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EFFECT OF SEAWEED BIOSTIMULANT APPLICATION IN SPRING WHEAT

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Abstract

Either increasing pressure of biotic and abiotic factors along with growing demand for the grains intended for fodder or edible purposes induce attempts to look for alternative elements of cultivation technology for supporting plant growth and yield. Among natural growth stimulation methods, a considerable role can be played by biostimulants.
The three-year field experiment, located in Poland (53°13'N; 17°51'E) with spring wheat Triticum aestivum L. was conducted to assess the response of grain yield, yield components as well as the content and uptake of N, P and K in grain to various methods of seaweed biostimulant application. The different times (developmental phases of wheat) and doses of biostimulant Kelpak (Ecklonia maxima Osbeck) application were tested. This biostimulant contains phytohormones: auxins and cytokinins (11 and 0.031 mg l^{-1}, respectively). Preparation was applied in a single dose of 2 l/ha at BBCH 22 or in a dose of 2 l/ha at BBCH 31, as well as two-times, 1.5 l/ha each, in both mentioned phases (sequential treatment). The study indicated that the biostimulant Kelpak had a favourable effect on the root weight, the number of grains per spike, thousand grain weight and grain yield of spring wheat, in sequential treatment. This method for biostimulant application also resulted in increase in the content and uptake of P and K in wheat grain in comparison with the control. Favourable response of the grain yield and nutrient uptake gives grounds for recommendations of sequential application of seaweed biostimulant Kelpak for spring wheat.

Key words*: root weight, yield component, grain yield, macroelement, wheat.*

INTRODUCTION

Wheat is one of the most important cereal species. In respect to the cropping area in the world, wheat takes the first place (FAOSTAT, 2017). This cereal is used mostly for food production (directly in the food industry or indirectly, as a raw material for feed production). An increase in the world population and meat production generate an increasing demand for grain of consumer and fodder cereals, but at the same time, there is a risk of limiting yields due to the growing pressure of biotic and abiotic factors. It is connected with withdrawal from the use of some pesticides, as well as with forecasting climatic changes, and an increased risk of drought and heat stress in some regions of cereal production (Sharma et al., 2014). Therefore new methods for stimulating of yields are sought for, and among them, biostimulants are very promising (Calvo et al., 2014; Craigie, 2011; Khan et al., 2009; Kotwica et al., 2014; Sharma et al., 2014). Among biostimulants, preparations produced from marine algae are an important group (Craigie, 2011). Plants treated with these biostimulants are more able to tolerate biotic and abiotic stress (pressure of diseases and pests, drought, temperature extremes, salinity, deficiency of nutrients (Beckett and Van Staden, 1990; Craigie, 2011; Khan et al., 2009; Papenfus at al., 2013; Sharma et al., 2014). The beneficial effects of alga biostimulant treatment include promoted root and shoot growth (Rayorath et al., 2008), and enhanced resistance to diseases (Stadnik and de Freitas, 2014), as well as pests (Lamparski and Szczepanek, 2014). Moreover enhanced index of the effectiveness of water use in photosynthesis (Mikiciuk and Dobromilska, 2014), and nutrient uptake (Jannin et al., 2012), as well as increased accumulation of some

nutrients (Becket and Van Staden, 1990; Shah et al., 2013) have been shown.
Currently, the economics of crop production constrain the use of macroalgal biostimulants mainly to high-value crops. However, rising prices for fertilizers and pesticides may change this situation. Biostimulants promoting plant growth and stress resistance can become an available option for less profitable agricultural and horticultural crops (Sangha et al., 2014; Sharma et al., 2014).
Developing recommendations for use of biostimulants requires research concerning the time, and dose of application, which form the basis for increasing the effectiveness of those preparations. The aim of the current study was to assess the response of grain yield and yield components, as well as the content and uptake of macronutrients in spring wheat grain to differentiated times (growing stages) and a dose of seaweed biostimulant Kelpak (*Ecklonia maxima* Osbeck) application.

