Journal of Elementology ISSN 1644-2296

Ekşi H.S., Sönmez I. 2022.
Effects of amino acid applications on yield, growth and mineral nutrition of greenhouse tomato.
J. Elem., 27(3): 545-557. DOI: 10.5601/jelem.2022.27.1.2258

RECEIVED: 23 February 2022
ACCEPTED: 27 July 2022

ORIGINAL PAPER

EFFECTS OF AMINO ACID APPLICATIONS ON YIELD, GROWTH AND MINERAL NUTRITION OF GREENHOUSE TOMATO*

Hüseyin Serdar Ekşi, İlker Sönmez

Department of Soil Science and Plant Nutrition
Akdeniz University, Antalya, Turkey

Abstract

The use of plant and animal origin amino acids in agricultural production has been increasing intensively in recent years. Amino acids make an important contribution to plant growth and quality because of the effect on the nitrogen concentration, and both root and foliar use of amino acids is possible. The aim of this study was to determine the effect of commercial amino acids used by root and foliar application on the growth, yield and mineral nutrient of greenhouse tomato. The experiment was planned with 16 treatment combinations involving four levels of root (0, 50, 100 and 200 ml da^{-1}) and foliar (0, 500, 1000 and 2000 ml da^{-1}) applications, following a factorial (4×4) randomized complete block design with three replications under greenhouse conditions. During the plant growing season, fruits were harvested, data recorded and measured to determine yield and some fruit properties, plant samples were taken, processed and analyzed to determine elemental nutrient concentrations. As a result of the research, it was found that different doses of amino acids applied to the root and leaves had significant effects on tomato yield, fruit weight, fruit diameter and some mineral element concentrations (N, P, Fe and Mn) in tomato leaves. R3 (100 ml da^{-1}) and F4 (2000 ml da^{-1}) doses in yield and fruit quality parameters, and R3 (100 ml da^{-1}), R4 (200 ml da^{-1}), F3 (1000 ml da^{-1}) and F4 (2000 ml da^{-1}) application doses in mineral element concentrations caused differences. The treatments with amino acids affected positively the yield, growth and some nutrient concentrations of tomato plants.

Keywords: amino acid, tomato, greenhouse, yield, fruit, leaf, mineral nutrition.

İlker Sönmez, Assoc. Prof. Dr, Department of Soil Science and Plant Nutrition, Akdeniz University, Turkey, Phone: 90 242 310 44 00, e-mail: ilkersonmez@akdeniz.edu.tr
* Source of funding, The Scientific Research Projects Coordination Unit of Akdeniz University, Project ID: FYL-2019-5082.

INTRODUCTION

It is common to use organic-based materials in agricultural areas, beside basic fertilization, and some parameters of the products can be improved by using these materials,. Particularly in recent years, humic-fulvic acids, seaweeds, amino acids of animal and vegetable origin, animal manures in solid and liquid forms, and composts can be given as examples. Amino acids play an important role as one of the materials whose use has increased in recent years and which contribute significantly to some yield and quality parameters.

Amino acids are organic nitrogenous compounds, called the building blocks of proteins. Amino acids, which play a role in protein synthesis, perform structural, metabolic and transport functions in plants (Liu et al. 2008, Sarojnee et al. 2009). Amino acids consist of molecules containing an amino group attached to the central carbon atom, a carboxyl group, a hydrogen ion, and a different side chain (R group). Proteins are formed by combining 20 kinds of amino acids in different shapes and ratios (Denli, Arabaci 2014).

Amino acids can directly or indirectly affect physiological activities in plant development, and also contribute to the growth, production, and quality of tomatoes in plastic greenhouses, for example via an exogenous application of amino acids (Boras et al. 2011). Amino acids, which are the precursors of phytohormones and other growth agents, have some important functions, such as improving product quality, increasing resistance to abiotic stresses, facilitating translocation-nutrient assimilation-nutrient use, increasing efficiency of plant metabolism (Calvo et al. 2014).

