Acta Sci. Pol. Hortorum Cultus, 20(6) 2021, 45–57

https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2021.6.6

ORIGINAL PAPER

Accepted: 19.01.2021

BIOSTIMULANTS CONTAINING AMINO ACIDS IN VEGETABLE CROP PRODUCTION

Robert Gruszecki[1], Aneta Stawiarz[2]

[1]Department of Vegetable and Herb Crops, University of Life Sciences in Lublin, Akademicka 15, 20-950 Lublin, Poland

[2]Gospodarstwo Rolne „Aneta i Krzysztof Stawiarz", Żurawniki 35, 27-540 Lipnik, Poland

ABSTRACT

Amino acids can induce defence reactions and reduce the impact of abiotic stresses on plants, yet their impact on the yield of vegetable crops is varied. For this reason, an analysis of the published research on the effect of biostimulants containing amino acids (BCAA) on the quantity and quality of vegetable crop yield was carried out. The results of the research indicate the multidirectional effect of BCAA on vegetable plants and they also show that the use of these biostimulants may increase yield quantity and quality as well as influence biometric features and chemical composition of plants. BCAA may also affect the amount of losses caused by pests and during the storage of vegetables. However, the variability of the effects is very large and depends on many factors: composition of BCAA, time, dose, number and method of application, cultivation cycle, weather conditions, and plant species or even cultivar. Therefore, the effective use of BCAA requires further research, while their proper application in horticultural practice will require taking into account many factors.

Key words: yield, plant growth, biometrical features, chemical composition

INTRODUCTION

The use of biostimulants is an innovative but increasingly common practice in agriculture [Van Oosten et al. 2017, Bulgari et al. 2019]. The interest in this group of products is constantly growing and its projected growth is expected to be 11.2% a year, reaching US$ 4.9 billion by 2025 [MarketsAndMarkets 2019]. Amino acids are one of the groups of biostimulants that in recent years have attracted more and more attention. Biostimulants containing amino acids are usually used to enhance plant tolerance to unfavourable environmental conditions and increase the quantity and quality of crops [Maini 2006, Botta 2013, Sadak et al. 2015, Stawiarz and Gruszecki 2015]. Generally it is believed that amino acids may induce defence responses of plants and increase their tolerance to various abiotic stresses, e.g. drought, soil salinity, low and high temperature [Maini 2006, Ashraf and Foolad 2007, Chen and Murata 2008, Mattioli et al. 2009, Lehmann et al. 2010, Jonytienė et al. 2012, Botta 2013, Calvo et al. 2014, Dar et al. 2016, Bulgari et al. 2019, Trovato et al. 2019]. Data regarding the effect of products containing amino acids on the quantity and quality of plant crops varies, but in many cases their beneficial effects have been proven [Maini 2006, Kowalczyk et al. 2008, Abd El-Aal et al. 2010, Raeisi et al. 2013, Calvo et al. 2014, El-Nemr et al. 2015, Kocira et al. 2015, Sadak et al. 2015, Stawiarz and Gruszecki 2015, Shafeek et al. 2018a, b, Abdel-Rahim et al. 2019, Ismail and Fayed 2020]. Attention is drawn that the effects of using BCAA may depend on many factors such as weather conditions, type of products, cultivar, plant stages, dose and method of application [Kowal-

robert.gruszecki@up.lublin.pl

czyk et al. 2008, Parrado et al. 2008, Grabowska et al. 2012, Calvo et al. 2014, Kocira et al. 2015, Mogor et al. 2018, Shehata and Abdel-Wahab 2018, Khalel and Sultan 2019]. Rational use of such products in vegetable production requires knowledge of the advantages and risks of their use as well as of factors influencing effects of their action. For this reason, an analysis was undertaken of the existing research on the use of BCAA in vegetable cultivation and their impact on plant growth, and quantity, and quality of crops.

Biostimulants containing amino acid compounds

Amino acids play a role in nitrogen storage and transport in plants and are necessary in protein biosynthesis. These compounds have a positive impact on plant growth and performance, and alleviate abiotic stresses [Kowalczyk et al. 2008, Mattioli et al. 2009, Lehmann et al. 2010, Jonytienė et al. 2012, Botta 2013, Calvo et al. 2014, Colla et al. 2014, El-Nemr et al. 2015, Dar et al. 2016, Bulgari et al. 2019, Trovato et al. 2019]. Currently on the market there are products containing amino acids of plant and animal origin [Calvo et al. 2014, du Jardin 2015, Kocira et al. 2015, Bulgari et al. 2019]. BCAA are obtained by thermal, chemical or enzymatic hydrolysis which may have a big impact on forms of obtained amino acids [Cavani et al. 2006, Maini 2006, Ertani et al. 2009, Kunicki et al. 2010, Grabowska et al. 2012, Trawczyński 2014, du Jardin 2015, Kocira et al. 2015, Moreno-Hernández et al. 2020]. Depending on the source of animal or plant material and method of hydrolysis, the percentage of individual amino acids and peptides varies [Parrado et al. 2008, Calvo et al. 2014, Moreno-Hernández et al. 2020]. For this reason, the composition of commercial products varies in concentration and proportion of amino acids and peptides, but also because of the content of other substances such as fertilizers, vitamins, organic acids, auxins, cytokinins, and other compounds that may interfere with the action of amino acid products (Tab. 1) [Gajc-Wolska et al. 2012, Calvo et al. 2014, Colla et al. 2014]. Differences in effects of BCAA application might also be a result of differences in doses, frequency and timing of applications used in experiments. For example, the frequency of using BCAA ranged from a single application to systematic spraying every 7 days during the cultivation (Tab. 2). BCAA are usually foliar applied, but they can also be introduced into the soil or used for seed soaking, which is not insignificant for the effects of their action (Tab. 2).

Plant growth

One of the most visible effects of the action of biostimulants is the intensification of plant growth. Many authors point out that products containing amino acids have a positive impact on plant height [Kowalczyk et al. 2008, Sarojnee et al. 2009, Abd El-Aal et al. 2010, Shaheen et al. 2010, Shehata et al. 2011, Fawzy et al. 2012, Shaheen et al. 2013, 2018, El-Abagy et al. 2014, Shalaby and El-Ramady 2014, Sadak et al. 2015, Kavasoğlu and Ceylan 2018, Shafeek et al. 2018a, b]. With increasing level of the products, plant height increased [Shafeek et al. 2018a, b], but also no dependency was found [Kavasoğlu and Ceylan 2018]. El-Abagy et al. [2014] noted that BCAA both increased and limited plant height, depending on the type of product and its level. Raeisi et al. [2013] did not find a beneficial effect of BCAA on the height of broad bean plants and Abou El Magd [2019] on the height of kohlrabi and broccoli plants. In many works it was noted that BCAA have a different effect on this trait, depending on weather conditions [Abd El-Aal et al. 2010, Shaheen et al. 2010, Shehata et al. 2011, Fawzy et al. 2012, Shalaby and El-Ramady 2014, Sadak et al. 2015]. In the research by Khalel and Sultan [2019], the type of products and method of application influenced the height of onion plants. In this experiment, only Azomine increased plant length regardless of the method of application, while other products only when they were both foliar and soil applied.

