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THE EFFECT OF CULTIVAR AND BIOSTIMULANT TREATMENT ON THE CARROT YIELD AND ITS QUALITY

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Summary

Modifications in growing techniques can affect the yield and nutritional quality of various cultivated plants. Among them, the use of biostimulants is environmental friendly method of stimulating crop productivity, stress resistance, and affecting yield or chemical composition of the plants. The aim of the investigation was determining of the effect of biostimulant treatment on yield and its quality of carrot grown for summer harvest. The experiment was carried out in 2009-2011 in the experimental station of the University of Agriculture in Krakow, south Poland. Two experimental factors were taken into consideration: (1) cultivar: Nandrin F_1 and Napoli F_1 (2) dose of Aminoplant (foliar application): 1.5 and 3.0 $dm^3 \cdot ha^{-1}$ and control (without Aminoplant). Total and marketable yield, root length, its diameter, leaf mass and leaf : root mass ratio were assessed. The dry matter, soluble sugar, carotenoids and nitrate ions contents were analyzed as main determinants of carrot nutritional quality.

Aminoplant influenced not only carrot productivity, but mainly chemical composition of the roots. The present results also suggest that carrot reaction to biostimulant treatment was depended on a cultivar more than on environmental conditions in particular growing seasons. The significant effect of Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$ on the yield of roots and leaf rosette mass of 'Nandrin F_1' appeared only in the first year of the experiment. Spraying with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ significantly increased the soluble sugars content in carrot roots of both cultivars but only in 2011. Dry matter content was also affected by biostimulant treatment mainly for 'Napoli F_1', which showed the lowest dry matter content when sprayed with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$. In 2010 control plants contained the greater amount of carotenoids, while in next year roots of plants treated with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ had more these compounds. The significant effect of Aminoplant on nitrates content in carrot roots was observed but were not repeatable in the experimental years, so different climatic conditions modified carrot reaction on biostimulant spraying.

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INTRODUCTION

Carrot is one of the most important vegetables of high biological value. It is the most important carotenoids source in a human diet. Carrots also contain a wide spectrum of other antioxidants, vitamins, carbohydrates, crude fiber, and minerals like Ca, P, Fe and Mg (Sharma *et al*. 2011). Carrot intake enhances the immune system, protect against cancer, high blood pressure, osteoporosis, cataracts, atherosclerosis, heart diseases, and many others (Brandt *et al*. 2004). The consumption of carrot and carrot products increases steadily, similarly as demand of carrot market for raw material of the best quality. The development of modern, environmental friendly technologies is necessary to support the carrot market in the area of production and maintenance of the highest product standards.

Paradikovic *et al*. (2011) stated, that the application of biostimulants could be considered as a good production strategy for obtaining high yields of nutritionally valuable vegetables with lower impact on the environment. Biostimulants are composed of single- or multi-ingredient plant extracts, containing hormones, enzymes, proteins, amino acids, vitamins, microelements and other biologically active compounds (Basak 2008). Biostimulants affect plant metabolism when applied in small quantities, through stimulation of natural hormone synthesis and activity, enhancement of nutrients uptake, stimulation of root growth, and increase of resistance to unfavourable conditions. The multiple functions of biostimulants have induced many researchers to investigate such effects on crops (Paradikovic *et al*. 2011). The dose of biostimulant, time and way of application, crop species or cultivar, growth conditions, and other environmental factors can affect the biostimulant action. Foliar applied biostimulants can be treated as systemic agents, so they must successfully penetrate the cuticle to reach active sites in the plant tissues. The time of penetration is limited, since the biostimulator must remain in a liquid state and these conditions are fulfilled when the relative air humidity is close to the saturated state. This is of great importance - especially in field conditions, where the treated plants are exposed to different extrinsic factors (Kolomaznik *et al.* 2012). Pecha *et al*. (2011) proposed a novel mathematical model based on diffusion transport to predict the protein biostimulant uptake at different climatic conditions. Authors showed, that overall uptake can be approximately 40 times lower at unsuitable climatic conditions compared to the recommendable ones. High-humidity increased the total uptake, so biostimulant should be applied when the air humidity is near the point of saturation, after rain, early in the morning, and in the evening. Also an increase in biostimulant layer thickness and initial biostimulant concentration

lead to higher total uptake (Pecha *et al*. 2011, Kolomaznik *et al*. 2012).

