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RESPONSE OF ONION (*Allium cepa* L.) TO THE METHOD OF SEAWEED BIOSTIMULANT APPLICATION

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ABSTRACT

Among methods for stimulation of plant growth an essential role can be played by seaweed biostimulants. The aim of the study was to assess the response of onion to the method of application of the seaweed biostimulant Kelpak SL. Doses of the seaweed extract applied from the three-leaf stage amounted to 3, 3 + 2, 3 + 2 + 2 dm^3 ha^{-1}, and from the four-leaf stage 2, 2 + 2, 2 + 2 + 2 dm^3 ha^{-1}, for a single, double and triple application, respectively. The biostimulant applied from the three-leaf stage increased the chlorophyll index after double or triple application, whereas applied from the four-leaf stage, also after a single application. The highest increases in the fresh weight yield of bulbs as well as fresh weight of roots resulted from the triple application of the biostimulant from the three- or four-leaf stages. Each dm^3 of the biostimulant caused an increase in the fresh weight yield of bulbs by 0.76 t ha^{-1}, and each additional application resulted in an increase in yield by 1.76 t ha^{-1}.

Key words: growth, leaf, leaf greenness index, root, bulb yield

INTRODUCTION

Onion is one of vegetables of the highest economic importance, which results from its taste and health supporting qualities including anticancer properties, antithrombotic and antiasthmatic activity as well as antibiotic effects [Suleria et al. 2015]. Poland is one of the major onion producers in Europe. In 2013 it was in the fourth and third positions, respectively, in the EU as regard the cropping area and the volume of production. However, in respect of the yield quantity it is considerably no match for leading producers and is only in 15 position [FAOSTAT 2014]. Moreover, high differentiation of yielding is observed depending on the weather conditions; over 2006–2013 the average national yield of bulbs ranged from 17 to 27 t ha^{-1} [FAOSTAT 2014]. A great variability of yield quantities results from the sensitivity of this species to stress environmental factors, which induces searching for ways of supporting the plant resistance. Among natural methods for stimulation of growth and development processes of cultivated crops, especially under conditions of environmental stress factors, an essential role can be played by biostimulants, and among them, seaweed extracts [Khan et al. 2009, Craigie 2011, Stirk and Van Staden 2014]. In cultivation of agricultural crops and vegetables it was indicated that they can reduce the draught stress [Khan et al. 2009, Sharma et al. 2014]. In bulbous vegetables a reduction in diseases severity: downy mildew in

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Allium cepa L. [Dogra and Mandradia 2012] and alernaria leaf spot in *Alium fistulosum* [Araújo et. al. 2012] were observed after soil application of seaweed granules. The beneficial effects of alga biostimulant application in the form of increasing yield were shown in many cultivated crops [Khan et al. 2009]. Also in onion cultivation practices with the use of seaweed extract significantly increased the percentage of marketable onions after storage [Boyhan at al. 2001]. The favourable effect of those preparations to the yield results from the stimulation of many physiological processes responsible for the above- and underground parts growth and development [Tarakhovskaya et al. 2007, Jannin et al. 2013, Kurepin et al. 2014, Mikiciuk and Dobromilska 2014]. Apart from the stimulation of growth and yield, the use of biostimulants based on algae may offer a possible way to increase quality of yield [Lola-Luz et al. 2014, Szczepanek et al. 2015].

The results of the previous studies conducted in India and USA indicate that the effect of preparations based on marine algae on onion growth and yield not always result in the expected increase in yields, and the plant response depends on the method of application [Sankar et al. 2001, Feibert et al. 2003, Dogra and Mandradia 2012]. The aim of the present study was to assess the response of growth of the above- and underground part and yield of onion to the number, dose and time of sequential foliar application of the seaweed biostimulant Kelpak SL (*Ecklonia maxima*) in the conditions of transitional climate of Central Europe.