Plants to which BCAA was applied are often characterised by more lush growth. Intense plant growth after amino acids application often manifests itself in higher fresh and dry plant weight [Sarojnee et al. 2009, Fawzy et al. 2012, Shaheen et al. 2013, 2018, Sadak et al. 2015, Ismail and Fayed 2020]. This effect may depend on the preparation dose since along with increasing biostimulant dose increasingly higher fresh and dry weight of faba bean [Sadak et al. 2015], onion [Shafeek et al. 2018a] and pea plant was noted [Shafeek et al. 2018b]. El-Abagy et al. [2014] found that BCAA not always contribute to increasing dry plant weight as these effects depend on the type of product and often its dose. BCAA may impact number of branches per plant, as well [Sarojnee et al. 2009, Ismail and Fayed 2020].

In many studies, using BCAA was found to have a positive effect on fresh and dry leaf weight [Shehata et al. 2011, Fawzy et al. 2012, El-Abagy et al. 2014, El-Nemr et al. 2015, Mogor et al. 2018]. The effectiveness of their application may depend on the type and dose of products, methods of application, and weather conditions [El-Abagy et al. 2014, Abou El Magd 2019, Khalel and Sultan 2019]. According to El-Abagy et al. [2014], using too high doses of BCAA in onion can result in lower fresh leaf weight contrary to using smaller dosages, but a too low dose resulted in reduction in dry weight of onion leaves. Several works focus on cultivar differences in the use of BCAA; Rahimi-Shokooh et al. [2013] found such differences in basil, whereas Stawiarz and Gruszecki [2015] in root parsley.

Application of BCAA can cause an increase in the number of leaves and such a reaction was observed in onion [Fawzy et al. 2012, Shaheen et al. 2013, El-Abagy et al. 2014, Shafeek et al. 2018a], garlic [Shalaby and El-Ramady 2014], broad bean [Sadak et al. 2015], eggplant [El-Nemr et al. 2015], pea [Shafeek et al. 2018b] and snap bean plants [Shaheen et al. 2018]. An increased number of leaves may be related to preparation dose; in broad bean and onion plants, number of leaves increased along with increasing preparation dose [El-Abagy et al. 2014, Sadak et al. 2015]. The BCAA effect may by modified by weather conditions, on which the optimum dose may depend [Fawzy et al. 2012, Shalaby and El-Ramady 2014]. Rahimi-Shokooh et al. [2013] showed that the impact of BCAA on number of basil leaves varies and depends on the type of products. This is confirmed in a study by Khalel and Sultan [2019], in which only Azomine increased the number of onion leaves regardless of the method of application, while other products only with both foliar and soil application. However, Shaheen et al. [2010] found no impact of BCAA on number of plant leaves in snap bean, while Abou El Magd [2019] in kohlrabi and broccoli. The research results concerning the impact of BCAA on plant leaf area vary because both an increase [Shaheen et al. 2018] and a decrease [Rahimi-Shokooh et al. 2013] in leaf area were found after applying such biostimulants.

Yield quantity and quality

By mitigating stress and improving conditions of plants, these products can affect plant density. The study by Stawiarz and Gruszecki [2015] points out that BCAA use affected an increase in number of plants during harvest and resulted in reduction of differences in plant density depending on the cultivar.

In many studies, the presented results demonstrate that that BCAA application has an impact on vegetable crop growth (Tab. 2).

The beneficial effect of BCAA on crops mainly depends on weather conditions, cultivation cycle, fertilization level and dose, application method, and type of products. Hence, depending on the combination of these factors, the impact can be bigger or smaller [Castro et al. 1988, Sarojnee et al. 2009, Abd El-Aal et al. 2010, Kunicki et al. 2010, Shehata et al. 2011, Fawzy et al. 2012, Grabowska et al. 2012, Koukounaras et al. 2013, Shaheen et al. 2013, Trawczyński 2014, Kocira et al. 2015, Kałużewicz et al. 2018, Mogor et al. 2018, Khalel and Sultan 2019]. However, in some works using BCAA was not found to have an impact on total yield or marketable yield of vegetables, and sometimes even a decrease in yields after their application was reported [Łyszkowska et al. 2008, Kunicki et al. 2010, Gajc-Wolska et al. 2012, Kałużewicz, et al. 2018, Kavasoğlu and Ceylan 2018, Shehata and Abdel-Wahab 2018, Abou El Magd 2019]. Kowalczyk et al. [2008] showed that with lower nitrogen fertilization (105 mg $N\text{-}NO_3$ dm^{-3}) of lettuce in the winter growing cycle, the use of Aminoplant decreased the yield, while at a higher level of fertilization (140 mg $N\text{-}NO_3$ dm^{-3}) it increased, but under better light conditions (in the spring growing cycle) the yield increased with both N doses. However, Trawczyński [2014] found that in potatoes BCAA was more effective in less favourable weather conditions. Some authors point out that plants of some cultivars after BCAA application may respond with an increase in yield, while other ones will not show any reaction or a negative one [Łyszkowska et al. 2008, Grabowska et al. 2012, Stawiarz and Gruszecki 2015]. The positive impact of BCAA may manifest itself in improvement in yield quality by increasing the share of marketable yield in total yield [Trawczyński 2014, Stawiarz and Gruszecki 2015]. Reduction of non-marketable yield after BCAA use is also observed. Stawiarz and Gruszecki [2015]

