	3.60	0.30	1.20	6.20	1.20	8.30	1.30	0.60	10.80	0.80	21.20	4.80	1.30
	20	27.60	3.70	3.60	0.30	1.00	8.00	1.00	8.70	1.20	0.60	12.40	0.80	22.00	6.40	1.70
Mean for IBA		27.40	3.77	3.60	0.30	1.13	6.07	1.07	8.43	1.20	0.60	10.67	0.73	21.30	5.07	1.40
NAA	5	28.80	4.10	3.80	0.20	1.30	8.00	1.00	8.70	1.20	0.60	10.20	0.80	20.00	4.40	1.20
	10	30.60	3.80	3.80	0.20	1.30	5.40	1.00	9.40	1.20	0.60	11.00	0.60	20.00	4.20	1.20
	20	28.80	3.60	3.40	0.20	1.00	4.00	1.00	9.40	1.20	0.50	10.80	0.80	20.00	4.00	1.10
Mean for NAA		29.40	3.83	3.67	0.20	1.20	5.80	1.00	9.17	1.20	0.57	10.67	0.73	20.00	4.20	1.17
GA_3	20	26.40	3.90	3.80	0.20	1.20	4.00	1.00	8.50	1.20	0.60	10.20	0.80	18.50	3.20	1.10
	40	27.20	3.90	3.60	0.20	1.20	6.20	1.00	8.10	1.20	0.60	11.00	0.90	19.40	4.00	1.20
	60	28.00	4.00	3.80	0.30	1.30	7.00	1.10	9.20	1.30	0.60	11.00	0.80	19.80	4.00	1.30
Mean for GA_3		27.20	3.93	3.73	0.23	1.23	5.73	1.03	8.60	1.23	0.60	10.73	0.83	19.23	3.73	1.20
BAP	5	27.60	3.90	3.60	0.20	1.20	5.40	1.30	9.40	1.40	0.60	11.00	0.60	20.00	5.00	1.20
	10	28.00	3.80	3.60	0.20	1.20	5.40	1.60	9.20	1.20	0.60	12.00	0.70	18.40	3.30	1.10
	20	27.20	3.80	3.80	0.20	1.20	4.00	1.10	9.00	1.20	0.60	10.20	0.60	19.80	3.80	1.10
Mean for BAP		27.60	3.83	3.67	0.20	1.20	4.93	1.33	9.20	1.27	0.60	11.06	0.63	19.40	4.03	1.13
Tria	0.1	27.20	3.80	3.60	0.20	1.30	4.00	1.30	8.50	1.20	0.60	11.00	0.80	20.00	4.60	1.30
	0.2	28.80	4.20	4.00	0.30	1.30	5.80	1.30	9.00	1.20	0.60	12.80	0.80	20.00	4.40	1.30
	0.4	26.80	4.20	4.00	0.20	1.30	5.40	1.30	8.30	1.10	0.60	11.00	0.90	20.00	4.10	1.30
Mean for Tria		27.60	4.07	3.87	0.23	1.30	5.07	1.30	8.60	1.17	0.60	11.60	0.83	20.00	4.37	1.30
$LSD_{0.01}$ for pgr		1.263	0.258	0.265	n.i.	0.157	2.530	0.288	0.606	n.i.	n.i.	n.i.	0.139	0.928	n.i.	n.i.

erally declined, both in grain and in vegetative parts. Mixtures of the growth regulators with magnesium sulphate increased the content of Mg in the flag leaf.

In another study on spring wheat, growth regulators, especially auxin and gibberellin, depressed the concentration of nitrogen in grain and vegetative of wheat except the second leaf (WIERZBOWSKA, BOWSZYS 2008a). Some other investigations have demonstrated that under the influence of kinetin and auxin, the concentration of potassium in grain and vegetative organs of spring wheat increased but decreased under the effect of gibberellin (WIERZBOWSKA 2006a). In turn, the concentration of calcium in wheat plants was more strongly dependent on growth regaulators than on the rate of potassium fertilisation. Growth regulators only slightly raised the concentration of magnesium in grain, but distinctly decreased its level in stems and leaves (WIERZBOWSKA 2006b). In turn, foliar application of NAA and magnesium sulphate (VI) increased the concentration of macronutrients in spring barley grain and modified their concentration in vegetative parts of this crop (CZAPLA, NOGALSKA 2000b).

In the present study, the highest protein yield per pot (8.53 g) was obtained after an application of NAA and the lowest one (7.68 g) when seeds were treated with another synthetic auxin, namely IBA. It was found out that the volue of protein yield per pot rose correspondingly to doses of growth regulators, but it was only when the seed material had been treated with IBA that the highest protein yield was obtained as a result of the application of the second rate of this phytohormone (Figure 1).