MATERIALS AND METHODS

Field experiments were carried out in Poland, in kuyavian-pomeranian region (53°13'N; 17°51'E) on the Alfisols [Komisja V Genezy, Klasyfikacji i Kartografii Gleb PTG 2011, IUSS World Group WRB 2015]. The soil content of organic carbon 7.55–7.80 g kg^{-1} and total nitrogen 0.69–0.75 g kg^{-1} were relatively low. The topsoil is characterized by a medium content of available K 95–150 mg kg^{-1}, and high or very high content of P 190–210 mg kg^{-1} (Egner-Riehm method, PN-R-04022, PN-R-04023), very low content of Mg < 20.0 mg kg^{-1} (Schetschabel method, PN-R-04020) and slightly acid reaction (pH in 1 mol KCl 5.7–6.1) (with the use of potentiometry, PN-ISO 10390). The subject of this study was onion of the cultivar Spirit F1 in field condition from the spring sowing. Foliar application of the biostimulant Kelpak SL was performer in successive years 2009–2011. This product is a pure organic concentrated product extracted from a marine alga (*Ecklonia maxima*) with the high-pressure technique results in cellular burst, obviating the use of chemicals, heat, freezing or dehydration. This ensures that the compounds are maintained in their active form. Kelpak SL contains phytohormones: auxins and cytokinins, 11 and 0.031 mg l^{-1}, respectively, alginians, amino acids, as well as small amounts of macro- and microelements. The seaweed extract was applied on fully formed leaves from the three-leaf and four-leaf stages, as a single, double or triple application, at two-week intervals. Doses of the biostimulant applied from the three-leaf stage amounted to 3, 3 + 2, 3 + 2 + 2 dm^3 ha^{-1}, and from the four-leaf stage 2, 2 + 2, 2 + 2 + 2 dm^3 ha^{-1}, respectively, for a single, double and triple application. The total dose of this kelp extract during the growth period was 2, 3, 4, 5, 6 and 7 dm^3 ha^{-1}. Kelpak SL was applied after dissolving in 300 dm^3 of water. The field study was conducted in the randomized block design with four replications. The area of plots for harvest was 12 m^2.

Sowing was carried out on 10–12 April using the Oyord type plot seeder. Row spacing was 21 cm and the seeding rate amounted to 3.5 kg ha^{-1}. In 2010, relatively low air temperatures occurred in April and at the beginning of May (tab. 1), which combined with heavy rainfalls caused mass dying of seedlings and the necessity of repeated sowing, which was performed on 20 May. Pre-sowing mineral fertilization was applied at rates of 35 kg ha^{-1} P (triple superphosphate), 83 kg ha^{-1} K (potash salt), 60 kg ha^{-1} N and additionally, top-dressing of 60 kg ha^{-1} N (ammonium nitrate). Weed control was carried out prior to emergences using glyphosate at 540 g ha^{-1} and directly after emergences using pendimethalin with 1320 g ha^{-1}. In the case of occurrence of monocotyledonous weeds, propachizaphop was applied at 80 g ha^{-1}. The mixture of mancozeb 1600 g + metalaxyl 200 g ha^{-1} was used to control pathogens. Harvest was performed in the middle of September in 2009 and 2011 or at the beginning of October in 2010.

Table 1. Mean monthly air temperature and total rainfall in the years 2009–2011 and in the multi-year period 1949–2011

Month	Air temperature (°C)				Rainfall (mm)			
	2009	2010	2011	1949–2011	2009	2010	2011	1949–2011
April	9.8	7.8	10.5	7.4	0.4	33.8	13.5	27.4
May	12.3	11.5	13.5	12.7	85.3	92.6	38.4	43.2
June	14.5	16.7	17.7	16.3	57.4	18.1	100.8	53.7
July	18.6	21.6	17.5	18	118	107.4	132.5	73.1
August	18.2	18.4	17.7	17.5	17.6	150.7	67.7	53.2
September	13.7	12.2	14.3	13.2	34.4	74.7	37.0	41.4

The leaf greenness index was evaluated using the N-Tester Yara. It measures the difference in light absorption with the wavelength of 650 nm, the maximal light absorption by chlorophyll a and b, and 940 nm, light kept by the leaf tissues. The quotient of those differences is displayed as SPAD (Soil-Plant Analyses Development) units and is called the leaf greenness index. Measurements were made three weeks after the last seaweed biostimulant application, on 20 July and 10 August, respectively for applications from the three-leaf and four-leafs stages, on the last fully formed leaf, 30 measurements on each plot. Due to delayed times of measurements resulting from repeated sowing, in 2010 those results were excluded from the analysis.