Table 1. Chemical composition of amino acid biostimulants

Biostimulant	Composition	Source	Producer
Aminolforte	FAA 3750 mg·dm^{-3}, organic components 2%, total N 1.1% (urea N 0.8%, organic N 0.3%)	Rahimi-Shokooh et al. 2013	Inagrosa Industries Agro Biologicals, Madrid, Spain
Amino green	TAA 15%, FAA: alanine, arginine, cycteine, escaliosin, glycine, glutamic, histidine, hystiden, lysine, methionine, phenylalanine, proline, hydroxy proline, serine, valine, Fe 2.9%, Mn 0.7%, Zn 1.4%	El-Nemr et al. 2015	
Amino-mix	mg 100 cm^{-3}: apartic acid 249, methionine 180, thiamine 45, isolucine 52, serine 56, therionine 38, glutamic acid 55, phenylalanine 22, glysine 50, histidine 12, alanine 100, lucine 40, proline 38, arginine 20, valine 68, tryptophan 20, cysteine 44, vitamin B_1 0.8, B_2 2.4, B_6 1.2, B_{12} 0.82, folic acid 4.2, pantothinic acid 0.52, niacine 0.14 ascorbic acid 1.0, g 100 cm^{-3}: Zn 2 Fe 1.5, Mn 0.5, Mg 0.004, Cu 0.004, Ca 0.025, Br 0.056, S 0.01, Co 0.03	Abd El-Aal et al. 2010, Shaheen et al. 2010, Shafeek et al. 2018a	Agrico international
Amino- -vit-plus	Amino-mix plus some other AA (i.e. asparagine, orinithine, G-amino-Butric, B-amino-Butric) and/or vitamins (i.e. vit-E), plant promoters (i.e. auxins, cytokinins)	Abd El-Aal et al. 2010	Agrico international
Aminopower Amino power	TAA 40%, FAA 20%, vitamins 3%, potassium cetrate 3.5%, chelated: Fe 1500 ppm, Zn 500 ppm, Mn 500 ppm FAA, citric acid 3%, potassium oxide 3.5% L-amino acids	El-Abagy et al. 2014, Shehata and Abdel-Wahab 2018	Arabian Group for Agriculture Service Co. Egypt
Amino Ruter	FAA 8.4%, N 6.6%, P2O5 6%, K2O 4.2%, Fe 0.036%, Mn 0.06%, Mo 0.012%, Zn 0.084%	Shalaby and El-Ramady 2014	
Amino total	tiroanine (3.05–3.56%), aspartic acids (3.2–3.45%), serine (3.76–4.49%), glutammic acids (7.24–9.12%), broline (2.23–3.5%), licyne (1.87–2.45%), alanine (2.16–2.20), cystine (1.87–2.45%),veline (2.8–3.1%), methionine (0.23–0.3%), isoleucine (1.26–1.7%), leucine (1.98–2.8%), tyrosine (0.48– 1.02%), phenylalanine (1.03–1.78%), lysine (1.39–2.3%), histidine (0.42–0.9%), arginine (5.2–6.2%)	Sadak et al. 2015	
Azomine	TAA 32%, organic N 5%, liquid organic N 4.5%, organic C 10%	Khalel and Sultan 2019	
Amino16®	FAA 11.3%, L-amino acids (alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine, valine), total N 4%, organic matter 25%	Koukounaras et al. 2013 Tsouvaltzis et al. 2014	EVYP (Greek Industry of Hydrolyzed Protein L.L.P),
Biomean	FAA 20%, ascorbic acid 0.001%, vitamins 0.01%, chelated: Fe 2.5%, Zn 2%, Mn 1%, B 0.001%, Cu 0.01%, Mo 0.0001%	El-Abagy et al. 2014	

Calcorium Liquide	ammonia N 7%, P_2O_5 3%, K_2O 10%, Calcorium complex 25%: Ca, Cu, Zn, Mn, Mo, Fe, AA (alanine, arginine, glutamine, glycine, lysine, proline, valine), pH 8.25	Stawiarz i Gruszecki 2015	FCA Fertilisants
Delfan plus	TAA 24%, total N 9%	Khalel and Sultan [2019]	
Fosnutren	FAA 3750 mg · dm^{-3}, organic components 2%, total N 3.8% (ammonia N 2.1%, nitric N, 1.4%, organic N 0.3%), P_2O_5 6%	Rahimi-Shokooh et al. 2013	Inagrosa Industries Agro Biologicals, Madrid, Spain.
Humiforte	FAA 3750 mg·dm^{-3}, organic components 2%, total N 6% (ammonia N 1.4%, urea N 3.7%, nitric N 0.5%, organic N 0.3%), K_2O 5%, P_2O_5 3%	Rahimi-Shokooh et al. 2013	Inagrosa Industries Agro Biologicals, Madrid, Spain.
Kadostim	FAA 3750 mg·dm^{-3}, organic components 2%, total N 4.2% (ammonia N 0.8%, nitric N 3.1%, organic N 0.3%), K_2O 6%	Rahimi-Shokooh et al. 2013	Inagrosa Industries Agro Biologicals, Madrid, Spain.
Perfectose™ Liquid Perfectose™ Powder	AA stimulant AA stimulant	Sarojnee et al. 2009	Priya Chemicals, India
Pepton	TAA 85%, FAA 16%, organic N 12%, K_2O 2.5%	El-Abagy et al. 2014	
Siapton	(g kg^{-1}) protein 660 ±23.0, FAA 85 ±2.1, organic matter 500 ±23.0, P 6.9 ±0.5, K 12.6 ±1.0, Ca 2.1 ±0.1, Mg 0.2 ±0.0, S 4.8 ±0.1, Na 11 ±0.5, Fe 63 ±3.5, Zn 3 ±0.1, B 40 ±3.1	Parrado et al. 2008	Isagro, Italy
Tecamin Max	TAA 14.4%, L-amino acids 12%, organic acids 60%, total N 7%, pH 6.6 AA complex, N 7.0%, organic C 60.0%	Khalel and Sultan 2019 Trawczyński 2014	AgriTecno, Spain
Tecnokel Mix Tecnokel Mg Tecnokel Ca Tecnophyt PK	AA complex, Fe 3.0%, Mn 0.7%, Zn 0.7%, Cu 0.3%, B 0.1%, Mo 0.1%; AA complex, MgO 6.0%; AA complex, CaO 10.0%, B 0.2%; AA complex, P_2O_5 30.0%, K_2O 20.0%	Trawczyński 2014	AgriTecno, Spain
Terra Sorb Complex	FAA 20%, organic matter 25%, N 5.5%, B 1.5%, Fe 1.0%, Mg 0.8%, Mn 0.1%, Mo 0.001%	Kocira et al. 2015	Bioiberica, Spain
Plant-derived protein hydrolysate	organic matter 35.5%, total N 5%, AA and soluble peptides 27%	Lucini et al. 2015	Trainer, Italpollina S.p.A., Rivoli Veronese, Italy
Carob germ enzymatic hydrolyzate extract	(g kg^{-1}) protein 642 ±32.0, FAA 80 ±3.2, organic matter 494 ±21.0, P 7.7 ±0.6, K 22.8 ±1.2, Ca 3.1 ±0.2, Mg 3.5 ±0.2, S 4.3 ±0.1, Na 0.9 ±0.0, Fe 65 ±3.3, Cu 17 ±1.1, Zn 24 ±1.2, B 34 ±2.1, Mo 14 ±0.8, Co 8 ±0.5, IAA, NAA, IBA, gibberellic acid, gibberellin A4 + A7, kinetin	Parrado et al. 2008	

AA – amino acids, FAA – free amino acids, TAA – total amino acids

Table 2. Application of amino acid biostimulants and its effects on vegetable yield