Boras et al. (2011) investigated the effects of root and foliar amino acid applications on tomato plant growth in greenhouse conditions, and significant increases in growth and yield were detected in tomato plants treated with foliar and root applications compared to the control. The best results were obtained in plant height, leaf area and yield values owing to the foliar application of amino acids. Koukounaras et al. (2013) determined that the effect of root and foliar application of amino acids on the growth and yield of greenhouse tomato subjected to different fertilization levels, and amino acids had a significant effect on the yield of the greenhouse tomato and the effectiveness of the way of application (root or foliar) depends on the level of pre-planting fertilization. Aslan (2019) investigated the effects of humic-fulvic acid and amino acid applications on some yield and quality characteristics of curly-leaf head salad (*Lactuca sativa* L.), and the highest plant weight was obtained from the humic-fulvic acid+amino acid treatment, while the highest marketable plant weight, head length and head diameter values were obtained from the amino acid application (8000 ml da^{-1}). Moraditochaee et al. (2012) determined that the effects of root nitrogen and foliar amino acid applications on the yield of cowpea plants, and the highest grain yield was obtained from the Nitrogen*Amino Acid interaction. Sahu (2016)

determined that amino acids increase the physiological parameters, dry matter ratio, productivity and quality of soybean. Kavasoğlu (2018) stated that different doses of foliar amino acid applications increased the grain yield and protein ratio in the bean plant.

This study was carried out to reveal some yield and nutritional characteristics of amino acid applications applied at different doses to the root and leaves of tomato plant.

MATERIAL AND METHODS

The experiment was carried out during the 6-month growing period in 2019-2020, in a greenhouse in Kumluca-Antalya, Turkey (30.15.58 E, 36.22.81 N). Some soil properties (0-20 cm) in the greenhouse were as follows: clay in texture, organic matter (4.77%), $CaCO_3$ (37.39 %), pH = 7.17, EC (0.75 dS m^{-1}), 0.33% total (N), 105.4 mg kg^{-1} available (P), 1.46 meq 100 g^{-1} extractable potassium (K), 8.87 meq 100 g^{-1} extractable calcium (Ca) and 2.79 meq 100 g^{-1}, extractable magnesium (Mg), 1.48 mg kg^{-1}, available iron (Fe), 4.36 mg kg^{-1}, available zinc (Zn), 3.9 mg kg^{-1} available manganese (Mn) and 13.71 mg kg^{-1} available copper (Cu). The experiment was set in a split-plot design and consisted of a total of 48 plots, including16 objects with three replications (Table 1).

Table 1

Amino acid treatments in the experiment

Treatments	Doses of amino acid	
	root (ml da^{-1})	foliar (ml 100 L^{-1})
1	0	0
2	0	50
3	0	100
4	0	200
5	500	0
6	500	50
7	500	100
8	500	200
9	1000	0
10	1000	50
11	1000	100
12	1000	200
13	2000	0
14	2000	50
15	2000	100
16	2000	200

The amino acid solution was applied to roots, sprayed over the plant, or combined (root + foliar application). In the root treatment, a dose of the solution per plant was applied, while in the foliar application the solution was sprayed until run-off. Amino acid treatments were repeated 4 times in total (30 days' intervals between each treatment). Drip irrigation was provided when the average soil suction in the field, measured at 30 cm depth, exceeded 350 hPa.

Tomato (*Lycopersicon esculentum* Mill., cv. Demiröz F1) was grown on the plots. The experiment was carried out with 3 replications, and the plot size was (1×2) 2.0 m^2. The irrigation water and fertilizer were applied through a drip irrigation system as fertigation. There were 8 tomato plants per plot. Tomato seedlings were planted on the plots and fertilization was applied as fertigation (160 kg ha^{-1} N, 160 kg ha^{-1} P_2O_5 and 310 kg ha^{-1} K_2O, 20 kg ha^{-1} MgO as basic fertilizers) after the seedlings had rooted into the soil. Irrigation was adjusted according to 70% of the field water capacity of the soil; the air temperature in the greenhouse varied between 16-26°C and the relative humidity was between 60-65% during the experimental period. All necessary horticultural and plant protection treatments were carried out uniformly for all the treatments during the entire experimentat.

The amino acid liquid products contained total amino acids 46.70%, total organic matter, organic N and organic carbon concentrations of 51.35%, 5.42% and 24.38%, respectively. Amino acids were applied 4 times on 30 day, 60 day, 90 day and 120 day from the seedling stage. For each time, all amino acids were diluted 100 times with water and sprayed on plant leaves.

The chemical composition of the commercial amino acid preparation (Bio Kraft) included glycine (1.45 g 100 g^{-1}), alanine (0.25 g 100 g^{-1}), valine (0.56 g 100 g^{-1}), isoleucine (0.34 g 100 g^{-1}), threonine (0.06 g 100 g^{-1}), serine (0.14 g 100 g^{-1}), lysine (0.28 g 100 g^{-1}), phenylalanine (0.23 g 100 g^{-1}), glutamate (0.42 g 100 g^{-1}), aspartate (0.12 g 100 g^{-1}), arginine (0.72 g 100 g^{-1}), proline (1.65 g 100 g^{-1}), leucine (0.37 g 100 g^{-1}), histidine (0.11 g 100 g^{-1}), asparagine (0.09 g 100 g^{-1}), cystine (0.04 g 100 g^{-1}), hydroxyproline (0.78 g 100 g^{-1}), methionine (0.45 g 100 g^{-1}), tryptophan (0.04 g 100 g^{-1}) and tyrosine (0.13 g 100 g^{-1}).

