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YIELD AND QUALITY PARAMETERS OF CARROT (*Daucus carota* L.) ROOTS DEPENDING ON GROWTH STIMULATORS AND STUBBLE CROPS

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Abstract. An improvement in growth, condition, raw material quality, and resistance of vegetable plants to adverse stress conditions or agricultural pests can be achieved by using foliar-applied biostimulators. Cover cropping is also of great importance since it contributes, among others, to a better use of environmental conditions and fertilization by plants. In the period 2009–2011, a field experiment was conducted on the effect of growth stimulators and cover crops on the structure of carrot root yield (in the cultivar 'Laguna F1') and accumulation of chemical components in the storage root. The study included three growth stimulators: Asahi SL, Bio-algeen S 90, and Tytanit. Plots without foliar application of these biological agents were the control treatment. The other factor investigated in the experiment was the stubble crops to be ploughed under: tansy phacelia as well as a mixture of spring vetch and field pea. Stubble crops were grown after spring barley. Total carrot root yield and its fractions (marketable yield, yield of small roots, unmarketable yield) as well as some components determining root quality (the content of dry matter, carotenoids, L-ascorbic acid, and total sugars) were all determined. The present study has proved that all growth stimulators had a positive effect on the quantitative and qualitative parameters of carrot roots. The absence of application of growth stimulators was minimally more beneficial only in the case of total carotenoid content in carrot roots. Stubble crops, in particular the mixture of legumes, also positively affected productivity and quality of carrot roots.

Key words: carrot productivity, chemical components of roots, biostimulators

INTRODUCTION

Productivity and quality parameters of carrot (*Daucus carota* L.) root yield depend on cultivar-specific, climatic, soil, and agronomic factors [Kaack et al. 2001, Gajewski

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et al. 2007]. The global trends to produce healthy food and to protect the natural environment have resulted in an increased interest in ecology-oriented methods of plant growth stimulation through the selection of a proper forecrop, the use of stubble cropping, or the application of foliar fertilization in the form of macro- and micronutrients as well as different biostimulators [Jabłońska-Ceglarek and Rosa 2002, Kołodziej 2004, Kwiatkowski and Kołodziej 2005, Kwiatkowski 2011]. The application of growth stimulators has been successfully used in growing some vegetables as well as herbal and industrial plants in West European countries and also in Poland for several years now [Carvajal and Alcaraz 1998, Kwiatkowski and Juszczak 2011]. The principal role of biostimulators is to improve and enhance the growth and condition of plants. They increase plant resistance to adverse stress conditions and support plant protective mechanisms, thereby effectively protecting plants against diseases and pests. Furthermore, biostimulators contribute to a better use of environmental conditions, among others, soil nutrient availability [Carvajal et al. 1994, Kołodziej 2004, Dobromilska et al. 2008]. Traditionally used animal manure is more and more frequently replaced by green manure (stubble crops that are ploughed under). Stubble crops contribute to reduced leaching of nutrients from the soil to groundwater by taking up nutrients and making them available to succeeding crops; moreover, they improve soil organic matter balance and stimulate greater biological activity of the soil [Jensen 1991, Kwiatkowski 2012].

Taking into account the above premises, a hypothesis was made in the study that the stimulation of growth of carrot plants by the application of biological stimulators would contribute to obtaining quantitatively higher and qualitatively better root yield compared to the method without foliar fertilization. An assumption was also made that the introduction of stubble crops to be ploughed under, as a forecrop grown directly before carrot, would allow a better use of soil minerals as well as it would perform the phytosanitary role and contribute to higher productivity and quality of raw material harvested (marketable yield). The aim of the present study was to analyse the structure of total carrot root yield and some quality parameters of the nutritional composition of roots as a result of application of different growth stimulators and stubble crops.