Species	Products	Application				Changes in yield (%)	Source
		method	time	number	dose		
Allium cepa L., onion	Azomine	F S F + S	60, 80, 100 DAP	3	4 $cm^3 \cdot dm^{-3}$	11.1–17.8	Khalel and Sultan 2019
	Tecamin Max				3 $cm^3 \cdot dm^{-3}$	8.5–12.9	
	Delfan plus				4 $cm^3 \cdot dm^{-3}$	4.5–7.6	
	Pepton Aminopower Biomean	F	30, 60 DAP	2	0.5, 1.0, 2.0 $cm^3 \cdot dm^{-3}$	–	El-Abagy et al. 2014
	Amino-mix	F	30 DAP, repeated every 15 days	3	1.0, 2.0 $cm^3 \cdot dm^{-3}$	5.2–15.0	Shafeek et al. 2018a
	Amino-mix	F	60 days old, repeated every 15 days	3	1000 ppm	43.8 –98.9	Shaheen et al. 2010
	from comp. contains 23.68% FAA	F	45, 60, 75 DAP	3	1 $g \cdot dm^{-3}$	18.8 T 22.7–25.8 M	Abdel-Rahim et al. 2019
Allium sativum L., garlic	Amino Ruter Amino total	F	MAP, repeated every15 days	3	1.2 $cm^3 \cdot dm^{-3}$	30.5–62.3 T	Shalaby and El-Ramady 2014
Apium graveolens L. var. *rapaceum*, celeriac	Amino total	F	MAP and repeated every 15 days	4	500, 750 ppm	root 1.8–10.2, leaves 1.2–12.2	Shehata et al. 2011
Beta vulgaris L., red beet	FAA from *Arthrospira platensis*	F	15 DAP, repeated every 7 days	6	1.5 $g \cdot dm^{-3}$	27.9–52.0	Mogor et al. 2018
					3.0 $g \cdot dm^{-3}$	60.1–65.8	
Brassica oleracea var. *gongylodes* L., kohlrabi	Aminotal	F	20 DAP, repeated after 15 days	2	500, 750 ppm	3.4–7.1 6.7–10.5	Abou El Magd 2019
Brassica oleracea var. *italica* L., broccoli	amino acid biostimulant	F	2, 4, 6 WAP	3	1.5 $dm^3 \cdot ha^{-1}$	–9.3–0.0 T –14.2–(–7.1) M	Kałużewicz et al. 2018
	Aminotal	F	20, 35 DAP	2	500, 750 ppm	0.4–1.2	Abou El Magd 2019

Capsicum annuum L., hot pepper	Perfectose™ Liquid	F	15, 45 DAP	2	1.0, 1.6 $cm^3 \cdot dm^{-3}$, 8.8–14.6 cm^3/plant	5.7–19.7	Sarojnee et al. 2009
	Perfectose™ Powder	S			0.27, 0.45 g/plant	48.4–75.9	
Capsicum annuum L., sweet pepper	Amino power	F	30, 45, 60 DAP	3	2 $cm^3 \cdot dm^{-3}$	–28.4–(–44.5) T	Shehata and Abdel-Wahab 2018
Cucurbita pepo L., squash	Amino-mix	F	25, 35, 45 days old	3	500, 1000 ppm	0.0–17.2 T	Abd El-Aal et al. 2010.
	Amino vit plus					5.0–25.1 T	
Lactuca sativa L., lettuce	Aminoplant (Siapton)	F	1, 3 WAP	2		–10–5.5 T –10–5.5 M	Łyszkowska et al. 2008
	Aminoplant (Siapton)	F	every 7 days	5	0.2%, 0.4%	–12.8–27.1	Kowalczyk et al. 2008
Petroselinum crispum ssp. *tuberosum*, root parsley	Calcorium Liquide	F	8–9 leaves	1	1.5 $dm^3 \cdot ha^{-1}$	2.1–49.5 T 35.9–88.4 M –11.3–75.8 T leaf	Stawiarz and Gruszecki 2015
Phaseolus vulgaris L., snap bean	Amino-mix	soaked	for 6 hours	1	2.5 $cm^3 \cdot dm^{-3}$	118.6–126.9	Shaheen et al. 2018
		F	2 leaves, repeated every 10 days	3	2.5 $cm^3 \cdot dm^{-3}$	131.7–155.2	
Solanum melongena var. *esculenta* L., eggplant	Amino green	F	at flowering stage, repeated after 10 days	2	2, 4, 8 $cm^3 \cdot dm^{-3}$	52.7– 83.0	El-Nemr et al. 2015
Solanum tuberosum L., potato	Tecamin Max Tecnokel Mix Tecnokel Mg Tecnokel Ca Tecnophyt PK	F	BBCH 29–30, BBCH 60, BBCH 65–67, BBCH 70–75	2–4	1–3 $dm^3 \cdot ha^{-1}$	11.2–21.1	Trawczyński 2014
Vicia faba L., broad bean	Amino total	F	45, 60 DAS	2	500, 1000, 1500 $mg \cdot dm^{-3}$	2.5–39.8 11.3–65.5 21.0–82.7	Sadak et al. 2015
	Humiforte Fosnutren Kadostim	F	12–13 leaves, 7 days after, and in flowering stage	3	1500, 3000 ppm	7.8–22.2	Raeisi 2013

Method of application: F – foliar, S – soil; time: DAP – days after planting, WAP – weeks after planting, MAP – one month after planting, DAS – days after sowing; yield: T – total yield, M – marketable yield harvested a smaller non-marketable yield in the case of two out of three cultivars of root parsley by reducing the proportion of forked and very large roots. In potato, Trawczyński [2014] obtained a reduction in the share of small tubers (up to 35 mm) and tubers with external defects (deformed and turned green tubers), while Abdel-Rahim et al. [2019] found a reduction in the share of double and bolting bulbs of onion. However, incorrect choice of products may delay yielding of tomato plants by delaying flowering and fruit formation, whereas well selected ones have no impact on earliness, but increase number of flowers and fruits per plant [Parrado et al. 2008].

Biometric features

The positive effect of amino acid biostimulants on biometric features of plants often depends on a number of factors, of which weather conditions, cultivar, fertilization, dose, and type and method of amino acid application are among the most frequently mentioned [Łyszkowska et al. 2008, Sarojnee et al. 2009, Grabowska et al. 2012, Kocira et al. 2015, Stawiarz and Gruszecki 2015, Shehata and Abdel-Wahab 2018, Khalel and Sultan 2019]. In the research by Stawiarz and Gruszecki [2015], BCAA contributed to obtaining a greater share of roots with a diameter of 30–60 mm, but the response of parsley cultivars was not uniform. According to Grabowska et al. [2012], Aminoplant application does not influence the average diameter of carrot roots and its influence on root length depends on the cultivar, weather conditions, and product dose. In a study by Mogor et al. [2018], BCAA use increased hypocotyl diameters of red beet, whereas El-Nemr et al. [2015] reported an increase in the length and weight of eggplant fruits, but not in their diameter. In sweet pepper, Shehata and Abdel-Wahab [2018] found no impact of BCAA on the length, diameter and flesh thickness of fruits, but the fruit weight was smaller. Sarojnee et al. [2009] obtained a higher length and diameter of chilli fruit after soil application of Perfectose™ Powder than after foliar application of Perfectose™ Liquid or for control plants. Amino acid biostimulants had a positive effect on the diameter and weight of onion bulb, though this influence depended on weather conditions, dose, and type and method of amino acid application [Shaheen et al. 2010, Fawzy et al. 2012, El-Abagy et al. 2014, Shafeek et al. 2018a, Abdel-Rahim et al. 2019, Khalel and Sultan 2019]. However, after BCAA application onion plants often showed a clear tendency to form thicker necks [Shaheen et al. 2010, 2013, Fawzy et al. 2012, El-Abagy et al. 2014, Shafeek et al. 2018a, Abdel-Rahim et al. 2019]. In a study by Khalel and Sultan [2019], the best effect was obtained by using both foliar and soil BCAA application, but the reaction also depended on the source of amino acid compounds. In garlic, BCAA was also found to have a positive effect on number of cloves as well as weight and diameter of bulbs [Shalaby and El-Ramady 2014].