Compared to the control, when IBA had been applied, the uptake of nitrogen with the spring triticale's biomass slightly rose, in contrast to the other growth regulators, which caused its small decline (Figure 2). Under the influence of the phytohormones, the accumulation of nitrogen in grain increased, especially when NAA and GA_3 had been applied as they raised the accumulation of this nutrient by about 20%. Except IBA, the growth regulators caused enhanced accumulation of phosphorus in the biomass and in grain (from 6% by NAA and BAP to 12% by GA_3 and Tria). IBA and triacontanol increased by 7% the accumulation of potassium in the aerial biomass of triticale, mainly in straw.

By treating the seed material with the growth regulators, it was possible to increase the contribution of grain to nitrogen accumulation in triticale's aerial biomass, mainly by decreasing (2.5- to 3-fold) the share of husks in the accumulation of this element. Compared to the control, NAA limited the distribution of potassium, calcium and magnesium to grain, but led to an increased accumulation of these elements in straw. A reverse tendency was observed under the influence of gibberellin.

WIERZBOWSKA and BOWSZYS (2008a) demonstrated that growth regulators caused a decrease in the accumulation of nitrogen in aerial parts of wheat, especially in grain, but under the effect of gibberellin, the accumulation of this nutrient in husks and stems rose. The contribution of grain to the

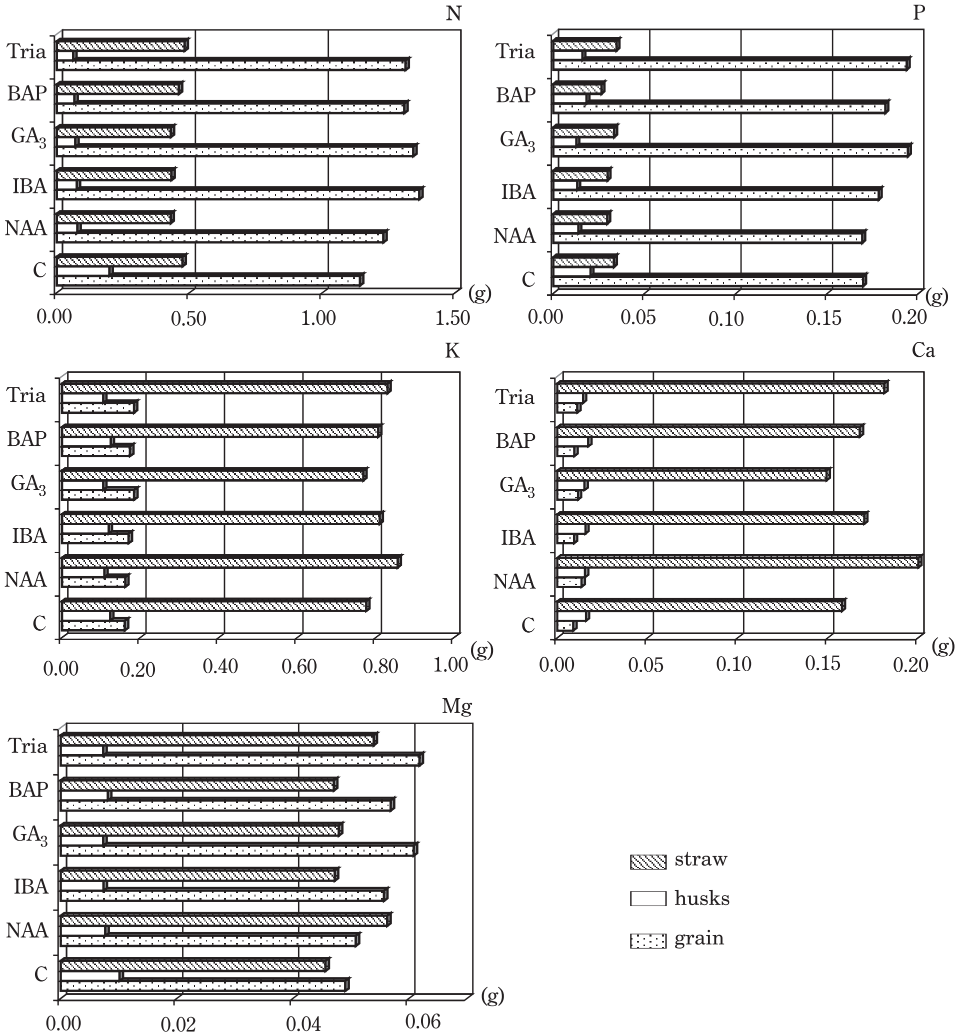

Fig. 1. Accumulation of macronutrients in organs of spring triticale

accumulation of nitrogen ranged from 62 to 68%. The growth regulators, especially gibberellin, depressed the contribution of grain in the accumulation of this nutrient. A study conducted by KLIKOCKA and KOMISARCZUK (2000) proved that as the nitrogen fertilisation level rises, so does the concentration and accumulation of magnesium in spring triticale grain. In contrast, simplifications in soil tillage lead to depressed concentrations of Mg in grain.