The height of aboveground part was determined two weeks after the last application of the Kelpak SL, on 20 randomly selected plants on each plot. The length of the root system, the fresh root weight, the number of leaves and the dry weight content in the roots and bulbs (with the dryer method) was determined 10–14 days prior to harvest on 20 randomly selected plants, in four replications of each treatment. After 7–10 days from digging out, the bulb yield was weighed and their number on each plot was determined. Based on that, the average bulb weight was calculated. The dry weight yield of the bulbs was calculated based on the fresh weight yield and the dry weight content in the bulbs.

The obtained results were subjected to the statistical analysis. The analysis of variance of single experiments in the years and the synthesis from the years in the mixed model were made using the statistical program Analysis of variance for orthogonal experiments by the UTP University of Sciences and Technology in Bydgoszcz. Significance of differences for the results were assessed with Tukey's test, assuming the significance level P = 0.05.

RESULTS AND DISCUSSION

The application of the seaweed extract Kelpak SL had a favourable effect on onion growth. The height of aboveground part, on average in the long-term period, was higher than in the control almost in each variant of the biostimulant application (except for one and two applications from the 3-leaf stage) (tab. 2). In subsequent study years differences of this feature after biostimulator application in relation to the control ware insignificant. The favourable effect of biostimulant on number of leaves was significant, on average in the long-term period and in 2011, after triple application from the three-leaf stage in doses 3 + 2 + 2 dm^3 ha^{-1}. An increase in plant height and the number of leaves after foliar spray of seaweed extract in *Allium cepa* is also reported by other authors [Sankar et al. 2001]. Dogra and Mandradia [2012], in turn, proved a favourable effect of soil application of seaweed granules, but this effect was dependent on the dose. The number of leaves per plant and shoot height were higher than in the control already from the lowest dose of 1.5 g m^{-2}. Further increase in values of these biometric traits was obtained at the dose 2.5 g m^{-2}, but there was no difference after the application of 2.5 and 3.5 g m^{-2}. In the present study, a growth stimulation of the onion aboveground part may result from better plant supply in nutrients after the biostimulant application by the better developed root system (tab. 3). The study by Lee [2010] indicates a significant relationship between the plant height and number of leaves and nutrient availability. Good supply in nutrients results in an increase in plant height,

Table 2. Height of aboveground parts and number of leaves of onion depending on the method of biostimulant Kelpak SL application, in the years 2009–2011

Treatment	Height of aboveground part (cm)				No. of leaves per plant			
	year							
	2009	2010	2011	mean	2009	2010	2011	mean
Control	58.6	45.2	72.8	58.9	9.23	9.64	9.09	9.32
†Kelpak 3 dm^3 ha^{-1}	62.3	48.8	72.6	61.2	9.25	9.78	9.51	9.51
†Kelpak 3 + 2 dm^3 ha^{-1}	60.0	47.6	75.1	60.9	9.38	9.82	9.52	9.58
†Kelpak 3 + 2 + 2 dm^3 ha^{-1}	63.2	50.4	71.6	61.7	9.60	10.00	9.77	9.79
‡Kelpak 2 dm^3 ha^{-1}	60.1	52.2	75.1	62.4	9.28	9.80	9.50	9.53
‡ Kelpak 2 + 2 dm^3 ha	60.2	52.5	74.2	62.3	9.34	9.84	9.53	9.57
‡Kelpak 2 + 2 + 2 dm^3 ha^{-1}	61.5	51.8	73.8	62.4	9.38	9.95	9.61	9.65
Mean	60.8	49.8	73.6	61.4	9.35	9.83	9.50	9.56
$LSD_{0.05}$	n.s.	n.s.	n.s.	2.5	n.s.	n.s.	0.54	0.40