Aminoplant (known also as Siapton®) ISAGRO, Italy, is a leaf-applied biostimulant composed of amino acidic solution derived from hydrolyzed animal proteins. Among them, alanine, glycine, proline, hydroxyproline, glutamic and aspartic acids are the most relevant in the biostimulating activity of Aminoplant. Based on the data obtained in *Arabidopsis thaliana* L. where plants were treated with Aminoplant, Cambri *et al*. (2008) concluded, that this biostimulant stimulated endogenous plant defense response to both biotic and abiotic stress factors. According to Mladenova *et al*. (1998), Siapton can interfere in the osmostress primary metabolic changes as a non-specific stress mitigating bioregulator. There are only few reports on the effect of Aminoplant on vegetables. According to Maini (2006) positive effects of Aminoplant application were found on some vegetables as tomato, and cucurbits. In the light of last investigations, this biostimulator rather affect the chemical composition of vegetable species than the yield potential. Kunicki *et al*. (2010) reported, that spraying with Aminoplant had no effect on spinach yield in spring and autumn cultivation. Gajc-Wolska *et al*. (2012) investigated the effect of Goëmar Goteo and Aminoplant on the yield and quality of curly endive. Biostimulants did not affect the endive yield but leaves treated with these substances synthesized more rutoside and astragalin in comparison with control. Spraying of lettuce with Aminoplant did not influence significantly the yield, dry matter and nitrates content (Łyszkowska *et al*. 2008). Grabowska and Kunicki (2009) stated the positive effect of leaf-applied Aminoplant applied in the transplant stage together with Goëmar Goteo soil-applied before formation of heads on the broccoli yield. The cited results suggest the need of future investigations on the wide spectrum of biostimulant action on vegetable yield and nutritional value. Vegetables are very differential group of cultivated plants, with different origin, taxonomy, morphology and physiology of harvestable organs. The including to the investigations new species and cultivars can extend the knowledge on biostimulants, a promising branch of modern horticulture.

The objective of the present study was to investigate the influence of biostimulant Aminoplant applied in different doses on nutritional quality, yield and chosen morphological parameters of two carrot cultivars grown in field conditions.

MATERIALS AND METHODS

Experiment design

The experiment was conducted in 2009-2011 at the University of Agriculture in Krakow, south Poland. The two cultivars of carrot (*Daucus carota* L.) were the object of the experiment (factor I): 'Nandrin F_1' and 'Napoli F_1'. The second experimental factor was spraying plants with Aminoplant in a dose of 1.5 and 3.0 $dm^3 \cdot ha^{-1}$. Control objects were not treated with biostimulant. The spraying was made

two times: in a phase of 5-7 leaves and when root had a diameter of 5-6 mm.

The experiment was established using randomized blocks method in three replications, the experimental plot size was 6.10 m^2. Plants were cultivated on standard ridges in two rows in spacing 8×4 cm. Distance between centre of ridges was 67.5 cm, and the height of a ridge was 30 cm. Seeds were sown 22.05.2009, 24.04.2010 and 10.05.2011. The fertilizers were applied to maintain the content of available nutrient forms on a level recommended for the investigated species, calculated on a base of the soil analysis, which showed pH (H_2O) - 6.2; organic carbon content of 2% and nutrient content presented in Table 1.

Table 1. Results of soil analysis in 2009-2011

Year	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca	Mg
	($mg \cdot dm^{-3}$)					
2009	23.2	21.0	47.5	191	778	84
2010	29.7	85.7	48.0	217	455	126
2011	14.0	33.2	80.0	142	1686	162

Data concerning the mean month temperature and sum of rainfall during vegetation seasons are presented in Table 2. The sum of rainfall was the highest in the second year of the study (801 mm). In 2009 and 2011, the sum of rainfall was comparable (392 and 391 mm, respectively), but its distribution was different. May, June, August and September in the third year of the study were characterized by lower rainfall as compared to 2009 and 2010, while higher rainfall was noted in May 2010. April and May were characterized by lower mean and maximum temperatures in 2010 as compared to 2009 and 2011. Basing on a mean air temperature it was noted, that July was the warmest month in 2010, June, August and September in 2011.