Under the effect of the growth regulators (excpet GA_3), the K:(Ca+Mg) ratio in grain and straw of triticale became narrower but the ratio of these ions in husks broadened (Figure 4). Under the influence of the tested phytohormones, the Ca:P mol ratios in vegetative organs of triticale became broad-

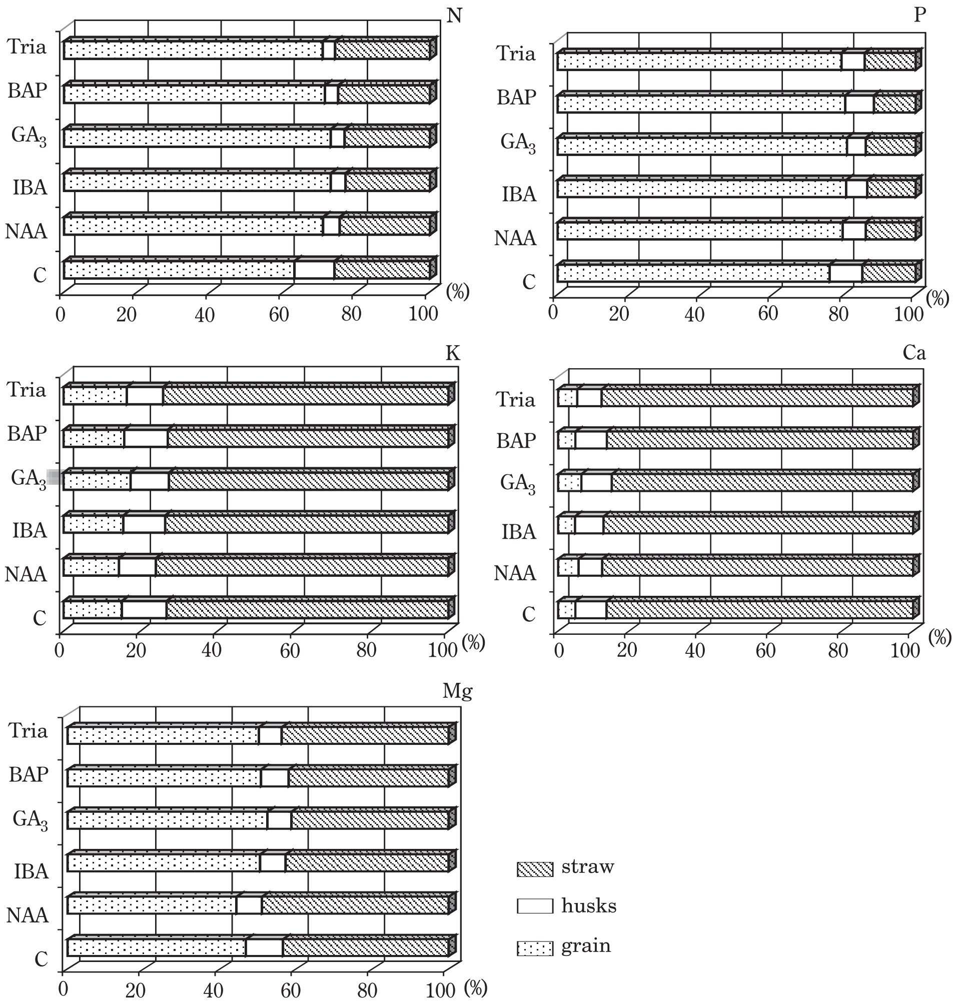

Fig. 2. Distribution of nutrients in spring triticale

er. In addition, IBA caused analogous changes both in vegetative parts and in grain (Figure 5). This ratio became most distinctly broader in husks under the effect of NAA and GA_3, and in straw – mostly under the effect of IBA. PILEJCZYK et al. (2004) found out that the value of mol ratios of K:Ca and K:Mg in grain and straw of triticale became narrower as the rate of the applied nitrogen rose; under the same condtions, the Na:K ratio became broader. It was also demonstrated that as the concentration of phosphorus in grain rose, so did the concentration of potassium and calcium. In our previous studies on spring wheat, the K:(Mg+Ca) proportions in grain and in vegetative organs were narrower under the influence of gibberellin but

