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Short Communication

Concentrations of Heavy Metals and Nitrates in Eggplant Grown with a Biostimulator

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Abstract

A greenhouse experiment was conducted in 2011-12 to determine the effects of fertilization using an Asahi SL biostimulator on heavy metal concentrations in two cultivars of eggplants (*Solanum melongena* L.) grown in an unheated plastic tunnel in the garden of the Research and Experimental Station of the University of Warmia and Mazury in Olsztyn. Eggplants with their high nutritional and biological values plus popularity, eggplants are an important crop economically. However, due to their temperature requirements, eggplants are difficult to grow in regions with less favorable climatic conditions. Biostimulants and biopreparations are applied to protect plants against exogenous stressors, and to promote their healthy growth and development. Such protective treatments are increasingly applied in the cultivation of thermophilous vegetables in colder climates. The Asahi SL biostimulator supports the plant's natural defense mechanisms, thus alleviating the negative effects of adverse environmental conditions. Under optimal growing conditions the biostimulator helps crops reach their full genetic potential. The experimental materials comprised plants of two eggplant cultivars: Black Beauty and Violetta Lunga. Seedlings were grown in line with the generally observed standards for eggplant cultivation. The heavy metal content of plant material (in fruit) was determined. The concentrations of heavy metals and nitrates (V) in eggplants grown in an unheated plastic tunnel did not exceed the maximum permissible levels. The biostimulator exerted varied effects on the heavy metal and nitrate (V) contents of eggplants, and it increased the accumulation of mercury in the edible parts of eggplants. A significant increase in the concentrations of cadmium and nitrates (V) was noted in the cv. Black Beauty control eggplants.

Keywords: vegetables, cadmium, lead, mercury, nitrates

Introduction

The eggplant (*Solanum melongena* L.; common name aubergine) is grown for its edible fruit. Eggplants are appreciated for their taste, nutritional value, and health-promoting properties, which contribute to their popularity among both dieticians and consumers [1]. According to the Food and Agriculture Organization [2], global eggplant production reached 48 million tons in 2013. Fleshy eggplant fruits are a rich source of minerals, in particular potassium, calcium, and phosphorus, and

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they have a low sodium content, which makes them an important component of the human diet [3, 4]. Due to unfavorable temperature and light conditions, eggplants are not grown in Poland – especially in the northeastern parts of the country. Thus, biostimulants such as the Asahi SL biostimulator can play an important role in eggplant cultivation. The biostimulator contains natural compounds found in plant cells that participate in physiological and biochemical processes in plants [5]. It protects crops against adverse environmental conditions, increases their stress tolerance, and stimulates their growth and development.

The objective of this study was to determine the effects of the biostimulator on the concentrations of heavy metals and nitrates (V) in the fruits of two eggplant cultivars (Violetta Lunga and Black Beauty), grown in an unheated plastic tunnel in northeastern Poland.

Materials and Methods

A two factorial experiment was conducted in 2011-12 in the garden of the Research and Experimental Station of the University of Warmia and Mazury in Olsztyn. Eggplants were grown in an unheated plastic tunnel in a randomized block design with three replications. The first experimental factor was eggplant cultivar (Black Beauty and Violetta Lunga) and the second experimental factor was the application of the biostimulator, which was sprayed onto the leaves of eggplants. Plants sprayed with water served as control.

Seedlings were grown in propagators, in line with the generally observed standards for eggplant cultivation. Each year, seedlings were planted in the ground in the middle of May, at 50 x 50 cm spacing. The experimental unit of each replicate consisted of 12 plants. Starting on the third day after transplanting, at 10-day-intervals, eggplants were sprayed three times with the biostimulator at a concentration of 0.1%. Control plants were sprayed with water.

The mineral composition of soil was determined in each year of the study. The average values for the entire experimental period were as follows (mg dm^{-3}): N-NO_3: 27, P: 235, K: 65, Ca: 1,260, Mg: 294, Cl: 12, pH in H_2O: 7.45, salinity: 0.34 mg dm^{-3}, and heavy metals Cd: 0.07 and Pb: 0.15 (mg·dm^{-3}). Chemical analyses were performed in the Chemical and Agricultural Station in Olsztyn. Nitrogen was determined using the Kjeldahl method.