MATERIALS AND METHODS

The study was based on field experiments located in Poland (53°13'N; 17°51'E), conducted in 2010-2012 on a typical *Alfisol* (USDA). The topsoil was characterized by a medium content of available P 190-210 mg kg^{-1} and K 95-150 mg kg^{-1} (determined with Egner-Riehm method), a very low content of Mg <20.0 mg kg^{-1} (Schetschabel method) and a slight acidic reaction (pH in 1M KCL 5.7-6.1) (with the use of potentiometry). The content of total N (0.69-0.75 g kg^{-1}) in the soil was relatively low. The study was conducted as one-factorial experiment with the spring wheat (*Triticum aestivum* ssp. *vulgare*) cultivar Katoda. In the experiment, the marine macroalga biostimulant Kelpak was used in three growing seasons. This biostimulant is obtained from (*Ecklonia maxima* Osbeck) belonging to the division of brown algae (*Phaeophyta*), harvested on the south coast of Africa. This biostimulant contains phytohormones: auxins and cytokinins (11 and 0.031 mg/l, respectively), brassinosteroids, alginians, amino acids, as well as small amounts of macro and microelements. Kelpak was applied in different doses and developmental stages of wheat: as a single dose of 2 l/ha at BBCH 22 (early treatment) or in a dose of 2 l/ha w BBCH 31 (late treatment), as well as two-times, 1.5 l/ha each, in both mentioned stages (sequential treatment). Preparation was applied as aqueous solution in a dose of 300 l/ha. The treatments with the biostimulant were compared with the control (without treatment).
The spring wheat was sown 02-04 of April in an amount of 230 kg/ha on plots with an area of 12 m^2, in four replications. Presowing fertilization of 31 kg/ha P (superphosphate), 66 kg/ha K (potassium chloride) and 80 kg/ha N (ammonium nitrate) was applied. At the beginning of the shooting stage, the second dose of N (ammonium nitrate) was applied in dose of 60 kg/ha. For weed control triasulfuron 118.6 g/ha + dicamba 7.4 g/ha were used at BBCH 22-24. Pest control was performed once at BBCH 59 using dimethoat 200 g/ha. To protect spring wheat against diseases epoxiconazole 93 g/ha + fenpropimorph 300 g/ha + metrafenone 112.5 g/ha at BBCH 34-39 and fusilazole 125 g/ha + carbendazim 250 g/ha at BBCH 51-59 were used. The harvest of the wheat was performed in the first ten days of August.
At flowering stage (BBCH 65) the dry matter of roots was determined based on 20 successive plants in a row. At the same time the number of generative tillers on the area of 1 m^2 and generative tiller length on 30 randomly chosen tillers were determined. At the full maturity stage the number of grains per spike was determined on 30 randomly selected spikes from each plot. The grain yield and moisture were determined directly after harvest, and straw yield 10 days after. The thousand grain weight was assessed – two months after harvest based on 200 grains from each plot. Presented yields of grain and straw were converted to the determined humidity 14%. Harvest index was calculated for each plot as the dry matter of grain divided by the sum of the dry matter of grain and straw yield. Wheat grain was ground before performing chemical analyses. Mineralization was performed by wet combustion of plant material with sulphuric acid and perhydrol. Analyses were made using the following methods: the content of total nitrogen with the Kjeldahl method, potassium content with flame photometry, and phosphorus

content with the vanadium-molybdenum method. The uptake of N, P and K were calculated for each plot as the product of grain dry matter yield and the content of macroelements. The obtained results were analysed statistically using the statistical program Analysis of variance for orthogonal experiments by the UTP University of Science and Technology in Bydgoszcz, Poland. The differences between the values were verified with Tukey's test on the significance level P=0.05. Pearson's correlation analyses were carried out using the Statistica for Windows.

RESULTS AND DISCUSSIONS

In the current study, application of the seaweed biostimulant had a favourable effect on the spring wheat root weight (Table 1). In each variant of the use of the preparation (early, late and sequential treatment) the root weight was higher than in the control. Moreover, it was found that sequential use of seaweed biostimulant (in a dose of 1.5 l/ha at BBCH 22 + 1.5 l/ha at BBCH 31) resulted in an increase in the root weight in relation to the single early treatment. Stimulation of the spring wheat root system growth may result from the action of phytohormones contained in the extract from algae, mainly auxins responsible for root initiation and branching (Kurepin et al., 2014). In the current study, the dose 1.5 l/ha applied twice (sequential treatment) stimulated the growth of the root weight more than the single application of the dose 2 l/ha at the tillering stage (early treatment). Similarly Kumar and Sahoo (2011) present the effect of an extract from algae used for soaking seeds on the development of the wheat root system. In that study, 20% concentration of the seaweed extract resulted in an increase in the root length and the number of lateral roots, as compared with the control.