Table 2. Sum of rainfall, mean, maximum and minimum temperature values in the experimental years

Month	2009				2010				2011			
	Temperature (°C)			Sum of rainfall	Temperature (°C)			Sum of rainfall	Temperature (°C)			Sum of rainfall
	mean	max.	min.	(mm)	mean	max.	min.	(mm)	mean	max.	min.	(mm)
April	11.9	22.2	1.7	1	8.5	14.3	3.3	37	13.4	20.5	6.6	82
May	13.3	20.5	6.6	91	12.8	16.8	9.4	302	14.1	20.1	7.2	55
June	15.5	20.8	10.5	128	17.6	22.6	12.1	122	18.6	24.4	12.8	41
July	19.5	26.6	13.1	83	20.9	26.5	15.1	110	18.0	22.8	13.7	163
August	18.9	27.4	12.0	53	18.7	24.6	13.5	138	19.4	25.8	13.3	37
September	15.1	23.4	8.0	35	12.4	17.1	8.4	92	15.5	22.5	9.2	14

The manual harvest was performed 04.08.2009, 03.08.2010 and 01.09.2011. Total and marketable yield were assessed. Directly after harvest the root length, diameter in the middle of the root, and leaf mass

were assessed on 20 roots in three replications. The leaf : root mass ratio was counted.

Chemical analysis

Directly after harvest, in 2010 and 2011, roots were subjected to analysis. All laboratory analysis were made in three repetitions. The roots were washed under running tap water, drained, manually peeled (1 mm), topped and tailed (1.0 to 1.5 cm) and homogenized. The dry matter content was determined by drying at 70°C until constant weight was obtained. The total soluble sugars were determined by anthrone method (Yemm & Willis 1954). Plant material was mixed with 80% ethanol. After addition of anthrone reagent, samples were placed for 30 min in a water bath (100°C), cooled down to room temperature and the absorbance was measured at 625 nm using Helios Beta spectrophotometer (Thermo Fisher Scientific Inc., USA). The total carotenoids content was determined by the modified Lichtenthaler and Wellburn (1983) method after ethanol extraction, at 470 nm, with Helios Beta spectrophotometer (Thermo Fisher Scientific Inc., USA). Nitrate ions content in plant material were determined using Orion® ion selective pH meter 920A (Thermo Electron Corp., USA) after extraction in 0.02M $Al_2(SO_4)_3\,18H_2O$.

All data obtained were subjected to two-way ANOVA, and the differentiation of the means was compared by the Tukey's HSD test at p=0.05.

RESULTS

The carrot yield was significantly depended on the cultivar in the first and third year of the experiment, when 'Nandrin F_1' gave higher marketable and total yield than 'Napoli F_1'. The significant effect of the biostimulant treatment on the carrot yield was found only in the first year of the study, when spraying with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$ significantly increased the carrot yield. The interaction of experimental factors affected the carrot yield in first and third year of the study. In 2009 the greatest yield was received as a result of spraying of 'Nandrin F_1' with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$. In 2011 significant differences were found between marketable yield of 'Napoli F_1' from control object and 'Nandrin F_1' sprayed with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$.

In 2010 and 2011 'Nandrin F_1' formed significantly longer roots than 'Napoli F_1'. In 2011, roots of 'Nandrin F_1' had also bigger diameter. In 2009 and 2011 spraying with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ significantly increased the root length as compared to control. In 2009 and 2010 it was found the significant interaction of the experimental factors in relation to length of the carrot roots but no repeatable dependence can be described.

Table 3. Total and marketable yield of carrot (t·ha^{-1}) depending on the cultivar and biostimulant treatment

Treatment	Total yield			Marketable yield		
	'Napoli F_1'	'Nandrin F_1'	Mean for treatment	'Napoli F_1'	'Nandrin F_1'	Mean for treatment
			2009			
Control	14.2 a	25.5 b	19.9 A	11.7 a	19.4 b	15.5 A
Aminoplant 1.5 dm^3·ha^{-1}	14.0 a	29.6 c	21.8 B	11.9 a	22.4 c	17.2 B
Aminoplant 3.0 dm^3·ha^{-1}	14.0 a	25.2 b	19.6 A	11.1 a	19.5 b	15.3 A
Mean for cultivar	14.1 A	26.8 B		11.6 A	20.4 B	
			2010			
Control	42.2 a	44.0 a	43.1 A	29 9 a	31.2 a	30.5 A
Aminoplant 1.5 dm^3·ha^{-1}	42.2 a	45.0 a	43.6 A	29.2 a	30.3 a	29.7 A
Aminoplant 3.0 dm^3·ha^{-1}	41.9 a	44.9 a	43.4 A	30.5 a	32.0 a	31.3 A
Mean for cultivar	42.1 A	44.6 A		29.9 A	31.2 A	
			2011			
Control	55.6 a	67.3 bc	61.5 A	39.3 a	45.0 ab	42.2 A
Aminoplant 1.5 dm^3·ha^{-1}	59.2 ab	67.6 bc	63.4 A	46.0 ab	54.5 ab	50.2 A
Aminoplant 3.0 dm^3·ha^{-1}	61.6 a-c	70.7 c	66.2 A	43.6 ab	57.9 b	50.7 A
Mean for cultivar	58.8 A	68.6 B		43.0 A	52.5 B	