MATERIALS AND METHODS

The field experiment in growing carrot (*Daucus carota* L.) for summer harvest of roots was carried out in the period 2009–2011 in Fajsławice (the central Lublin region). The experiment was set up as a split-plot design with 3 replicates, in 10 m^2 plots. The total experimental area was 360 m^2. Carrot (cv. 'Laguna F1') was grown on incomplete podzolic soil (pH in 1 mol KCl = 6.4), classified as good wheat complex. Throughout the study period, the soil was characterized by high availability of essential macronutrients (P = 86.3–88.7; K = 98.5–101.9; Mg = 34.7–35.5 $mg \cdot kg^{-1}$). The soil humus content was 1.45–1.51%.

The experimental design included the following factors:

I. Growth stimulators:

A – No application of biostimulators (control treatment);

B – Foliar spraying with Asahi SL – Atonik (0.1%);

C – Foliar spraying with Bio-algeen S 90 (1.0%);
D – Foliar spraying with Tytanit (0.05%).

II. Stubble crop to be ploughed under:
1. Without stubble crop (control);
2. Stubble crop – tansy phacelia (*Phacelia tanacetifolia* B.) – cv. 'Natra';
3. Stubble crop – spring vetch (*Vicia sativa* L.) – cv. 'Jaga' + field pea (*Pisum arvense* L.) – cv. 'Roch'.

The choice of plant species grown as stubble crops resulted from agricultural practices used in the area of Fajsławice (the study site). Spring barley (*Hordeum sativum* ssp. *vulgare*), cv. 'Justina', was the previous crop for stubble crops in the whole experimental area. Since stubble crops were grown as "green manure", farmyard manure was not applied. Economical fertilization was used. In stubble cropping, a seedbed cultivator was used after harvest of barley as well as mineral N fertilization was applied (20 kg·ha^{-1}) before sowing tansy phacelia. Stubble crops were sown in the 2nd decade of August at the following rates: 14 kg·ha^{-1} (tansy phacelia) and 40 + 60 kg·ha^{-1} (field pea + spring vetch). Stubble biomass was determined in the 3rd decade of October (before the stubble crops were ploughed in). Whole plants were pulled out from an area of 1 m^2 in each plot. After the stubble crops were first cut, the remaining stubble biomass left in the plots was ploughed under in the autumn. The fertilizer value of the stubble crops is shown in Table 1. Total stubble biomass yield (fresh matter and dry matter) and the amount of nutrients incorporated into the soil with stubble biomass (N, P, K, Ca, Mg) were similar for tansy phacelia and the legume mixture. It can be therefore concluded that both stubble crops had a similar fertilizer effect for carrot.

Table 1. Amount of ploughed-in stubble biomass and mineral nutrients incorporated with it (mean for 2009–2011)

Stubble crops	Fresh matter t·ha^{-1}	Dry matter t·ha^{-1}	N t·ha^{-1}	P t·ha^{-1}	K t·ha^{-1}	Ca t·ha^{-1}	Mg t·ha^{-1}
Tansy phacelia	8.76	1.42	50.4	5.06	24,7	12.1	3.44
Spring vetch + field pea	9.51	1.62	58.6	5.12	22.5	11.3	3.27

Each year, carrot was sown into the soil in the third decade of April. Seeding was done using a pneumatic precision seed drill at a rate of 4.5 kg·ha^{-1} (1.2 million seeds). Mineral fertilization was the same for all the treatments. Taking into account initial soil nutrient availability (calculated on a per hectare basis), which was similar throughout the study years, fertilization was applied at the following rates: N – 70 kg (before sowing); P – 40 kg (before sowing); K – 150 kg (before sowing). Mineral N fertilization was applied in the form of 34% ammonium nitrate, P in the form of 46% granulated triple superphosphate, whereas K as 50% potassium salt. Conventional tillage was used in carrot growing, adapted to the specificity of the analysed plant.

Before sowing, carrot seeds were dressed with the seed dressing Marshal 250 DS against diseases (at a rate of 70 g·kg^{-1} of seeds). The herbicide Stomp 330 EC was used for chemical weed control (3 l·ha^{-1}) 5 days after seeding. Mechanical weed control was performed twice: 1) inter-row hoeing at the 3–5 true leaf stage of carrot; 2) hand weeding before row closure.

The growth stimulators (treatments B-D) were applied using a field sprayer under a pressure of 0.25 MPa. They were used at the 6–7 true leaf stage of carrot (according to the manufacturer's recommendations).