BCAA increased the mean weight of seeds in pea [Shafeek et al. 2018b] and the number and weight of seeds in broad bean [Ismail and Fayed 2020]. Raeisi et al. [2013], however, did not find BCAA to impact the mean weight of broad bean seeds. According to Kocira et al. [2015], BCAA did not affect weight of common bean seeds, but it can increase number of seeds and pods; however, plant reaction depends on the cultivar, dose, and number of product applications. Kavasoğlu and Ceylan [2018] also draw attention to the possibility of increasing the number of seeds in the pod and on the bean plant.

After BCAA use, Kałużewicz et al. [2018] did not find any changes in mean weight and diameter of broccoli head. According to Kowalczyk et al. [2008], the use of Aminoplant can increase lettuce head weight compared to plants not sprayed, yet it depends on the growing cycle and weather conditions. The spraying of amino acids improved the uniformity of the fresh weight of lettuce plants [Tsouvaltzis et al. 2014].

Pests and disease

There are relatively few reports on the impact of BCAA on the occurrence of pests in vegetable cultivation. Wojdyła and Sobolewski [2016] point out that amino acids can help to reduce the occurrence of *Sclerotinia sclerotiorum* on beans. Stawiarz and Gruszecki [2015] did not find differences in the share of diseased roots in parsley after application of BCAA. However, they observed a certain tendency towards an increase in the proportion of roots damaged by pests in plants sprayed with BCAA in all of the studied cultivars. Tomczyk and Andryka [2016] found that the use of Siapton has an effect on reducing the population of

Tetranychus urticae and the predator *Amblyseius swirskii* on cucumber plants.

Chemical composition of vegetables

Providing plants with amino acids may affect the dry weight of edible parts of vegetables, but no effect, an increase, or a decrease of dry weight after application of this kind of products was noted [Kowalczyk et al. 2008, Łyszkowska et al. 2008, Kunicki et al. 2010, El-Abagy et al. 2014, Mogor et al. 2018, Khalel and Sultan 2019]. The reasons for obtaining such different results are due to many factors: type and dose of product, method of application, cultivar, weather conditions, and growing cycle [Kowalczyk et al. 2008, Łyszkowska et al. 2008, Sarojnee et al. 2009, Kunicki et al. 2010, El-Abagy et al. 2014, Khalel and Sultan 2019]. In experiments, a higher dry weight of onion bulbs was noted after the application of BCAA [El-Abagy et al. 2014, Abdel-Rahim et al. 2019, Khalel and Sultan 2019]. However, El-Abagy et al. [2014], by spraying onion plants with three BCAAs, obtained different results for each of them; Peptone increased the dry weight at each analysed level, Aminopower only at the highest one, and Biomean in smaller concentrations reduced the dry weight of onion bulb. After application of Perfectose ™ Powder to the soil, Sarojnee et al. [2009] obtained a higher dry weight of pepper fruits than after application of the liquid form of this product to leaves.

Kunicki et al. [2010] found that BCAA in a higher dose lowered dry matter in spinach leaves, but the response of the cultivars was different, additionally modified by weather conditions and growing cycle. According to Kowalczyk et al. [2008], the growing cycle may also modify the effect of BCAA in lettuce. Aminoplant used in the winter cycle did not affect the dry weight of lettuce, while its higher dose in the spring cycle increased it.

Vegetables most often react to the use of BCAA by increasing their carbohydrate content [Łyszkowska et al. 2008, Shehata et al. 2011, Grabowska et al. 2012, Sadak et al. 2015, Kałużewicz et al. 2018, Shafeek et al. 2018a]. The dose and type of products, cultivar, and weather conditions can modify the effect of BCAA [Łyszkowska et al. 2008, Shehata et al. 2011, Shafeek et al. 2018a], causing the carbohydrate content to be even lowered compared to untreated plants [Grabowska et al. 2012].

The use of BCAA has a positive effect on protein content in vegetable crops [Shaheen et al. 2010, 2018, Sadak et al. 2015, Kavasoğlu and Ceylan 2018, Shafeek et al. 2018a, b, Ismail and Fayed 2020] because often along with an increase in the dose of amino acids an increase in the content of crude protein in seeds of faba bean was noted [Sadak et al. 2015, Shafeek et al. 2018a, b]. However, the effect of BCAA on the protein content of beans may depend on the cultivar, dose of biostimulants, and weather conditions [Kocira et al. 2015].

BCAA, as a source of nitrogen, can increase the content of nitrate in vegetables, but it is strongly influenced by environmental conditions in a growing season [Kowalczyk et al. 2008, Kunicki et al. 2010, Shehata et al. 2011, Grabowska et al. 2012]. No effect [Shehata and Abdel-Wahab 2018] or reduction in the content of nitrate after the use of BCAA [Łyszkowska et al. 2008, Kunicki et al. 2010, Grabowska et al. 2012] was also found. The level of nitrates may depend on the dose of products, but applying a higher dose is not always associated with an increase in their content [Kowalczyk et al. 2008, Kunicki et al. 2010]. There is also an unequal accumulation of nitrate in plants of different cultivars after BCAA application [Łyszkowska et al. 2008, Kunicki et al. 2010, Grabowska et al. 2012].

As with other compounds, the effect of BCAA on the content of chlorophylls varies. Shehata et al. [2011] found an increase in the content of chlorophylls a, b and a+b in celery leaves after the application of BCAA. In the studies of Mogor et al. [2018], the chlorophyll content in red beet increased with increasing level of amino acid application. Kowalczyk et al. [2008] found that the effects of BCAA depended on the lettuce growing cycle. Aminoplant caused a decrease in the content of chlorophyll b at both times, an increase in chlorophyll a in the spring cycle, and a decrease in chlorophyll a + b in the winter growing cycle. Other authors found no effect of BCAA application on chlorophyll content in basil [Rahimi-Shokooh et al. 2013] and broccoli leaves [Kałużewicz et al. 2017], but Kałużewicz et al. [2017] draw attention to the possibility of a different response of cultivars.

The effect of BCAA on the content of carotenoids is not conclusive and depends on weather conditions, level of amino acid application, and cultivar; the studies showed an increase, decrease, or no change in the content of these compounds [Kowalczyk et al. 2008, Shehata et al. 2011, Grabowska et al. 2012]. The results regarding the use of different doses of BCAA on the level of these pigments are also inconclusive since with increasing dose no response was reported [Kowalczyk et al. 2008] as well as lower [Shehata et al. 2011] and higher carotenoid content [Sadak et al. 2015, Aly et al. 2019].