† First application at 3-leaf stage, at multiple applications next ones every 2 weeks
‡ First application at 4-leaf stage, at multiple applications next ones every 2 weeks

Table 3. Length, fresh and dry weight of onion roots depending on the method of biostimulant Kelpak SL application, in the years 2009–2011

Treatment	Length of roots (cm)				Fresh weight of roots per plant (g)				Dry weight of roots per plant (g)			
	year											
	2009	2010	2011	mean	2009	2010	2011	mean	2009	2010	2011	mean
Control	11.5	14.5	13.4	13.2	1.41	2.60	2.59	2.20	0.245	0.385	0.238	0.289
†Kelpak 3 dm^3 ha^{-1}	12.3	14.3	13.6	13.4	1.54	2.60	2.52	2.22	0.278	0.410	0.241	0.310
†Kelpak 3 + 2 dm^3 ha^{-1}	12.4	14.0	13.6	13.3	1.73	2.75	2.67	2.38	0.248	0.313	0.273	0.278
†Kelpak 3 + 2 + 2 dm^3 ha^{-1}	13.2	15.7	14.9	14.6	1.80	3.02	2.96	2.59	0.258	0.413	0.264	0.311
‡Kelpak 2 dm^3 ha^{-1}	12.6	14.5	14.0	13.7	1.54	2.76	2.62	2.31	0.248	0.445	0.249	0.314
‡ Kelpak 2 + 2 dm^3 ha	12.0	14.3	13.9	13.4	1.59	2.68	2.71	2.33	0.258	0.348	0.255	0.287
‡Kelpak 2 + 2 + 2 dm^3 ha^{-1}	12.8	14.5	14.5	14.0	1.59	2.98	3.12	2.56	0.283	0.500	0.298	0.360
Mean	12.4	14.5	14.0	13.6	1.60	2.77	2.74	2.37	0.259	0.402	0.260	0.307
$LSD_{0.05}$	n.s.	n.s.	0.8	0.3	0.29	0.40	0.37	0.12	n.s.	n.s.	n.s.	0.041

†, ‡ Explanations see Table 2

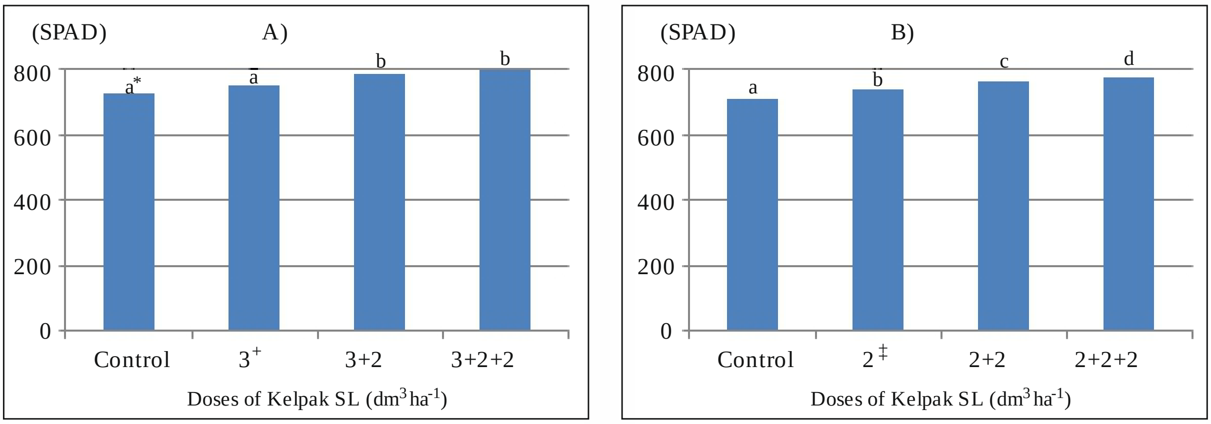


Fig. 1. Leaf greenness index on July 20th A) and August 10th B), mean for 2009 and 2011