Carrot roots were harvested in the first decade of September.

Total and marketable carrot yield and the yield structure were all determined, including marketable yield (UNECE Standard FFV-10) as well as yield of small and deformed roots (infected and branched). Total and marketable yield are expressed in terms of t·ha^{-1}. Immediately after harvest, 20 roots were sampled from marketable yield in each treatment and they were subjected to chemical analysis. Dry root matter was determined by drying the samples at 105°C to constant weight (PN-90/A-75101/03). L-ascorbic acid was determined by Tillmans' method modified by Pijanowski (PN-90/A-75101/11), while total sugars – by the method proposed by Luff-Schroorl (PN-90/A-75101/07). Carotenoid content in roots was determined spectrophotometrically according to the Polish Standard PN-90/A-75101/12. Deeply frozen samples of roots were grounded with anhydrous sodium sulphate and extracted by hexane. Total carotenoid content was determined with a UV-120IV spectrophotometer (Shimadzu, Japan), using a wavelength of 450 nm [Gajewski et al. 2009].

The results were analysed statistically by analysis of variance. LSD values were determined by Tukey's test at $\alpha = 0.05$.

The study results obtained did not differ significantly between experimental years; therefore, the averages for 2009–2011 are shown in the tables.

RESULTS

The application of growth stimulators had a beneficial effect on total yield of carrot roots (tab. 2). Compared to the control treatment, significantly higher total root yield (on average by 7%) was found in the plots sprayed with the growth stimulator Asahi SL. Growing stubble crops after harvest of spring barley positively affected total carrot yield. In relation to the treatments without cover crops, the treatments with legume stubble were found to produce statistically proven higher total yield of carrot roots; the average difference was 4.3 t·ha^{-1} (6.3%).

All growth stimulators applied had a significant effect on the increase in marketable yield of carrot roots in relation to the control plots, on average by 20.2% (Asahi SL and Bio-algeen S 90) and 16.7% (Tytanit). Irrespective of growth stimulators, the stubble-cropped plot with the mixture of spring vetch and field pea had an effect on significantly higher marketable yield of carrot roots (on average by 7.7%) in comparison with the yield found in the treatments without stubble crop. The tansy phacelia cover crop also affected positively marketable carrot root yield, but the increasing trend was not statistically significant (tab. 3).

Table 2. Total yield ($t \cdot ha^{-1}$) of carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	62.7	66.7	65.3	64.8	64.9
Tansy phacelia	64.9	69.6	69.1	67.5	67.8
Spring vetch + field pea	65.8	71.4	70.2	69.4	69.2
Mean	64.5	69.2	68.2	67.2	–

LSD $NIR_{\alpha = 0.05}$
growth stimulators (a) = 3.8
stubble crops (b) = 3.8
interaction (a·b) = n.s.

Table 3. Marketable yield ($t \cdot ha^{-1}$) of carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	40.3	51.6	50.2	48.9	48.0
Tansy phacelia	42.2	53.2	54.4	52.3	50.5
Spring vetch + field pea	45.1	54.9	55.3	52.8	52.0
Mean	42.5	53.2	53.3	51.0	–

LSD $NIR_{\alpha = 0.05}$
growth stimulators (a) = 3.4
stubble crops (b) = 3.2
interaction (a·b) = n.s.

Another advantage of the foliar-applied growth stimulators was a statistically significant reduction in yield of small carrot roots in comparison with the control treatment (tab. 4). The highest reduction in small root yield was observed under the influence of the biological stimulators Bio-algeen S 90 and Tytanit, on average by 3.3 $t \cdot ha^{-1}$ (27.3%), while a slightly lower reduction was found as a result of spraying the carrot crop with Asahi SL (on average by 22.4%). The tansy phacelia stubble crop did not have a major effect on the percentage of small roots in total carrot yield, whereas the legume stubble crop had a destructive effect in this case, contributing to higher, on average by 7.9%, yield of small roots compared to the treatment without stubble crop.