According to Aly et al. [2019], vitamin C content of hot pepper fruits increases with the dose, but according to Sarojnee et al. [2009] only higher doses, with soil or foliar application, increased ascorbic acid contents in chilli fruits. Shehata et al. [2011] found no effect of BCAA on the content of vitamin C in celery roots, and Kałużewicz et al. [2018] in fresh broccoli heads. Kowalczyk et al. [2008] found that these products may cause a decrease in vitamin C content, both in the winter and spring cycle of lettuce cultivation. In the light of the research conducted so far, the influence of BCAA on vitamin C content depends, among others, on the composition of the products. Abd El-Aal et al. [2010] showed a beneficial effect of BCAA on the content of vitamin C in squash fruit, but the enrichment of the products with some other amino acids, vitamins and some plant promoters, such as auxins and cytokinins, resulted in a higher content of ascorbic acid.

Increased content of macro- and micronutrients was often observed after using BCAA, though it can be a result of the composition enriched with mineral elements. The use of BCAA often causes increased content of N, P, and K in plants [Shaheen et al. 2010, Fawzy et al. 2012, El-Nemr et al. 2015, Sadak et al. 2015, Shaheen et al. 2018, Shafeek et al. 2018a, b, Ismail and Fayed 2020]. However, in some research application of BCAA did not affect N content [Castro et al. 1988, Abdel-Rahim et al. 2019, Khalel and Sultan 2019], but it might depend on the type of product and method of application [Khalel and Sultan 2019]. BCAA application may not change P content [Castro et al. 1988, Kowalczyk et al. 2008, Abdel-Rahim et al. 2019, Abd El-Aal et al. 2010] or lower it [Shehata et al. 2011]. Ambiguous results also relate to K content because in some research BCAA did not affect K level [Castro et al. 1988, Abd El-Aal et al. 2010, Shehata et al. 2011, Abdel-Rahim et al. 2019], or even a decrease in K content in lettuce was observed [Kowalczyk et al. 2008]. BCAA has a beneficial effect on micronutrient content (Fe, Cu, Zn, Mn, B) [Shaheen et al. 2010, Fawzy et al. 2012, Abdel-Rahim et al. 2019, Ismail and Fayed 2020], but they can also have no such effect or such effect will only manifest itself during some growing seasons [Castro et al. 1988, Abd El-Aal et al. 2010, Shaheen et al. 2018]. Content of mineral elements after using BCAA depends on weather conditions during the growing season [Abdel-Rahim et al. 2019], cultivar, number of sprayings, BCAA dose [Kocira et al. 2015], or even time of conducted analysis [Castro et al. 1988].

Changes in the composition of essential oil can also be the result of BCAA application, and with the right selection of products it can even increase its content [Rahimi-Shokooh et al. 2013]. Likewise, BCAA can increase the content of anthocyanins, flavonoids, and phenolic compounds and change the composition of phenolic compounds [Aly et al. 2019].

Storage

There is little information regarding the impact of BCAA on vegetable storage, but it seems to indicate bigger weight loss after BCAA application. In an experiment conducted by Shalaby and El-Ramady [2014], garlic plants sprayed with BCAA were characterised by higher natural weight loss and in the greatest extent shrank during storage. In the research by Abdel-Rahim et al. [2019], the use of BCAA increased the total weight loss of onion during 180 days of storage. Shehata and Abdel-Wahab [2018] reported increased weight loss in stored sweet pepper after spraying with amino acids, but Khan et al. [2018] found that pre-harvest spraying with amino acids reduced weight loss and decay during storage of bell pepper fruits. The use of BCAA might also have an effect on total sugar and vitamin C content in fresh broccoli heads during storage, but the impact of weather conditions during cultivation contributed to a large extent to the obtained results [Kałużewicz et al. 2018].

CONCLUSIONS

The use of biostimulants containing amino acids is one of the ways to increase stability of plant crop even in less favourable growing conditions. However, the use of BCAA in vegetable growing in the light of the presented results does not seem to be a simple matter. Some of the problems result from production technology of products themselves, often with different amounts of individual amino acids and other ingredients, which may affect the effectiveness or predictability of their use. Other factors which have to be included in order to achieve satisfactory effects are related to the application of products alone: growing stage, dose, method and number of product applications, in addition to species and cultivar variability. Furthermore, the dependence of the obtained results on weather conditions does not facilitate the use of these products. High hopes related to BCAA use are not unfounded as these products may have a positive impact on plant growth, the quantity and quality of yield, including its structure, and biometric features and biological value of the crop. There are many indications that the correct application of BCAA in practice still requires a lot of research and proper choice of BCAA for a species or even cultivar, taking into account the cultivation technology, and proper selection of application time and procedures.

SOURCE OF FUNDING

The research was funded by subvention no. OKZ/s/42/2021.

REFERENCES

Abd El-Aal, F.S., Shaheen, A.M., Ahmed, A.A., Mahmoud, R. (2010). The effect of foliar application of urea and amino acids mixtures as antioxidants on the growth and yield and characteristics of squash. Res. J. Agric. Biol. Sci., 6(5), 583–588.

Abdel-Rahim, G.H., Gamie, A.A., Al-Bassuny, M.S.S., Abd Allah, M.A.A. (2019). Response of onion crop to foliar application by amino acids, yeast extract and boron in Upper Egypt. Assiut J. Agric. Sci., 50(1), 149–159. https://doi.org/10.21608/ajas.2019.33496

Abou El Magd, M.M. (2019). Foliar application of amino acids and seaweed extract on the growth and yield of some cruciferous crops. Middle East J. Agric. Res., 8(3), 782–787.

Aly, A., Eliwa, N., Abd El Megid, M.H. (2019). Improvement of growth, productivity and some chemical properties of hot pepper by foliar application of amino acids and yeast extract. Potravinarstvo Slovak J. Food Sci., 13(1), 831–839. https://doi.org/10.5219/1160

Ashraf, M., Foolad, M.R. (2007). Roles of glycinebetaine and proline in improving plant abiotic stress tolerance. Environ. Exp. Bot., 59(2), 206–216. https://doi.org/10.1016/j.envexpbot.2005.12.006

Botta, A. (2013). Enhancing plant tolerance to temperature stress with amino acids: an approach to their mode of action. Acta Hortic., 1009, 29–35. https://doi.org/10.17660/ActaHortic.2013.1009.1

Bulgari, R., Franzoni, G., Ferrante, A. (2019). Biostimulants application in horticultural crops under abiotic stress conditions. Agronomy, 9, 306. https://doi.org/10.3390/agronomy9060306

Calvo, P., Nelson, L., Kloepper, J.W. (2014). Agricultural uses of plant biostimulants. Plant Soil, 383(1/2), 3–41. https://doi.org/10.1007/s11104-014-2131-8

Castro, B.F., Locascio, S.J., Olson, S.M., (1988). Tomato response to foliar nutrient and biostimulant applications. Proc. Florida State Hort. Soc.,103, 117–119.