+, ‡ Explanations see Table 2

* Values marked with the same letters do not differ significantly at $p < 0.05$

the number of leaves and fresh weight of shoot [Jain et al. 2014]. Favourable effect of biostimulant from algae on plants may be also explained by increasing the rate of CO_2 assimilation and the index of effectiveness of water use in the photosynthesis [Mikiciuk and Dobromilska 2014]. Chenping and Leskovar [2015] in turn proved that under drought stress seaweed extracts enhanced growth of spinach (e.i. fresh and dry weight of leaves and specific leaf area) by improving leaf water relations, maintaining cell turgor pressure and reducing stomatal limitation, which in turn led to large leaf area and high photosynthetic rate.

In the present study, measurement of leaf greenness index was used to assess the state of plant nutrition. For applications starting from the three-leaf stage (fig. 1 A), the chlorophyll index value was higher than in the control if the biostimulant was applied two or three times. For applications from the four-leaf stage (fig. 1 B), a single application already increased the value of this parameter as compared with the control. The double application caused a further increase in this parameter, and after the triple application the chlorophyll index was the highest. Also in the study of other vegetables it was indicated that the spraying of leaves with biostimulants based on marine algae extracts resulted in a significant increase in chlorophyll a, b, a + b levels [Mikiciuk and Dobromilska 2014]. Microscopy observation showed a clear and early effect of seaweed extract (*Ascophyllum nodosum*) on the chloroplast number per cell of oilseed rape [Jannin et al. 2013]. According to Blunden at al. [1996] enhanced leaf chlorophyll content of plant treated with biostimulant treated with seaweed extract is dependent on betaines present.

The present study indicated a significant effect of the seaweed biostimulant on the root system growth (tab. 3). On average in the long-term period and in 2011 the onion roots were longer, and the fresh weight of roots was higher in comparison with the control after triple applications of the biostimulant from the three-leaf or four-leaf stages. Also the double application from the three- or four-leaf stages had a favourable effect on the fresh root weight, on average in the long-term period. Differentiation of quantities of dry weight of onion roots as affected by the biostimulant was smaller. Only the triple application of the seaweed extract from the four-leaf stage caused, on average in the long-term period, an increase in the root dry weight as compared with the control. According to Kurepin et al. [2014], stimulation of the root system growth by extracts from algae may result from the action of phytohormones con-

Table 4. Fresh yield of bulbs and average weight of bulb depending on the method of biostimulant Kelpak SL application, in the years 2009–2011

Treatment	Fresh weight yield of bulbs (t ha^{-1})				Average weight of bulb (g)			
	year							
	2009	2010	2011	mean	2009	2010	2011	mean
Control	30.9	11.6	67.3	36.6	88.9	48.0	102.7	79.9
†Kelpak 3 dm^3 ha^{-1}	30.6	11.6	68.7	37.0	93.3	48.1	108.1	83.1
†Kelpak 3 + 2 dm^3 ha^{-1}	35.3	11.9	67.6	38.3	100.4	45.7	103.9	83.3
†Kelpak 3 + 2 + 2 dm^3 ha^{-1}	35.0	15.0	72.8	40.9	103.0	57.2	119.5	93.2
‡Kelpak 2 dm^3 ha^{-1}	32.9	12.5	68.7	38.0	93.2	50.7	105.3	83.1
‡ Kelpak 2 + 2 dm^3 ha	33.8	12.7	69.4	38.6	94.9	50.7	108.7	84.8
‡Kelpak 2 + 2 + 2 dm^3 ha^{-1}	32.3	12.1	78.8	41.1	94.8	49.0	123.2	89.0
Mean	33.0	12.5	70.5	38.6	95.5	49.9	110.2	85.2
$LSD_{0.05}$	3.5	2.7	4.1	1.3	8.5	6.4	10.5	3.3