Table 1. Biometric features and yield of wheat depending on biostimulant rate and growth stage during application, means from 2009-2011

Characteristics	Biostimulant rate and growth stage of wheat			
	2 l/ha BBCH 22	1.5 l/ha BBCH 22 1.5 l/ha BBCH 31	2 l/ha BBCH 31	Control
Root weight† [g]	18.3 B‡	19.7 A	19.3 AB	16.1 C
Generative tiller length [cm]	72.3 A	72.1 A	70.4 B	73.5 A
Generative tiller density [no/mm^2]	532 A	505 A	505 A	513 A
Grain number per spike [no]	28.5 B	30.4 A	28.7 B	28.8 B
Thousand grain weight [g]	39.9 B	41.4 A	40.3 B	39.6 B
Grain yield [kg/ha]	4757 B	4947 A	4874 AB	4697 B
Straw yield [kg/ha]	5341 D	6222 A	5555 C	6031 B
Harvest index	0.476 A	0.457 BC	0.472 AB	0.442 C

†dry root weight from 20 plants; ‡within a row for each characteristic, values followed by different letters are significantly different according to LSD (0.05).

The effect of the biostimulant on the development of the wheat aboveground part indicated in the current study differed depending on the analysed feature. Generative tillers were longer in the early and sequential treatments, as well as in the control, as compared with the late treatment. No significant effect of the biostimulant application (early, sequential, late treatment) on the generative tiller density was shown. The results presented in the literature prove that the aboveground part response to preparations from algae depends on the application method. Carvalho et al. (2014) report that wheat was higher after the application of an extract from algae, but only when the preparation was used as soil irrigation, but there was no effect on seed treatment. In the experiment of Muhammad et al. (2013), after the application of a seaweed extract with humic acid, wheat tillers were longer than in the control. In the study by Kumar and Sahoo (2011), a positive effect of soaking seeds in an extract from algae was proved both for the number of branches and for the tiller length. In the current study, the yield structure elements responding to the extract from algae include the number of grain per spike and the thousand grain weight. These structural yield elements were higher after the application of the preparation in the sequential treatment (two times 1.5 l/ha), but a single dose of 2 l/ha, applied at the tillering or shooting stages (early and late treatment), did not differentiate the values of those traits in comparison with the control. The effect of the biostimulant from algae on the number of grains per spike and the dry weight of grain is also reported in the study by Kumar and Sahoo (2011). In this study, soaking seeds before sowing in 20% solution of the extract from algae resulted in an increase in those yield structure elements, and a higher concentration caused their decrease. Also, an extract from algae applied together with humic acids had a favourable effect on the thousand seed weight (Muhammad et al., 2013).

Table 2. Pearson's correlation coefficients for the relation between biometric features and yield of wheat

Characteristics	1.	2.	3.	4.	5.	6.	7.
1. Root weight [g]							
2. Generative tiller length [cm]	0.67*						
3. Generative tiller density [no/mm^2]	0.17 ns	0.26 ns					
4. Grain number per ear [no]	0.61*	0.84*	0.06 ns				
5. Thousand grain weight [g]	-0.19 ns	-0.48*	0.20 ns	-0.77*			
6. Grain yield [kg/ha]	0.68*	0.67*	0.42*	0.32*	0.25 ns		
7. Straw yield [kg/ha]	0.66*	0.90*	0.28 ns	0.75*	-0.34 *	0.71*	
8. Harvest index	-0.19	-0.52*	0.10 ns	-0.75*	0.87*	0.19 ns	-0.54*