Analyses of soil composition was carried out with the standard methods acidity in water with the concentrations of phosphorus and potassium determined by the Egner-Riehm method, magnesium by the Schachtschabel method, and calcium by the universal method proposed by Nowosielski. Heavy metals content was determined by atomic absorption spectrometry (AAS). The soil in which eggplant seedlings were planted was found to be abundant in phosphorus and magnesium, and no supplemental fertilization with those elements was needed throughout the experiment. Due to the low nitrate nitrogen content of soil, nitrogen was applied at a single rate of 90 kg·ha^{-1} in the form of ammonium nitrate, before transplanting the seedlings in the middle of May.

The recommended cultivation practices for eggplants were carried out. The fruits were harvested at the stage of commercial maturity, from mid-July to the end of September. The fruits intended for chemical analyses were collected in the middle of the growing season (around 10 August). Plant material was collected from the marketable yield in each replication to obtain an average sample per treatment.

At the laboratory of the Department of Horticulture, University of Warmia and Mazury in Olsztyn, the edible parts of plants were assayed for:

– Dry matter by drying to constant weight at 105ºC [PN-90/A-75101/03].
– Nitrates (V) using the colorimetric method with salicylic acid.

Averaged samples of the three fruits collected from the marketable yield in each treatment were comminuted, dried at 65ºC to constant weight, and ground in an electric grinder.

In a certified laboratory of the Chemical and Agricultural Station in Olsztyn (accreditation certificate No. AB 277 issued by the Polish Center for Accreditation in Warsaw), the plant material was mineralized with concentrated sulfuric acid and assayed for Cd, Pb, and Hg using AAS:.

The results of two years of research, given as the average of the two years, were processed statistically by analysis of variance (ANOVA). The significance of differences between means was estimated using Tukey's confidence intervals at $\alpha = 0.05$.

Results and Discussion

Asahi SL contains natural compounds found in plant cells, which participate in physiological and biochemical processes in plants. The biostimulator enhances the resistance of plants to abiotic stresses such as low temperature, drought, excessive moisture, and salinity [5]. By activating specific metabolic pathways, plants can adapt to adverse growing conditions [6]. However, their defensive responses are usually insufficient to prevent yield and quality losses. Asahi SL supports natural processes of plant growth and development, and improves their energy efficiency [5]. The use of biostimulants is recommended when vegetables are grown in areas with less favorable climatic conditions, such as the region of Warmia where the climate is cooler and average daily air temperatures are lower than in other Polish regions, which considerably shortens the growing season [7]. The optimum temperature for growing eggplants is above 10ºC. Lower temperatures negatively affect plant development by reducing water and nutrient uptake, leading to growth inhibition and wilting [4]. Temperatures in northeastern Poland vary over space and time due to considerable differences between local habitats [8]. Average daily air temperatures during the

Table 1. Average daily air temperatures during the growing season of eggplants in 2011-12, based on data provided by the Olsztyn Hydrological and Meteorological Station.

Months	Average daily air temperatures (°C)			
	Year		Montly average (2011-2012)	Long-term average 1981-2010
	2011	2012		
May	13.4	13.4	13.3	13.5
June	17.1	15.0	16.1	16.1
July	17.9	19.0	18.5	18.7
August	17.6	17.7	17.6	17.9
September	14.1	13.5	13.8	12.8
October	8.3	7.4	7.9	8.0

growing season of eggplants are shown in Table 1, based on data provided by the Hydrological and Meteorological Station in Olsztyn.

Throughout the experimental period, average daily air temperatures were higher than the long-term average of 1981-2010 by 0.2ºC in July, by 0.3ºC in August, by 1.0ºC in September, and by 0.1ºC in October.

The dry matter content of fruits is presented in Table 2. A statistical analysis revealed that the cultivar x fertilizer interaction had a significant effect on the dry matter content in. As regards the interaction effect, the highest dry matter content was determined in cv. Black Beauty fertilized with Asahi SL and cv. Violetta Lunga from the control treatment.

Heavy metals present in the edible parts of plants pose a threat to human health, and their accumulation is largely determined by their concentrations in the environment [9]. The heavy metal content of vegetables varies depending on the metal-accumulating capacity of plants [10]. The fruits of the analyzed eggplant cultivars sprayed with the biostimulator contained various amounts of heavy metals (Table 2), but the noted differences were not statistically significant.