*values of total or marketable yield for particular years of the experiment marked with the same letter do not differ significantly at p = 0.05 (Tukey's HSD test); capital letters for main effects and small letters for interaction

Table 4. Biometrical measurement of carrot roots depending on the cultivar and biostimulant treatment

Treatment	Root length (cm)			Root diameter (cm)		
	'Napoli F_1'	'Nandrin F_1'	Mean for treatment	'Napoli F_1'	'Nandrin F_1'	Mean for treatment
			2009			
Control	18.2 ab	17.2 a	17.7 A	2.03 a	2.03 a	2.03 A
Aminoplant 1.5 dm^3·ha^{-1}	17.9 ab	19.0 ab	18.5 AB	2.08 a	2.06 a	2.07 A
Aminoplant 3.0 dm^3·ha^{-1}	18.0 ab	19.5 b	18.6 B	1.92 a	2.01 a	1.97 A
Mean for cultivar	18.0 A	18.6 A		2.01 A	2.04 A	
			2010			
Control	17.2 ab	18.0 ab	17.6 A	2.50 a	3.13 a	2.82 A
Aminoplant 1.5 dm^3·ha^{-1}	17.0 a	18.4 ab	17.7 A	2.60 a	3.27 a	2.93 A
Aminoplant 3.0 dm^3·ha^{-1}	17.2 ab	19.5 b	18.4 A	2.56 a	2.88 a	2.72 A
Mean for cultivar	17.1 A	18.6 B		2.55 A	3.09 A	
			2011			
Control	20.8 a	21.3 a	21.1 A	2.90 a	3.24 a	3.07 A
Aminoplant 1.5 dm^3·ha^{-1}	20.6 a	21.5 a	21.1 A	2.89 a	3.16 a	3.03 A
Aminoplant 3.0 dm^3·ha^{-1}	19.6 a	22.1 a	20.9 B	2.98 a	3.27 a	3.13 A
Mean for cultivar	20.3 A	21.6 B		2.93 A	3.22 B	

*abbreviations: see Table 3

The leaf mass was depended on cultivar in first and third year of the experiment, when 'Nandrin F_1' produced leaf rosettes of a greater mass. The effect of biostimulant treatment was significant only in the first year of the experiment. Spraying plants with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$ significantly increased the leaf mass in comparison to the object treated with biostimulant in a dose of 3.0 $dm^3 \cdot ha^{-1}$. The interaction of the experimental factors showed significant differences only in the first year of the experiment, when 'Nandrin F_1' from objects treated with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$ produced the greater leaf rosettes. Leaf: root mass ratio was not depended on the investigated experimental factors.

Table 5. Leaf mass ($t \cdot ha^{-1}$) and leaf: root mass ratio of carrot depending on the cultivar and biostimulant treatment