†, ‡ Explanations see Table 2

Table 5. Content of dry matter in bulbs and dry weight yield of bulbs depending on the method of biostimulant Kelpak SL application, in the years 2009–2011

Treatment	Content of dry matter in bulbs (%)				Dry weight yield of bulbs (t ha^{-1})			
	year							
	2009	2010	2011	mean	2009	2010	2011	mean
Control	10.02	11.62	9.68	10.44	3.09	1.35	6.51	3.65
†Kelpak 3 dm^3 ha^{-1}	9.88	11.39	9.43	10.23	3.03	1.32	6.48	3.61
†Kelpak 3 + 2 dm^3 ha^{-1}	9.89	10.47	9.44	9.94	3.50	1.24	6.38	3.71
†Kelpak 3 + 2 + 2 dm^3 ha^{-1}	9.32	10.84	9.70	9.95	3.26	1.63	7.08	3.99
‡Kelpak 2 dm^3 ha^{-1}	10.33	11.36	8.73	10.15	3.40	1.42	6.02	3.61
‡ Kelpak 2 + 2 dm^3 ha	9.56	10.96	9.28	9.93	3.24	1.39	6.44	3.69
‡Kelpak 2 + 2 + 2 dm^3 ha^{-1}	10.57	11.59	9.49	10.55	3.42	1.40	7.49	4.10
Mean	10.02	11.62	9.39	10.17	3.28	1.39	6.63	3.77
$LSD_{0.05}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	0.31

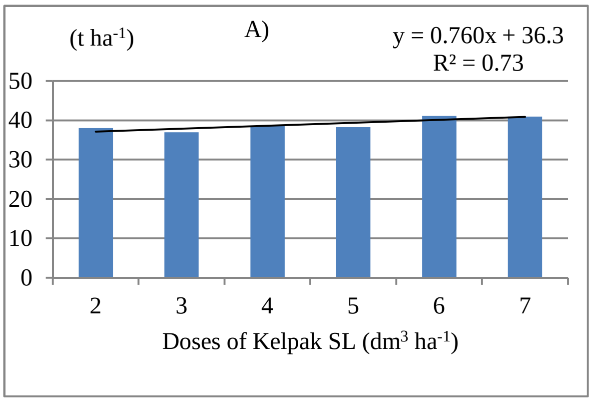
†, ‡ Explanations see Table 2

tained in them, mostly auxins. Rayorath et al. [2008] base on the enzymatic assay of *Arabidopsis thaliana* showed, that *A. nodosum* extract modulated the concentration and localisation of auxin, which could account for the enhanced root growth. According to Kurepin et al. [2011] both auxins and cytokinins are considered to be important in the initiation of lateral and adventitious root development, as well causing increases in total root biomass. Halpern et al. [2014] report that a change in root morphology was one of the major mechanisms by which seaweed extracts affect nutrient uptake.

In the present study, the fresh weight yield of bulbs, on average in the long-term period, was nearly

1.5 times higher than the mean yields in the country [FAOSTAT 2014], but a very high differentiation was noted in individual years (tab. 4). In 2011 under favourable hydro-thermal conditions during germination and emergences, as well as during later growth (tab. 1), very high bulb yield was obtained. In contrast, in 2010 low air temperatures and heavy rainfalls in April and at the beginning of May caused mass dying of seedlings and the necessity of another sowing, which resulted in a very high reduction in yield in comparison with the other years of the study. Very high sensitivity of onion to the weather conditions, particularly during the end of emergence and beginning of leaf bending, is confirmed by other authors [Kalbarczyk and Kalbarczyk 2014, 2015].