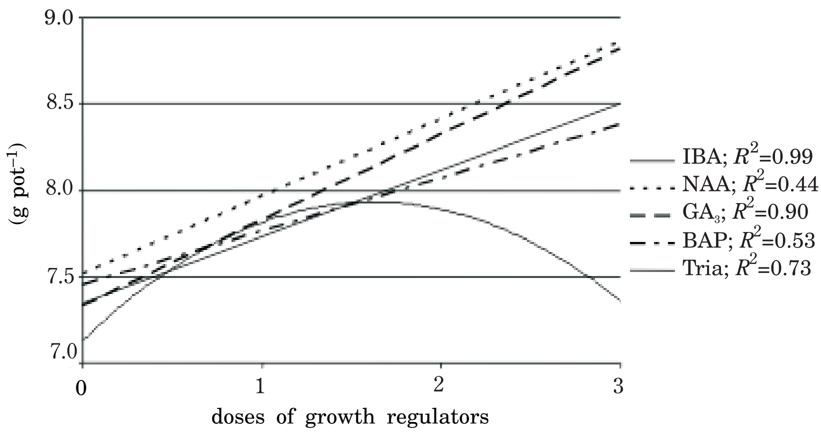

Fig. 3. Protein yield in triticale grain

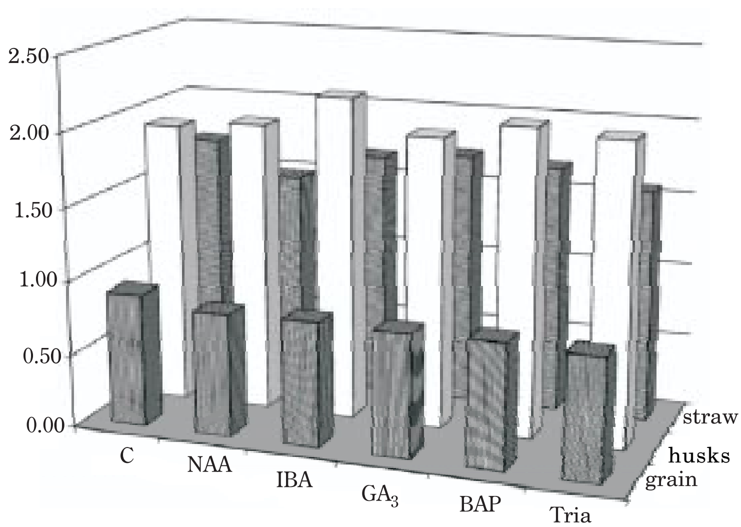

Fig. 4. K:(Ca+Mg) ionic ratios

broader when kinetin or auxin (NAA) had been applied. Auxin broadened this ratio in grain and leaves but narrowed it in husks and in the stem (WIERZBOWSKA, BOWSZYS 2008a,b, WIERZBOWSKA 2006b).

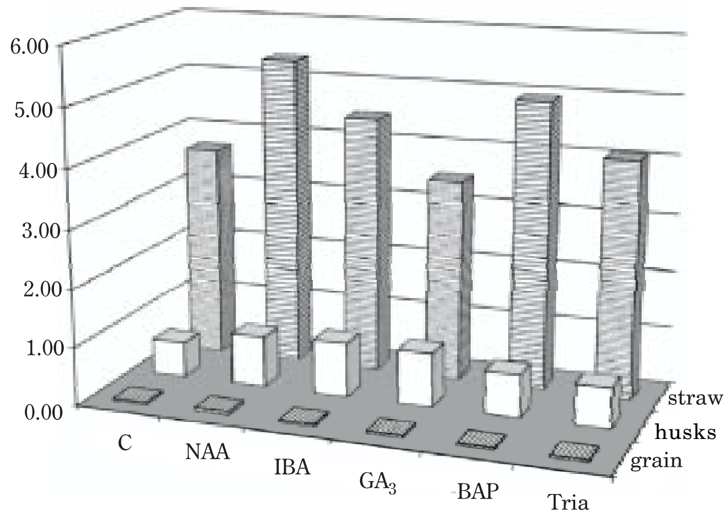

Fig. 5. Ca:P mol ratios

CONCLUSIONS

1. The growth regulators, especially NAA, significantly affected the concentration of nitrogen in grain and depressed its amount in husks. Triacontanol caused an increase in the concentration of phosphorus, potassium and calcium in grain. The phytohormones increased the concentration of potassium and depressed that of phosphorus in triticale straw.

2. The highest protein yield in triticale grain was obtained when seed material had been treated with NAA before sowing, and generally increased proportionately to the concentration of the growth regulators.

3. The growth regulators, especially NAA and GA_3, raised the uptake and accumulation of nitrogen and phosphorus in grain; IBA and triacontanol increased the uptake of potassium and its accumulation on straw.

4. The phytohormones increased the contribution of grain to the accumulation of phosphorus and potassium.

5. The growth regulators caused the narrowing of the K:(Ca + Mg) ionic ratios in grain and straw, but broadened it in husks. After the application of the phytohormones, the Ca:P ratio in vegetative organs, and under the influence of IBA also in grain, became broader.

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