Treatment	Leaf mass			Leaf : root mass ratio		
	'Napoli F_1'	'Nandrin F_1'	Mean for treatment	'Napoli F_1'	'Nandrin F_1'	Mean for treatment
			2009			
Control	5.06 a	11.09 b	8.07 AB	0.36 a	0.44 a	0.40 A
Aminoplant 1.5 $dm^3 \cdot ha^{-1}$	4.90 a	13.31 c	9.10 B	0.35 a	0.45 a	0.40 A
Aminoplant 3.0 $dm^3 \cdot ha^{-1}$	4.94 a	10.14 b	7.54 A	0.35 a	0.40 a	0.38 A
Mean for cultivar	4.96 A	11.51 B		0.35 A	0.43 B	
			2010			
Control	13.03 a	14.25 a	13.64 A	0.30 a	0.32 a	0.31 A
Aminoplant 1.5 $dm^3 \cdot ha^{-1}$	12.05 a	14.24 a	13.15 A	0.29 a	0.32 a	0.30 A
Aminoplant 3.0 $dm^3 \cdot ha^{-1}$	13.62 a	14.35 a	13.99 A	0.32 a	0.32 a	0.32 A
Mean for cultivar	12.90 A	14.28 A		0.31 A	0.32 A	
			2011			
Control	17.08 a	24.83 a	20.96 A	0.31 a	0.37 a	0.34 A
Aminoplant 1.5 $dm^3 \cdot ha^{-1}$	18.98 a	20.82 a	19.90 A	0.32 a	0.31 a	0.32 A
Aminoplant 3.0 $dm^3 \cdot ha^{-1}$	18.87 a	21.42 a	20.96 A	0.31 a	0.30 a	0.30 A
Mean for cultivar	18.31 A	22.36 B		0.31 A	0.33 A	

*abbreviations: see Table 3

Dry matter content in carrot roots was significantly depended on both experimental factors. In 2010 and 2011 'Napoli F_1' contained more dry matter than 'Nandrin F_1'. Control plants contained more dry matter than sprayed with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$. The analysis of interaction of experimental factors showed, that in 2010 control 'Napoli F_1' plants were characterized by greater dry matter content than 'Nandrin F_1' plants, both control and sprayed with biostimulant. In 2011, 'Napoli F_1' plants from control and treated with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ objects had greater dry matter content as compared to remaining objects. In both years of the experiment 'Napoli F_1' contained more soluble sugars than 'Nandrin F_1' plants. In 2011 spraying with Aminoplant (3.0 $dm^3 \cdot ha^{-1}$) signif-

icantly increased soluble sugar content. The analysis of interaction let to found that in 2011 both cultivars produced roots with a higher content of soluble sugars in objects sprayed with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$.

Table 6. Dry matter ($g \cdot 100\ g^{-1}$ f.m.) and soluble sugars ($mg \cdot 100\ g^{-1}$ f.m.) content in carrot roots depending on the cultivar and biostimulant treatment

Treatment	Dry matter			Soluble sugars		
	'Napoli F_1'	'Nandrin F_1'	Mean for treatment	'Napoli F_1'	'Nandrin F_1'	Mean for treatment
			2010			
Control	9.95 b	9.53 a	9.74 B	3.48 ab	3.20 a	3.34 A
Aminoplant 1.5 $dm^3 \cdot ha^{-1}$	9.67 ab	9.47 a	9.57 A	3.64 b	3.37 ab	3.51 A
Aminoplant 3.0 $dm^3 \cdot ha^{-1}$	9.70 ab	9.49 a	9.59 A	3.65 b	3.34 ab	3.49 A
Mean for cultivar	9.77 B	9.50 A		3.59 B	3.30 A	
			2011			
Control	11.08 c	10.23 a	10.66 B	4.82 bc	4.67 b	4.74 B
Aminoplant 1.5 $dm^3 \cdot ha^{-1}$	10.39 ab	10.58 b	10.49 A	4.72 b	4.42 a	4.57 A
Aminoplant 3.0 $dm^3 \cdot ha^{-1}$	10.86 c	10.59 b	10.72 B	5.08 d	4.98 cd	5.03 C
Mean for cultivar	10.78 B	10.47 A		4.87 B	4.69 A	

*abbreviations: see Table 3

'Nandrin F_1' was characterized by higher carotenoids content as compared to 'Napoli F_1' in 2010. The effect of biostimulant treatment on carotenoids level was different between years of the investigation. In 2010 control plants contained the greater amount of carotenoids. In 2011 roots of plants treated with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ were characterized by a higher carotenoids level. No clear repeatable interaction of the experimental factors on the carotenoids content can be described.

In 2010 'Nandrin F_1' accumulated 72% more of nitrates than 'Napoli F_1' but such dependence did not appear in 2011. In both years, plants sprayed with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$ were characterized by higher nitrates content as compared to control and a dose of 1.5 $dm^3 \cdot ha^{-1}$, taking into consideration means for cultivars. The interaction between experimental factors had also significant effect on the nitrates content in carrot roots but no clear repeatable interaction can be described.