Plant analysis

During the plant growing period, tomato fruits were harvested, and then fruit yield, average fruit weight, fruit stem diameter were determined. Same as in Geraldson et al. (1973), the plant samples were rinsed with distilled water after washing with tap water, and then they were blotted dry with paper towels and dried in an air-forced oven at 65°C to constant weight (Kacar, Inal 2008). The tomato plants were harvested (between 09.11.2019-08.02.2020) and prepared for analysis in laboratory. The plant and fruit samples were rinsed with distilled water and dried in an air-forced oven at 65°C to constant weight for chemical analysis. The plant and fruit

samples were subjected to wet combustion with an $HNO_3/HClO_4$ (4:1) acid mixture, and the amounts of macro- and microelements (K, Ca, Mg, Fe, Zn, Mn, Cu) were determined by using inductively coupled plasma (Perkin Elmer Optima DV7000-ICP OES) – Kacar, Inal (2008). Kjeldahl nitrogen (N) was determined by Kjeldahl digestion according to the Bremner (1965). Phosphorus (P) was measured by spectrophotometry (Kacar, Kovanci 1982).

Statistical analysis

All data obtained from the study were subjected to analysis of variance. The Duncan's Multiple Range Test was used to determine the significance of differences between treatments using SPSS software, so as to determine the importance of the effects of the treatments ($p<0.05$).

RESULTS AND DISCUSSION

Different levels of amino acid root and foliar applications caused significant increases in tomato yield, and the effects of amino acid applications in different doses and in root and foliar applications were found to be statistically significant (Table 2). While all doses contributed to yield in root applications, the F4 (200 ml L^{-1}) dose led to the highest yield increase in foliar applications ($p<0.001$). In the R×F interaction, the R3×F4 application was determined to result in the highest yield ($p<0.05$).

Table 2

Effects of different doses of amino acid root and foliar applications on the total yield per tomato plant

Total yield (g $plant^{-1}$)	Foliar application (ml 100 L^{-1})				
Root application (ml da^{-1})	F1	F2	F3	F4	mean
R1	3042.9*d*	3790.4*c*	3909.5*c*	4166.7*abc*	3727.4*B*
R2	3771.0*c*	4070.4*bc*	4182.1*abc*	4056.9*bc*	4020.1*A*
R3	4064.3*bc*	4026.8*bc*	4116.7*bc*	4559.1*a*	4191.7*A*
R4	4165.5*abc*	4002.3*bc*	4044.3*bc*	4344.5*ab*	4139.1*A*
Mean	3760.9(C)	3972.4(*B*)	4063.13(*B*)	4281.8(*A*)	
Root (R)	10.938***				
Foliar (F)	11.825***				
R × F interaction	3.428*				

* $p<0.05$, *** $p<0.001$

The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

The effect of the limited basic fertilization on the increase in yield was significant, and the lowest yield values were obtained from the control application. The vegetative growth and development were positively affected because amino acids contained nitrogen-rich compounds. Amino acid applications improve yield values in plants (Boras et al. 2011, El-Razek et al. 2018). Koukounaras et al. (2013) stated that the application of different doses of amino acids to tomato plants via root and leaves or in the Leaf*Root interaction compared to the control applications. With the application of 2.7% Amino16® to the roots, both the total and marketable yield increased, which arose from the increase in fruit number. Garcia et al. (2011) reported that amino acid applications to tomato plants caused an increase in the K, Fe, Cu and Mn concentrations of leaves.

The effects of different doses of amino acids applied to the root and leaves on the average tomato fruit weight were found to be statistically significant. R3 (1000 ml da^{-1}) dose caused the highest value in root applications, and the highest value was obtained with F3 (200 ml L^{-1}) dose via foliar application (Table 3).