Heavy metals may cause acute or chronic poisoning. Many patients remain asymptomatic for a long time, but eventually heavy metals may lead to mutations in human and animal cells [11]. A significant correlation has been found between the concentrations of heavy metals in foods and cancer mortality rates [12]. In the present study, the heavy metal content of eggplant fruit remained within permissible limits in all treatments [13].

Eggplant cultivars had no significant effect on the accumulation of heavy metals in the fruit. In cv. Black Beauty, heavy metals content was as follows: Cd: 0.00119 $mg \cdot kg^{-1}$ DM, Pb: 0.047 $mg \cdot kg^{-1}$ DM, and Hg: 0.00105 $mg \cdot kg^{-1}$ DM. In cv. Violetta Lunga the respective values were 0.00085 $mg \cdot kg^{-1}$ DM, 0.038 $mg \cdot kg^{-1}$ DM, and 0.00112 $mg \cdot kg^{-1}$ DM (Table 2). Asahi SL had no significant influence on the accumulation of cadmium and lead in eggplant fruit, but it contributed to an increase in mercury content. An analysis of the interaction between the experimental factors revealed that in cv. Black Beauty Cd content reached 0.00158 $mg \cdot kg^{-1}$ DM in the control treatment and 0.00080 $mg \cdot kg^{-1}$ DM in the Asahi SL treatment, whereas the respective values for Hg content were 0.00095 and 0.00116 $mg \cdot kg^{-1}$ DM. In Violetta Lunga, Cd and Hg content was 0.00082 $mg \cdot kg^{-1}$ DM and 0.00102 $mg \cdot kg^{-1}$ DM, respectively, in the control treatment, and 0.00089 $mg \cdot kg^{-1}$ DM and 0.00122 $mg \cdot kg^{-1}$ DM, respectively, in the Asahi SL treatment. The noted differences were statistically significant.

Nitrates (V), regarded as undesirable mineral compounds in fruits, determine their suitability for processing or fresh consumption. Maximum levels for

Table 2. The effect of cultivar and fertilization with Asahi SL on the concentrations of heavy metals (Cd, Pb, Hg) in the dry matter of eggplant fruit (mean values for 2011-12).

Cultivar	Treatment	Dry matter (%)	Heavy metals ($mg \cdot kg^{-1}$ DM)			Nitrates ($mg\ NO_3^{-1} \cdot kg^{-1}$ fresh weight)
			Cd	Pb	Hg	
Black Beauty	Control	8.76	0.00158	0.043	0.00095	323.3
	Asahi SL	9.54	0.00080	0.050	0.00116	293.1
Mean values for cultivars		9.15	0.00119	0.047	0.00105	308.2
Violetta Lunga	Control	9.69	0.00082	0.032	0.00102	176.5
	Asahi SL	8.49	0.00089	0.044	0.00122	217.8
Mean values for cultivars		9.09	0.00085	0.038	0.00112	197.2
Mean values for treatments	Control	9.23	0.00120	0.038	0.00098	249.9
	Asahi SL	9,02	0.00084	0.047	0.00114	255.5
$LSD_{0.05}$						
Cultivar (a)		n.s.	n.s.	n.s.	n.s.	27.1
Treatment (b)		n.s.	n.s.	n.s.	0.00012	n.s.
Interaction (a×b)		0.19	0.00019	n.s.	0.00019	3.1

nitrates in eggplant fruit were not set by Commission Regulation (EU) No. 1258/2011 of 2 December 2011 [13]. Therefore, in this study nitrate concentrations in eggplants were compared with those determined in the edible parts of cucumbers, and they were found to be within permissible limits. The fruits of cv. Black Beauty contained significantly higher concentrations of nitrates (V) than the fruits of cv. Violetta Lunga (Table 1). Asahi SL had no impact on nitrate (V) accumulation in eggplants. The fruits of cv. Black Beauty in the control treatment had the highest nitrate (V) content, and the lowest nitrate (V) levels were noted in the fruits of cv. Violetta Lunga in the control treatment.

Conclusions

1. The concentrations of heavy metals and nitrates (V) in eggplants grown in an unheated plastic tunnel did not exceed the maximum permissible levels.
2. The biostimulator Asahi SL exerted varied effects on the heavy metal and nitrate (V) content of eggplants, and it increased the accumulation of mercury in the edible parts of eggplants.
3. A significant increase in the concentrations of cadmium and nitrates (V) was noted in control eggplants of cv. Black Beauty.

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