Table 7. Carotenoids (mg·100 g^{-1} f.m.) and nitrates (mg NO_3^-·kg^{-1} f.m.) content in carrot roots depending on the cultivar and biostimulant treatment

Treatment	Carotenoids			Nitrates		
	'Napoli F_1'	'Nandrin F_1'	Mean for treatment	'Napoli F_1'	'Nandrin F_1'	Mean for treatment
			2010			
Control	8.57 ab	9.83 c	9.20 B	263 a	409 c	336 A
Aminoplant 1.5 dm^3·ha^{-1}	8.53 a	9.03 ab	8.78 A	261 a	595 d	428 C
Aminoplant 3.0 dm^3·ha^{-1}	8.80 ab	9.13 b	8.97 AB	303 b	418 c	361 B
Mean for cultivar	8.63 A	9.33 B		276 A	474 B	
			2011			
Control	11.27 b	10.33 a	10.80 A	50.7 a	93.8 d	72.2 B
Aminoplant 1.5 dm^3·ha^{-1}	10.07 a	11.57 b	10.82 A	102.6 e	72.6 c	87.6 C
Aminoplant 3.0 dm^3·ha^{-1}	11.53 b	11.13 b	11.33 B	74.7 c	59.7 b	67.2 A
Mean for cultivar	10.96 A	11.01 A		76.0 A	75.4 A	

*abbreviations: see Table 3

DISCUSSION

The results of many investigations conducted for the last 20 years suggested that amino-acid-based biostimulants affect plant development in different ways, with significant influence not only on the yield but mainly on physical and chemical plant parameters. Łyszkowska *et al*. (2008), Kunicki *et al*. (2010) and Gajc-Wolska *et al*. (2012) did not found a significant effect of Amino-plant spraying on iceberg lettuce, endive, and spinach yielding cultivated in the field. On the other hand, Kowalczyk *et al*. (2008) stressed, that Aminoplant positively affected the yield of lettuce grown in rockwool. In the conditions of present experiment, the significant effect of Aminoplant in a dose of 1.5 dm^3·ha^{-1}on the yield of roots and leaf rosette mass of 'Nandrin F_1' appeared only in 2009. The present results suggest that carrot reaction against biostimulant treatment was depended on a cultivar more than on environmental conditions in particular growing seasons. Low yield noted in the first year of the experiment was first of all caused by shorter period of vegetation in comparison with the other two years, which affect the development of roots with lower mass and diameter. It is interesting that significant effect of Aminoplant treatment was found just in this year of the study, but only for 'Nandrin F_1'. Earlier investigations showed, that Siapton increased crops yield due to the organic nitrogen content but also as a result of acceleration of N absorption from the soil, especially in the drought conditions (Mladenova 1998, Maini 2006). Our results confirm this observations, and they allowed to state, that biostimulant action is also highly dependent on the genetic factor.

Biostimulants influence not only crop productivity, but mainly chemical composition of the yield. The content of dry matter, carotenoids and total sugars are the main quality parameters of carrot roots, but there are

no bibliography on the effect of amino-acid-containing biostimulants on carrot quality. In a present experiment spraying with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ significantly increased the soluble sugars content in carrot roots of both cultivars but only in 2011. Dry matter content was also affected by biostimulant treatment mainly for 'Napoli F_1', which showed the lowest dry matter content when sprayed with Aminoplant in a dose of 1.5 $dm^3 \cdot ha^{-1}$. In 2010 control plants contained the greater amount of carotenoids. In 2011 roots of plants treated with Aminoplant in a dose of 3.0 $dm^3 \cdot ha^{-1}$ were characterized by a higher carotenoids level. Tejada and Gonzales (2003) report on the increase of soluble carbohydrates in the root system of the asparagus plant as an effect of foliar fertilization with amino acids and humic acids. Paradicovic *et al*. (2011) showed, that biostimulants improved the antioxidant activity, vitamin C and phenolic contents in pepper fruits as well as the pigment content in leaves.