The growth stimulators have a beneficial effect on the proportion of infected and deformed carrot roots, thus on unmarketab. root yield (tab. 5). The highest reduction (on average by 40.8%) in unmarketable yield of carrot roots, compared to the control treatment, was found in the plots sprayed with Bio-algeen S 90 as well as in the treatments where Asahi SL was applied (on average by 36.0%). The application of Tytanit resulted in an about 31.1% decrease in unmarketable carrot root yield. The introduction of stubble crops after harvest of the main forecrop for carrot (spring barley) had a positive influence on the proportion of unmarketable carrot roots in total yield; however, a significant decrease in this yield component (on average by 6.5%), in relation to the treatment in which the cereal forecrop alone was used, was observed only in the case of the legume stubble crop (spring vetch + field pea).

Table 4. Yield ($t \cdot ha^{-1}$) of small carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	11.9	8.2	8.5	9.0	9.4
Tansy phacelia	12.3	9.9	8.7	7.9	9.7
Spring vetch + field pea	12.0	10.1	9.2	9.6	10.2
Mean	12.1	9.4	8.8	8.8	–

LSD $NIR_{\alpha = 0.05}$
growth stimulators (a) = 0.6
stubble crops (b) = 0.5
interaction (a·b) = n.s.

Table 5. Unmarketable yield ($t \cdot ha^{-1}$) of carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	10.5	6.9	6.6	6.9	7.7
Tansy phacelia	10.4	6.5	6.0	7.3	7.5
Spring vetch + field pea	9.9	6.4	5.7	7.0	7.2
Mean	10.3	6.6	6.1	7.1	–

LSD $NIR_{\alpha = 0.05}$
growth stimulators (a) = 0.5
stubble crops (b) = 0.4
interaction (a·b) = n.s.

The growth stimulators investigated in the present experiment did not have a major effect on the increase in dry matter content in carrot roots (tab. 6). However, the stubble crops had a significant impact on the formation of root dry matter. Irrespective of foliar application of the stimulators, stubble cropping using the mixture of spring vetch and field pea as well as tansy phacelia resulted in an increase in dry weight of carrot roots on average by 0.75% DW and 0.66% DW, respectively, compared to the treatment without cover crop.

The content of L-ascorbic acid in carrot roots was significantly dependent on both experimental factors (tab. 7). Foliar fertilization with the growth stimulators Asahi SL and Bio-algeen S 90 caused higher L-ascorbic acid accumulation in relation to the control treatment, on average by 12.2% and 15.1%, as well as in comparison with the plot sprayed with Tytanit, on average by 7.1–10.2%. Growing carrot in the stand after spring barley (without stubble crop), regardless of the growth stimulators, caused decreased L-ascorbic acid content in carrot roots compared to the stubble cropped plots, on average by 9.4% (spring vetch + field pea) and 6.1% (tansy phacelia).

Table 6. Dry matter (%) content in carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	10.88	11.09	11.18	10.97	11.03
Tansy phacelia	11.64	11.83	11.72	11.59	11.69
Spring vetch + field pea	11.56	11.92	12.01	11.63	11.78
Mean	11.36	11.61	11.63	11.39	–

LSD NIR$_{\alpha = 0.05}$
growth stimulators (a) = n.s.
stubble crops (b) = 0.65
interaction (a·b) = n.s

Table 7. L-ascorbic acid content (mg·100 g^{-1} FW) in carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	6.39	7.19	7.24	6.47	6.82
Tansy phacelia	6.58	7.45	7.92	7.11	7.26
Spring vetch + field pea	6.79	7.86	8.11	7.33	7.52
Mean	6.59	7.50	7.76	6.97	–

LSD NIR$_{\alpha = 0.05}$
growth stimulators (a) = 0.39
stubble crops y (b) = 0.40
interaction (a·b) = n.s.

Carrot roots were found to have significantly lower total sugar content under the control conditions than after foliar application of the growth stimulators (tab. 8). Tytanit had the most beneficial effect on total sugar content (an average increase in sugar content by 19.9%), followed by Bio-algeen S 90 (an 8.1% increase) and Asahi SL (a 6.8% increase). The stubble crops did not differentiate significantly the trait in question, but an increasing trend was observed in total sugar content.