Repeated application of the biostimulant Kelpak SL during the growth period had a favourable effect on the fresh weight yield of onion bulbs (tab. 4). In the successive years of the study in 2009–2010 the triple application of seaweed extract from the three-leaf stage caused a significant increase in the fresh yield weight of bulbs as compared with the control. In 2009, a similar effect was obtained after the double application in doses 3 + 2 dm^3 ha^{-1}. In 2011 in turn, the highest yield was recorded after the triple application from the four-leaf stage. A similar effect of the biostimulant application method in individual years of the study was observed for the average weight of bulbs. The fresh weight yield of bulbs, on average in the long-term period, was the highest after



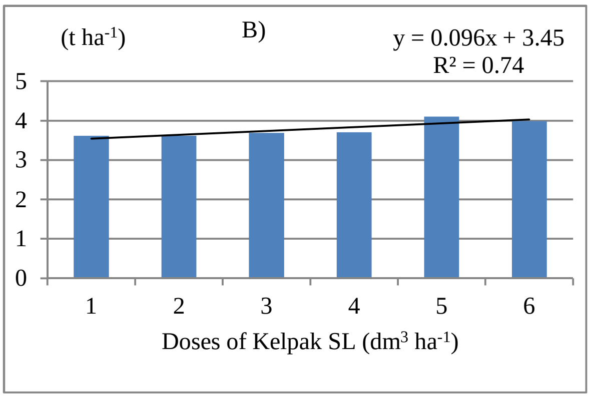
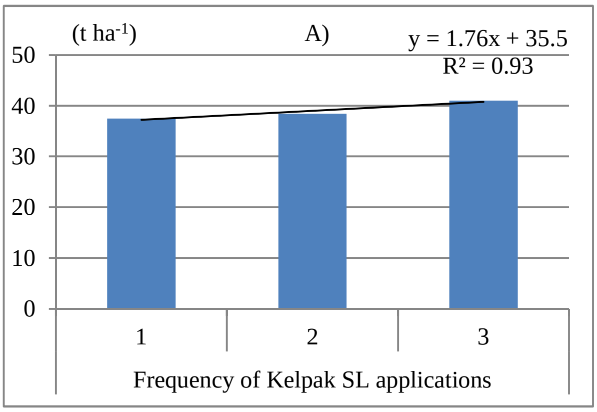


Fig. 2. Fresh yield (A) and dry yield (B) of bulbs depending on the dose of biostimulator application, mean for 2009–2011



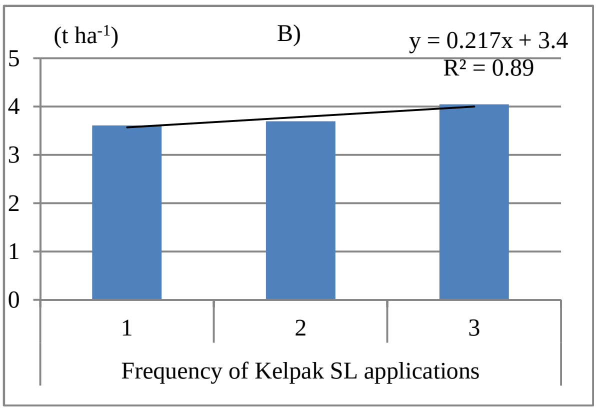


Fig. 3. Fresh yield (A) and dry yield (B) of bulbs depending on the frequency of biostimulator application, mean for 2009–2011

the triple application of Kelpak SL in doses 3 + 2 + 2 dm^3 ha^{-1} from the three-leaf stage or 2 + 2 + 2 dm^3 ha^{-1} from the four-leaf stage (higher by 11.7 and 13.1%, respectively, than in the control). The triple application of the kelp extract from the three-leaf or four-leaf stages also caused, on average in the long-term period, the highest increments of the average bulb weight, by 16.6 and 11.4%, respectively, as compared with the control. The increase in the average weight and yield of onion bulbs indicated in the present study may be explained by the growth stimulation of the root system (tab. 3), responsible for the uptake of water and nutrients. At the good supply in nutrients, the bulb weight and bulb yield increase [Jain et al. 2014]. Many studies presented in the literature indicate that the effect of biostimulants based on algae in onion cultivation depends on the method, timing and dose of application. In the study by Feibert et al. [2003] no effect of seaweed extract applied to soil as band pre-plant on bulb yield was proved. Similarly, a single application immediately after commencement of bulbing had no effect on yield [McGeary and Birkenhead 1984]. In contrast, the one-year study of onion grown from seedlings showed no response of yield, but a favourable effect on the chemical composition was observed [Lola-Luz et. al. 2014]. Another study conducted in southeast Georgia show that in the best combination (two-time foliar spray of Kelpak SL 0.4 dm^3 ha^{-1} each) an increase in total and Jumbo class bulb yields were 10 and 12.3%, respectively [Boyhan et al. 2008]. The study conducted under sub-tropical conditions in India, in turn, showed very favourable effects of the soil application of seaweed extract granules [Dogra and Mandradia 2012]. An increase in yield was the highest, 20.8% as compared to the control, at the average rate 2.5 g m^2. The indicated increase in bulb yield resulted, just as in the present study, from an increase in bulb weight. Also other study conducted in India showed an increase in bulb yield and weight after the foliar application of a seaweed extract 30, 45 and 60 days after transplanting [Sankar et al. 2001].