Leaf and root vegetables should be considered as important source of nitrates in a human diet. Amino acid biostimulants can affect the utilization of nutrients in plants due to stimulation of main enzyme systems (Maini 2006). Earlier, Mladenova *et al*. (1998) reported the positive influence of Siapton on nitrate reductase activity in maize, which lead to increase of N absorption mainly in water stress conditions. Also Ertani *et al*. (2009) stresssed, that protein hydrolyzate-based fertilizers increase nitrate reductase and glutamine synthetase activities in maize leaves, suggesting a positive role of the hydrolyzates in the induction of nitrate conversion into organic nitrogen. A role of amino acids and small peptides of the protein hydrolyzate-based fertilizers was suggested in the regulation of the nitrogen pathway. According to Maini (2006), Siapton application reduced the risk of polluting the groundwater with nitrates and their accumulation in plants, mainly leaf vegetables. The investigations on Siapton effect on nitrate reductase activity were applied to leaves of investigated species, so present results can shed a light on biostimulant action on root vegetables, which can have unexpected effect. In present investigations we showed the significant effect of Aminoplant on nitrates content in carrot roots but were not repeatable in the experimental years, so different climatic conditions modified carrot reaction on biostimulant spraying.

CONCLUSIONS

Aminoplant influenced not only carrot productivity, but mainly chemical composition of the roots. The present results also suggest that carrot reaction to biostimulant treatment was depended on a cultivar more than on environmental conditions in particular growing seasons. Spraying with Aminoplant had a significant influence on the yield of roots only in the first year of the experiment, for the dose 1.5 $dm^3 \cdot ha^{-1}$. The significant effects of Aminoplant on analyzed chemical compounds carrot roots but were not repeatable in the experimental years, so different climatic conditions considerably modified carrot reaction on biostimulant spraying.

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WPŁYW ODMIANY I STOSOWANIA BIOSTYMULATORA NA WIELKOŚĆ I JAKOŚĆ PLONU MARCHWI

Streszczenie

We współczesnym ogrodnictwie stosowane są szeroko nowoczesne techniki optymalizujące wysokość i jakość plonu. Wśród nich wykorzystanie biostymulatorów jest przyjazną środowisku metodą zwiększającą produktywność roślin, tolerancję na czynniki stresowe, jak również plon i wartość odżywczą. Celem prezentowanych badań była ocena wpływu biostymulatora na wysokość i jakość plonu marchwi, uprawianej na zbiór letni. Eksperyment przeprowadzono w latach 2009-2011 w Uniwersytecie Rolniczym w Krakowie, obejmował on dwa czynniki badawcze: (1) odmiana: Nandrin F_1 i Napoli F_1, (2) dawka biostymulatora Aminoplant, zastosowanego dolistnie: kontrola (bez aplikacji biostymulatora), 1.5 i 3.0 $dm^3 \cdot ha^{-1}$. Określono plon ogólny i handlowy marchwi, długość korzenia, jego średnicę, masę rozety liściowej oraz stosunek masy liści do masy korzenia. Oznaczono zawartość suchej masy, cukrów rozpuszczalnych, karotenoidów i azotanów, jako głównych wyznaczników wartości odżywczej marchwi.

Aplikacja Aminoplantu wpłynęła nie tylko na produktywność marchwi, ale przede wszystkim na skład chemiczny korzeni. Prezentowane wyniki pozwalają na stwierdzenie, że reakcja marchwi na dolistne zastosowanie biostymulatora zależała przede wszystkim od odmiany oraz od warunków środowiskowych w latach badań. W pierwszym roku zaznaczył się istotny wpływ Aminoplantu w dawce 1.5 $dm^3 \cdot ha^{-1}$ na plon korzeni i masę rozety odmiany Nandrin F_1. Aplikacja biostymulatora w dawce 3.0 $dm^3 \cdot ha^{-1}$ istotnie zwiększyła zawartość cukrów rozpuszczalnych w korzeniach badanych odmian, ale tylko w 2011 roku. W korzeniach odmiany Napoli F_1 najniższą zawartość suchej masy stwierdzono przy oprysku dawką biostymulatora 1.5 $dm^3 \cdot ha^{-1}$. W 2010, najwyższy poziom karotenoidów stwierdzono w roślinach kontrolnych, podczas gdy w roku następnym – w roślinach traktowanych Aminoplantem w dawce 3.0 $dm^3 \cdot ha^{-1}$. Odnotowano również istotny wpływ badanego biostymulatora na zawartość azotanów, ale bez powtarzalnych tendencji w poszczególnych latach badań. W przypadku tego parametru odmienne warunki klimatyczne modyfikowały reakcję roślin na opryskiwanie biostymulatorem.