Table 8. Total sugar content (mg·100 g^{-1} FW) in carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	4.63	4.95	5.07	5.83	5.12
Tansy phacelia	4.94	5.12	5.19	6.14	5.35
Spring vetch + field pea	4.82	5.39	5.42	6.02	5.41
Mean	4.80	5.15	5.22	5.99	–

LSD NIR$_{\alpha = 0.05}$
growth stimulators (a) = 0.34
stubble crops (b) = n.s.
interaction (a·b) = n.s.

Table 9. Total carotenoid content (mg·100 g^{-1} FW) in carrot roots (mean for 2009–2011)

Specification	Growth stimulators				
Stubble crops	control	Asahi SL	Bio-algeen	Tytanit	mean
Without stubble crop (control)	17.11	16.66	16.98	17.08	16.95
Tansy phacelia	18.19	17.64	17.25	17.79	17.71
Spring vetch + field pea	18.35	17.97	18.02	18.19	18.13
Mean	17.88	17.42	17.41	17.68	–

LSD NIR$_{\alpha = 0.05}$
growth stimulators (a) = n.s.
stubble crops (b) = 1.05
interaction (a·b) = n.s.

The application of growth stimulators resulted in a slight decrease in total carotenoid content in carrot roots, but these differences were within the margin of experimental error (tab. 9). On the other hand, a statistically proven increase in carotenoid accumulation was observed under the influence of the stubble crop (spring vetch + field pea). The carotenoid content determined under such conditions was higher on average by about 7% compared to that recorded in raw material obtained from the treatments without stubble crop.

DISCUSSION

Total carrot yield obtained in the present experiment as well as yield structure were similar to the results reported by other autors [Majkowska-Gadomska and Wierzbicka 2010, Błażewicz-Woźniak and Wach 2011, Kjellenberg et al. 2012]. The growth stimulators investigated in the present experiment contributed to an increase in total carrot root yield and, what is important, they resulted in statistically proven higher marketable root yield. The most beneficial influence on yield was noted in the case Asahi SL and Bio-algeen S 90, while Tytanit showed a slightly lower effect in this respect. Many authors [Carvajal et al. 1994, Carvajal and Alcaraz 1998, Czeczko and Mikos-Bielak 2004, Djanaguirman et al. 2005, Prusiński and Kaszkowiak 2005, Król 2009, Kwiatkowski 2011] draw attention to the positive influence of foliar application of growth stimulators. In the scientific literature, there is a lack of studies on the direct effect of biostimulators on small and unmarketable root yield. It should be noted, however, that these growth regulators have an indirect effect on the above-mentioned parameters. Biostimulators positively affect plant defence mechanisms against agricultural pests and thus contribute to an improvement in plant productivity and health. In consequence, the fraction of marketable roots increases, while the percentage of small roots decreases [Czeczko and Mikos-Bielak 2004, Sulewska and Kruczek 2005].

Asahi SL contains sodium salts of 5-nitroguaiacolate as well as ortho- and para-nitrophenolates. These are natural plant components occurring in small amounts which, when applied exogenously, have an effect on the acceleration of electron transport in plant photosynthesis and on the flow of assimilates from leaves to the place of their storage [Czeczko and Mikos-Bielak 2004]. Bio-algeen S 90 is a natural extract from sea algae from the group of brown algae and contains numerous natural chemical compounds, including vitamins, amino acids, and alginic acid. This biological growth stimulator affects root system development, thereby increasing plant resistance to adverse environmental conditions [Sulewska and Kruczek 2005]. Tytanit (Ti 0.8%) contains sodium salts of 5-nitroguaiacolate as well as ortho- and para-nitrophenolates. It has a beneficial effect on plant growth and development by activating metabolic processes. Titanium is also a catalyst through which plants use nutrients better [Carvajal and Alcaraz 1998]. In the experiments of Kwiatkowski [2011] as well as of Kwiatkowski and Juszczak [2011], the growth stimulators Asahi SL and Tytanit had a positive effect on dry herb yield of garden thyme and common basil increasing their productivity at a level of 7–12% (thyme) and 22–31% (basil). The above-mentioned growth stimulators generally contributed to a worsening of the chemical composition of herbal raw material. Also in the study of Król [2009], foliar-applied agents caused a slight reduction in essential oil content in thyme raw material. In studying the response of carrot to extracts of natural origin obtained from algae of the genus *sargassum* (AlgaminoPlant) and to extracts derived from leonardite (HumiPlant), Dobrzański et al. [2008] found the growth stimulators applied to have a beneficial effect on yield and chemical composition of carrot roots. Furthermore, a trend was observed towards a decrease in nitrate content, while the carotenoid content increased. Kołota and Biesiada [2000] indicate the positive influence of foliar fertilization on carrot roots. The study of Smoleń and Sady [2007] shows that foliar fertilization contributed to a reduction in the content of soluble sugars, but it had no effect on the content of carotenoid and phenolic compounds in carrot.