Cavani, L., Halle, A.T., Richard, C., Ciavatta, C. (2006). Photosensitizing properties of protein hydrolysate-based fertilizers. J. Agric. Food Chem., 54, 9160–9167. https://doi.org/10.1021/jf0624953

Chen, T.H.H., Murata, N. (2011). Glycinebetaine protects plants against abiotic stress: mechanisms and biotechnological applications. Plant Cell Environ., 34,1–20. https://doi.org/10.1111/j.1365-3040.2010.02232.x

Colla, G., Rouphael, Y., Canaguier, R., Svecova, E., Cardarelli, M., (2014). Biostimulant action of a plant-derived protein hydrolysate produced through enzymatic hydrolysis. Front. Plant Sci., 5, 448. https://doi.org/10.3389/fpls.2014.00448

Dar, M.I., Naikoo, M.I., Rehman, F., Naushin, F., Khan, F.A. (2016). Proline accumulation in plants: roles in stress tolerance and plant development. In: Osmolytes and plants acclimation to changing environment: emerging omics technologies, Iqbal, N., Nazar, R., Khan, N.A. (eds). Springer, India, 155–166. https://doi.org/10.1007/978-81-322-2616-1_9

du Jardin, P. (2015). Plant biostimulants: definition, concept, main categories and regulation. Sci. Hortic., 30(196), 3–14. https://doi.org/10.1016/j.scienta.2015.09.021

El-Abagy, H.M., El-Tohamy, W.A., Abdel-Mawgoud, A.M.R., Abou-Hussein, S.D. (2014). Effect of different amino acid sources and application rates on yield and quality of onion in the newly reclaimed lands. Middle East J. Agric. Res., 3(1), 81–88.

El-Nemr, M.A., El-Bassiony, A.M., Tantawy, A.S., Fawzy, Z.F. (2015). Responses of eggplant (*Solanum melongena* var. *esculenta* L.) plants to different foliar concentrations of some bio-stimulators. Middle East J. Agric. Res., 4(4), 860–866.

Ertani, A., Cavani, L., Pizzeghello, D., Brandellero, E., Altissimo, A., Ciavatta, C., Nardi S. (2009). Biostimulant activity of two protein hydrolyzates in the growth and nitrogen metabolism of maize seedlings. J. Plant Nutr. Soil Sci., 172(2), 237–244. https://doi.org/10.1002/jpln.200800174

Fawzy, Z.F., Abou El-magd, M.M., Li, Y., Zhu, O., Hoda, A.M. (2012). Influence of foliar application by EM "Effective Microorganisms", amino acids and yeast on growth, yield and quality of two cultivars of onion plants under newly reclaimed soil. J. Agric. Sci., 4(11), 26–39. https://doi.org/10.5539/jas.v4n11p26

Gajc-Wolska, J., Kowalczyk, K., Nowecka, M., Mazur, K., Metera, A. (2012). Effect of organic-mineral fertilizers on the yield and quality of endive (*Cichorium endivia* L.). Acta Sci. Pol., Hort. Cultus, 11(3), 189–200.

Grabowska, A., Kunicki, E., Sekara, A., Kalisz, A., Wojciechowska, R. (2012). The effect of cultivar and biostimulant treatment on the carrot yield and its quality. Veg. Crops Res. Bull., 77, 37–48.

Ismail, A.Y., Fayed, A.A.M. (2020). Response of dry seed yield of Faba bean "*Vicia faba*, L." to spraying with amino acids, organic acids, (NAA) growth regulator and micro nutrients. Alex. J. Agric. Sci., 65(1), 7–16.

Jonytienė, V., Burbulis, N., Kupriene, R., Blinstrubiene, A. (2012). Effect of exogenous proline and de-acclimation treatment on cold tolerance in *Brassica napus* shoots cultured in vitro. J. Food Agric. Environ., 10, 327–330

Kałużewicz, A., Krzesiński, W., Spiżewski, T., Zaworska, A. (2017). Effect of biostimulants on several physiological characteristics and chlorophyll content in broccoli under drought stress and re-watering. Not. Bot. Horti Agrobot. Cluj-Napoca, 45, 197–202. https://doi.org/10.15835/nbha45110529

Kałużewicz, A., Spiżewski, T., Krzesiński, W., Zaworska, A. (2018). The effect of biostimulants on the yield and quality of broccoli heads during storage. Nauka Przyr. Technol., 12(1), 45–54. https://doi.org/10.17306/J.NPT.00223

Kavasoğlu, A., Ceyhan, E. (2018). Effects on agricultural characters of application of amino acids in Kınalı bean cultivar Selcuk. J. Agr. Food Sci., 32(1), 43–49. https://doi.org/10.15316/SJAFS.2018.62

Khalel, A.M.S., Sultan, F.I. (2019). Influence of foliar spray and soil application of three aminoacids compounds in growth and yield of onion (*Allium cepa* L.). Plant Arch., 19(1), 531–534.

Khan, R.I., Hafiz, I.A., Shafique, M., Ahmed, TA, Qureshi, A. (2018). Effect of pre-harvest foliar application of amino acids and seaweed (*Ascophylum nodosum*) extract on growth, yield, and storage life of different bell pepper (*Capsicum annum* L.) cultivars grown under hydroponic conditions. J. Plant Nutr. 41(18), 2309–2319. https://doi.org/10.1080/01904167.2018.1504966

Kocira, S., Kocira, A., Szmigielski, M., Piecak, A., Sagan, A., Malaga-Toboła, U. (2015). Effect of an amino acids-containing biostimulator on common bean crop. Przem. Chem., 94(10), 1732–1736. https://doi.org/10.15199/62.2015.10.16

Koukounaras, A., Tsouvaltzis, P., Siomos, A.S. (2013). Effect of root and foliar application of amino acids on the growth and yield of greenhouse tomato in different fertilization levels. J. Food. Agric. Environ., 11(2), 644–648. https://doi.org/10.1234/4.2013.4387

Kowalczyk, K., Zielony, T., Gajewski, M. (2008). Effect of aminoplant and asahi on yield and quality of lettuce grown on rockwool. Conference of biostimulators in modern agriculture "Vegetable crops". 7–8 February 2008, Warsaw, 35–43.

Kunicki, E., Grabowska, A., Sękara, A., Wojciechowska, R. (2010). The effect of cultivar type, time of cultivation, and biostimulant treatment on the yield of spinach (*Spinacia oleracea* L). Folia Hortic., 22, 9–13. https://doi.org/10.2478/fhort-2013-0153

Lehmann, S., Funck, D., Szabados, L., Rentsch, D. (2010). Proline metabolism and transport in plant development. Amino Acids, 39, 949–962. https://doi.org/10.1007/s00726-010-0525-3

Łyszkowska, M., Gajc-Wolska, J. Kubić, K. (2008). The influence of biostimulators on yield and quality of leaf and iceberg lettuce grown under field conditions. Conference of biostimulators in modern agriculture "Vegetable crops". 7–8 February, Warsaw, 28–34.