The content of dry matter in bulbs was similar to that indicated by other authors [Lee and Lee 2014] (tab. 5). However, its substantial diversity was observed in years with markedly different yield levels. The highest dry weight concentration was recorded in 2010, where the yield of bulbs was the lowest. By contrast, in 2011, which was very favourable for onion yielding, the dry weight concentration was the lowest. No significant effect of the method of biostimulant application on dry weight concentration in onion bulbs was indicated. Nevertheless, a significant effect of the biostimulant application on the dry weight yield of bulbs, on average in the long-term period, was proved (tab. 5). Similarly to the fresh weight yield of bulbs (tab. 4), the dry weight yield of bulbs after triple applications of the biostimulant from the three-leaf as well as four-leaf stage, in doses of 3 + 2 + 2 dm^3 ha^{-1} or 2 + 2 + 2 dm^3 ha^{-1} b, respectively, was significantly higher than without any application.

Analysis of relationship between the fresh or dry weight yields of bulbs and the total dose of Kelpak SL during the growing period indicated that each additional litre of the biostimulant within the range from 2 to 7 dm^3 ha^{-1} caused an increase in fresh weight yield by 0.76 t ha^{-1}, and in dry weight yield by nearly 0.10 t ha^{-1} (fig. 2). Each additional application of the biostimulant within the range from 1 to 3 caused an increase in the fresh weight of bulbs by 1.76 t ha^{-1} and in dry weight yield by 0.22 t ha^{-1} (fig. 3).

CONCLUSION

1. Response of onion growth and yield to foliar application of the seaweed biostimulant Kelpak SL depended on the number, dose and time of applications, and the hydrothermal conditions during the growing season of onion.

2. Almost in each treatment the aboveground part of onion was higher than without biostimulant, whereas the number of leaves increased after the triple application from the three-leaf stage, in doses of 3 + 2 + 2 dm^3 ha^{-1}. The application of the biostimulant from the three-leaf stage increased the chlorophyll index after double or triple applications, in doses 3 + 2 or 3 + 2 + 2 dm^3 ha^{-1}, respectively, whereas in the case of application from the four-leaf stage, also after a single application of 2 dm^3 ha^{-1}.

3. On average in the long-term period the biostimulant had a favourable effect on the growth of the root system after double or triple applications. The roots were longer and the fresh weight was higher than in the control after the triple application of seaweed extract from the three- or four-leaf stages, in doses of 2 + 2 + 2 or 3 + 2 + 2 dm^3 ha^{-1}, respectively. Also the double application of Kelpak SL in doses of 3 + 2 or 2 + 2 dm^3 ha^{-1} resulted in an increase in the root mass.

4. The highest increases in the fresh weight yield of bulbs and the bulb mean weight resulted from the triple application of kelp extract from the three- or four-leaf stages, in doses of 3 + 2 + 2 or 2 + 2 + 2 dm^3 ha^{-1}, respectively. Each additional litre of the biostimulant from 2 to 7 dm^3 ha^{-1} caused an increase in the fresh weight yield of bulbs by 0.76 t ha^{-1}.

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