In the experiment under discussion, the growth stimulators did not result in a decrease in the values of the quality parameters investigated; on the contrary, they caused a significant increase in some components (L-ascorbic acid, total sugars). The values for the content of dry matter, total sugars, and L-ascorbic acid obtained in the present experiment were similar to the results reported in some national studies [Wierzbicka et al. 2004, Gajewski et al. 2009, Majkowska-Gadomska and Wierzbicka 2010] and in foreign studies [Brunsgaard et al. 1994, Kaack et al. 2001, Singh et al. 2001, Arscot and Tanumihardio 2010, Singh et al. 2012]. In the opinion to Kidmose and Martens [1999], Tsukakoshi et al. [2009], Leong and Oey [2012], Kjellenberg et al. [2012] total concentrations of sugars in carrot roots were found to be between 5 and 7 mg·kg^{-1}. This is the same level as in the present investigation. Sharma et al. [2012] report a slightly lower content of total sugars in carrot roots – 2.7–4.5 mg·kg^{-1}. In comparison to the presented results of the investigation, Singh et al. [2012] reported lower content of L-ascorbic acid in carrot roots with mean of 0.25–3.5 mg·100 g^{-1} FW. Sharma et al. [2012], when analysing chemical composition of carrot, indicated the content of L-ascorbic acid in carrot roots similar to the results under discussion – at a level of 4.0 mg·100 g^{-1} FW. The observed differences can be explained by genetic features of particular carrot varieties as well as by the type of the fertilization applied [Singh et al. 2001, Nicolle et al. 2004, Singh et al. 2012]. Greater variations in the results related to carotenoids whose content in carrot roots is largely associated with cultivar traits as well as time of harvest and soil conditions [Kaack et al. 2001, Gajewski et al. 2009]. Leong and Oey [2012] reported the content of carotenoids similar to the content obtained in the analysed study.

There are too few studies on the effects of stubble crops on yield and quality of carrot roots. The yielding ability of the mixture of field pea and tansy phacelia proved to be comparable with the results of the studies cited by Gawęda [2011] and Kwiatkowski [2012], whereas Jabłońska-Ceglarek and Rosa [2002] found values of nutrients incorporated into the soil with stubble biomass which are similar to the results of the present study. In this experiment, stubble crops played an important role, positively affecting the structure of carrot root yield and the content of root dry matter, L-ascorbic acid, and carotenoids. The legume stubble crop proved to be particularly worth recommending. The supply of an additional amount of organic carbon to the soil in the form of stubble crop biomass allows an appropriate organic matter level, biological activity and good phytosanitary condition of the soil to be maintained. Stubble cropping results in an improvement of soil sorption, buffer, filtration, and retention properties. Ploughed-in biomass of stubble crops provides to the soil as much organic matter as a 1/2 rate of animal manure [Bruce et al. 1990, Gondek and Zając 2003, Marshall et al. 2003]. Kwiatkowski [2007] as well as Kwiatkowski and Juszczak [2011] showed the positive influence of stubble crop biomass on productivity of some herbal plants (thyme, basil) and on essential oil content in herbal raw material. The positive influence of stubble crops on vitamin C content in red beet is described also by Jabłońska-Ceglarek and Rosa [2002].