Maini, P. (2006). The experience of the first biostimulant based on amino acids and peptides: a short retrospective review on the laboratory researches and the practical results. Fertil. Agrorum, 1(1), 29–43.

MarketsAndMarkets (2019). Biostimulants market by active ingredient (humic substances, amino acids, seaweed extracts, microbial amendments), crop type (fruits & vegetables, cereals, turf & ornamentals), application method, form, and region – global forecast to 2025. Available: https://www.marketsandmarkets.com/Market-Reports/biostimulant-market-1081.html

Mattioli, R., Costantino, P., Trovato, M. (2009). Proline accumulation in plants. Not only stress. Plant Signal. Behav., 4(11), 1016–1018. https://doi.org/10.4161/psb.4.11.9797

Mogor, A.F., de Oliveira Amatussi, J., Mogor, G., de Lara, G.B. (2018). Bioactivity of cyanobacterial biomass related to amino acids induces growth and metabolic changes on seedlings and yield gains of organic red beet. Amer. J. Plant Sci., 9, 966–978. https://doi.org/10.4236/ajps.2018.95074

Parrado, J., Bautista, J., Romero, E.F., García-Martínez, A.M., Friaza, V., Tejada, M. (2008). Production of a carob enzymatic extract: potential use as a biofertilizer. Bioresour. Technol., 99, 2312–2318. https://doi.org/10.1016/j.biortech.2007.05.029

Raeisi, M., Farahani, L., Shams, S. (2013). Effects of chemical fertilizers and biostimulants containing amino acid on yield and growth parameters of broad bean (*Vicia faba* L.). Int. J. Agric. Crop Sci., 5(21), 2618–2621.

Rahimi-Shokooh, A., Dehghani-Meshkani, M.R., Mehrafarin, A., Khalighi-Sigaroodi, F., Naghdi-Badi, H. (2013). Changes in essential oil composition and leaf traits of basil (*Ocimum basilicum* L.) affected by bio-stimulators/fertilizers application. J. Med. Plant., 12(47), 83–92.

Sadak, M.S.H., Abdelhamid, M.T., Schmidhalter, U. (2015). Effect of foliar application of amino acids on plant yield and some physiological parameters in bean plants irrigated with seawater. Acta Biol. Colomb., 20, 141–152. https://doi.org/10.15446/abc.v20n1.42865

Sarojnee, D.Y., Navindra, B., Chandrabose, S. (2009). Effect of naturally occurring amino acid stimulants on the growth and yield of hot peppers (*Capsicum annum* L.). J. Anim. Plant Sci., 5(1), 414–424.

Shafeek, M.R., Ali, A.H., Mahmoud, A.R., Helmy, Y.I., Omar, N.M. (2018a). Effects of foliar application of amino acid and bio fertilizer on growth and yield of onion plant under newly reclaimed land conditions. Middle East J. Appl. Sci., 8(4), 1197–1206.

Shafeek, M.R., Ali, A.H., Mahmoud, A.R., Helmy, Y.I., Omar, N.M. (2018b). Bio fertilizer doses and foliar application of amino mix to enhance the performance of pea plant under newly reclaimed land conditions. Middle East J. Appl. Sci., 7(2), 254–263.

Shaheen, A.M., El-Samad, E.H.A., Rizk, F.A., Behairy, A.G., Adam, S.M. (2018). Effect of application methods of plant growth stimulants on growth and yield of snap bean. J. Anim. Plant Sci., 28(3), 854–864.

Shaheen, A.M., Fatma, A.R., Hoda. A.M., Habib, A.E., Baky, M.M.H. (2010). Nitrogen soil dressing and foliar spraying by sugar and amino acids as affected the growth, yield and its quality of onion plant. J. Amer. Sci., 6(8), 420–427.

Shaheen, A.M., Fatma, A.R., Omaima, M.S., Bakry, M.O. (2013). Sustaining the quality and quantity of onion productivity throughout complementrity treatments between compost tea and amino acids. Middle East J. Agric. Res., 2(4), 108–115.

Shalaby, T.A., El-Ramady, H. (2014). Effect of foliar application of bio-stimulants on growth, yield, components, and storability of garlic (*Allium sativum* L.). Austral. J. Crop Sci., 8(2), 271–227.

Shehata, S.A., Abdel-Wahab, A. (2018). Influence of compost, humic acid and amino acids on sweet pepper growth, productivity and storage-ability. Middle East J. Appl. Sci., 8(3), 922–927.

Shehata, S.M., Abdel-Azem, H.S., El-Yazied, A.A., El-Gizawy, A.M. (2011). Effect of foliar spraying with amino acids and seaweed extract on growth chemical constitutes, yield and its quality of celeriac plant. Europ. J. Sci. Res., 58(2), 257–265.

Stawiarz, A., Gruszecki, R. (2016). Effect of Calcorium Liquide on the quality and quantity of Hamburg parsley (*Petroselinum crispum* ssp. *tuberosum*) yield. Annales UMCS sec. EEE Horticulturae, 26(1), 13–21.

Tomczyk, A., Andryka, P. (2016). Effectiveness of Swirski-mite (*Amblyseius swirskii* Athias-Henriot) in control of two-spotted spider mite (*Tetranychus urticae* Koch) on cucumber plants treated with biostimulants. Prog. Plant Prot., 56(2), 175–179. https:doi.org/10.14199/ppp-2016-029

Trawczyński, C. (2014). Wpływ biostymulatorów aminokwasowych – Tecamin- na plon i jakość ziemniaków. Ziemn. Pol., 3, 29–34.

Trovato, M., Forlani, G., Signorelli, S., Funck, D. (2019). Proline Metabolism and Its Functions in Development and Stress Tolerance. In: Osmoprotectant-mediated abiotic stress tolerance in plants, Hossain, M.A., Kumar, V., Burritt, D.J., Fujita, M., Mäkelä, P.S.A. (eds). Recent advances and future perspectives. Springer Nature Switzerland, 41–72. https://doi.org/10.1007/978-3-030-27423-8_2

Tsouvaltzis, P., Koukounaras, A., Siomos, A.S. (2014). Application of amino acids improves lettuce crop uniformity and inhibits nitrate accumulation induced by the supplemental inorganic nitrogen fertilization. Int. J. Agric. Biol. 16, 951–955. https://doi.org/13-300/2014/16-5-951-955

Van Oosten, M.J., Pepe, O., De Pascale, S., Silletti, S., Maggio, A. (2017). The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. Chem. Biol. Technol. Agric., 4–5. https://doi.org/10.1186/s40538-017-0089-5

Wojdyła, T.A., Sobolewski, J. (2016). Możliwość wykorzystania środków zawierających aminokwasy w ochronie fasoli przed *Sclerotinia sclerotiorum*. Zesz. Nauk. Instyt. Ogrod., 4, 131–140.