*significant at P<0.05; ns - non significant

In the current study, an increase in the grain yield in relation to the control was caused by the sequential application of the biostimulant. Also an increase in the yield structure elements, such as the number of grains per spike and thousand grain weight, was recorded in the sequential treatment. Favourable effect of the application of an extract from algae on wheat yield is also presented in the literature (Matysiak et al., 2012; Muhammad et al., 2013; Shah et al., 2013). In the study by Shah et al. (2013), this favourable effect is attributed to an increase in the thousand grain weight. Also, Matysiak et al. (2012), in the growing period characterized by dry spring, obtained a positive effect of the biostimulant Kelpak on the yield and thousand grain weight of winter wheat. Beckett and Van Staden (1989), in turn, in conditions of potassium deficiency, indicated an increase in both the number of grain in the spike and the average grain mass after the foliar application of the seaweed preparation. The increase in grain yield of spring wheat in our study may be attributed to an increased root weight (positive correlation with the grain yield), which could result in a better supply of water and nutrients for plants. Also, Zodape et al. (2009) indicated a significant growth of wheat grain yield, as well as the thousand seed weight, after the application of the algae *(Kappaphycus alvarezii)* preparation. They claim this resulted from the increase in the root system weight. In the study by Beckett and Van Staden (1989), the growth in the root weight after foliar application of the seaweed preparation contributed to an increase in the grain weight per spike. According to Foulkes et al. (2009), the well-developed root system of wheat forms the basis for an increase in nutrient-use efficiency determining the yield quantity and quality. Wheat treated with the biostimulant two times (sequential treatment) formed significantly higher straw weight in comparison with the control and the other variants of the preparation application. The harvest index was significantly higher in the case of early and late application, in comparison with the sequential and the control. No significant difference in the harvest index was shown after the sequential application of the biostimulant and the control.

Positive correlation was indicated between grain yield and the root weight, straw yield, generative tiller length and density as well as the number of grains per spike (Table 2). The number of grains per spike positively correlated with the root weight, straw yield and tiller length, but negatively with the thousand grain weight. The length of generative tillers was significantly positively correlated with the root weight but negatively with the thousand grain weight. The straw yield was positively correlated with the root weight and the generative tiller length and negatively with the thousand grain weight. There was a negative correlation between the harvest index with the tiller length, straw yield and the number of grains per spike and a positive correlation with the thousand grain weight.

Table 3. Content and uptake of N, P, K in wheat grain depending on biostimulant rate and growth stage during application, means from 2009-2011

Macroelement	**Biostimulant rate and growth stage of wheat**			
	2 l/ha BBCH 22	**1.5 l/ha BBCH 22 1.5 l/ha BBCH 31**	**2 l/ha BBCH 31**	**Control**
Content [g/kg]				
N	20.6 A‡	21.3 A	21.0 A	21.2 A
P	3.67 C	3.75 A	3.74 A	3.69 B
K	3.14 C	3.17 B	3.24 A	3.13 C
Uptake [kg/ha]				
N	86.5 B	92.5 A	89.7 AB	87.6 AB
P	15.7 B	16.7 A	16.4 AB	15.7 B
K	12.2 AB	12.8 A	13.0 A	12.0 B

‡Within a row for each macroelement, values followed by different letters are significantly different according to LSD (0.05).

Data presented in the literature indicates that the application of algae preparations may also have a favourable effect on macroelement concentration in wheat grain (Matysiak at al., 2012; Zadope et al., 2009). In the current study, the application of the biostimulant Kelpak did not have a significant effect on N content or uptake in the spring wheat grain (Table 3). There was indication, however, of an increase in P and K content and uptake in the grain after the sequential application of the preparation in comparison with the control treatment. This could result from forming a larger root weight, creating favourable conditions for nutrient uptake from soil (Foulkes et al., 2009). The study by Jannin et al. (2012) proved an increase in the expression of genes responsible for nutrient uptake after the application of preparations from algae. Shah et al. (2013), following Becket and Van Staden (1990), explains that an increase in P and K concentration in wheat grain after the application of algae preparation resulted from an increase in the photosynthesis rate or delayed senescence of the last two leaves.

CONCLUSIONS

Response of spring wheat to the foliar application of seaweed extract Kelpak (*Ecklonia maxima* Osbeck) depended on the dose and developmental stage of plant during application. Sequential treatment (biostimulant in a dose of 1.5 l/ha at BBCH 22 and in a dose of 1.5 l/ha at BBCH 31) had a favourable effect on the number of grains per spike, thousand grain weight, and grain yield. This method of application also stimulated growth of the root mass, and increased P and K concentration and uptake in grain as compared to the control. Favourable response of the grain yield and nutrient (P and K) uptake gives grounds for recommendations of the foliar application of seaweed biostimulant Kelpak in sequential treatment for spring wheat.

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