However, it is commonly claimed that application of growth stimulators could be beneficial only in cases when treated plants are grown under unfavourable conditions (weaker soil, worse forecrop, reduced dose of mineral fertilization) [Kołodziej 2004, Król 2009, Kwiatkowski and Juszczak 2011]. The results obtained by Przybysz et al. [2010] clearly showed that Asahi SL applied on plants (*Arabidipsis thaliana* L. and ornamenthal amaranth) can also be effective and beneficial when they are grown under optimal conditions. The above observation is fully confirmed by the results of the present study. The best effect of applying growth stimulators were obtained in conditions of a good forecrop (stubble crop from leguminous plants).

CONSLUSIONS

1. The foliar-applied growth stimulators used in the present experiment (Asahi SL, Bio-algeen S 90, Tytanit) had a positive effect on marketable carrot root yield by reducing the fraction of small roots and the unmarketable fraction (infected and deformed roots) in total root yield.
2. Stubble crops grown after the main forecrop for carrot (spring barley) contributed to higher total root yield and marketable root yield; the legume mixture (spring vetch + field pea) was the best stubble crop.
3. The growth stimulators had a positive influence on the content of L-ascorbic acid and total sugars in carrot roots, whereas their effect on dry matter content and carotenoid content was neutral.
4. The positive effect of stubble crops on the nutritional composition of carrot roots was primarily manifested in an increased content of dry matter, L-ascorbic acid, and carotenoids, with the legume stubble crop producing better parameters.
5. The results of comparative evaluation of the growth stimulators included in this experiment on carrot are similar for all of them and unequivocally positive, in particular with respect to Asahi SL and Bio-algeen S 90. Tytanit had a slightly lower effect on the reduction in unmarketable root yield and on some parameters of the nutritional composition of roots (lower L-ascorbic acid content).

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PLONOWANIE I PARAMETRY JAKOŚCIOWE KORZENI MARCHWI (*Daucus carota* L.) W ZALEŻNOŚCI OD STYMULATORÓW WZROSTU ORAZ MIĘDZYPLONÓW ŚCIERNISKOWYCH

Streszczenie. Polepszenie wzrostu, kondycji, jakości surowca oraz odporności roślin warzywnych na niekorzystne warunki stresowe czy agrofagi można uzyskać, stosując biostymulatory w formie oprysku dolistnego. Duże znaczenie odgrywa także uprawa międzyplonów, które wpływają m.in. na lepsze wykorzystanie przez rośliny warunków środowiska i nawożenia. W latach 2009–2011 przeprowadzono doświadczenie polowe, którego celem było określenie wpływu stymulatorów wzrostu oraz międzyplonów na strukturę plonu korzeni marchwi (odmiana 'Laguna F1') i gromadzenie się składników chemicznych w korzeniu spichrzowym. W badaniach uwzględniono trzy stymulatory wzrostu: Asahi SL, Bio-algeen S 90 i Tytanit. Obiektem kontrolnym były poletka bez dolistnego stosowania stymulatorów wzrostu. Drugi czynnik badany w doświadczeniu stanowiły międzyplony ścierniskowe na przyoranie: facelia błękitna i mieszanka wyki jarej z peluszką. Międzyplony uprawiano na stanowisku po jęczmieniu jarym. Określano plon ogólny korzeni marchwi i jego frakcje (plon handlowy, plon korzeni drobnych, plon niehandlowy) oraz wybrane składniki decydujące o jakości korzeni (zawartość suchej masy, karotenoidów, kwasu L-askorbinowego, cukrów ogółem). Badania dowiodły, że wszystkie stymulatory wzrostu oddziaływały dodatnio na parametry ilościowe i jakościowe korzeni marchwi. Brak aplikacji stymulatorów wzrostu był minimalnie korzystny tylko w przypadku zawartości karotenoidów ogółem w korzeniach marchwi. Pozytywne oddziaływanie na produkcyjność i jakość korzeni marchwi miały także międzyplony, w szczególności mieszanka roślin strączkowych.

Key words: produkcyjność marchwi, skład chemiczny korzeni, biostymulatory

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