Table 3

Effects of different doses of amino acid root and foliar applications on the average fruit weight values

Fruit weight (g)	Foliar application (ml 100 L^{-1})				
Root application (ml da^{-1})	F1	F2	F3	F4	mean
R1	119.2	123.5	123.8	128.8	123.8*C*
R2	124.7	125.0	128.6	130.7	127.2*BC*
R3	128.4	129.3	133.9	134.7	131.6*A*
R4	127.8	130.9	131.4	132.5	130.7*AB*
Mean	125.0(*C*)	127.2(*BC*)	129.4(*AB*)	131.7(*A*)	
Root (R)	7.389***				
Foliar (F)	4.837**				
R × F interaction	0.258ns				

** $p<0.01$, *** $p<0.001$, ns – not significant
The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

Root and foliar amino acid applications increased the average fruit weight by 5-6% compared to the control, and these increases made up an increase in the total efficiency of 12-14%, which would significantly increase the economic gain and productivity. Root and foliar applications were found to be statistically significant in the stem diameter values of tomato fruits. The highest values were obtained from the doses R3 (1000 ml da^{-1}) and

Table 4

Effects of different doses of amino acid root and foliar applications on the average fruit diameter values

Fruit diameter (mm)	Foliar application (ml 100 L^{-1})				
Root application (ml da^{-1})	F1	F2	F3	F4	mean
R1	62.1	63.2	63.2	64.7	63.3*B*
R2	63.3	63.2	64.1	64.5	63.8*B*
R3	64.0	64.7	66.6	66.4	65.4*A*
R4	64.3	65.3	65.3	66.4	65.3*A*
Mean	63.4(*C*)	64.1(*BC*)	64.8(*AB*)	65.4(*A*)	
Root (R)	10.34***				
Foliar (F)	6.78***				
R × F interaction	0.53ns				

*** $p<0.001$, ns – not significant

The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

R4 (2000 ml da^{-1}) in amino acid root applications, and F4 dose (200 ml L^{-1}) in foliar applications (Table 4).

An increase in the stem diameter was achieved in tomato fruits treated with amino acid applications. Foliar application of amino acids promotes vegetative growth, yield parameters and biochemical components of vegetable crops (Sadak et al. 2015, Aly et al. 2019). Salim et al. (2021) stated that amino acids have positive impact on vegetative growth and leaf element concentrations, increasing the total yield and fruit quality of tomato. Amino acid applications increase the number of flowers, fruit formation, fruit yield and plant biomass (Neeraja et al. 2005, Basanth Mahesh 2018).

The effects of different doses of amino acid root and foliar applications on the mineral nutrient concentrations in the leaves of tomato were found to be statistically significant. The highest N concentration was obtained from R3 (1000 ml da^{-1}) and R4 (2000 ml da^{-1}) doses in amino acid root applications made, and F4 (200 ml L^{-1}) foliar applications. Similarly, root and foliar applications were found to be statistically significant in the phosphorus concentration of leaves, and the highest phosphorus concentrations were obtained from R4 (2000 ml da^{-1}) root applications, and F3 (100 ml L^{-1}) foliar applications (Table 5).

Root and foliar applications of amino acid applications did not lead to differences in the potassium, calcium, and magnesium concentrations of tomato plants (Tables 6, 7).

Amino acids can improve plant growth and yield productivity by the improvement of the biosynthesis of proteins, phytohormones, enzyme activa-

Table 5

Effects of different doses of amino acid root and foliar applications on the nitrogen and phosphorus concentration of the leaves

Nitrogen (g kg^{-1})						Phosphorus (g kg^{-1})				
foliar (ml 100 L^{-1})						foliar (ml 100 L^{-1})				
Root	F1	F2	F3	F4	mean	F1	F2	F3	F4	mean
R1	27	30	30	31	29C	2.2	2.4	2.8	2.7	2.5B
R2	30	31	32	32	31B	2.7	2.6	2.7	2.5	2.6AB
R3	32	33	34	34	33A	2.5	2.7	2.8	2.5	2.6AB
R4	33	32	33	34	33A	2.6	2.7	2.8	2.9	2.8A
Mean	31(*B*)	31(*AB*)	32(*AB*)	33(*A*)	-	2.5(*B*)	2.6(*AB*)	2.8(*A*)	2.6(*AB*)	-
Root (R)		11.728***				3.216*				
Foliar (F)		3.420*				3.733*				
R × F interaction		0.269ns				0.067ns				

* $p<0.05$, *** $p<0.001$, ns – not significant
The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

Table 6

Effects of different doses of amino acid root and foliar applications on the potassium concentration of the leaves

Potassium (g kg^{-1})	Foliar application (ml 100 L^{-1})				
Root application (ml da^{-1})	F1	F2	F3	F4	mean
R1	10.4	10.0	10.8	12.6	11.0
R2	10.3	9.1	11.2	11.0	10.4
R3	10.2	11.0	10.8	9.4	10.4
R4	9.5	11.0	10.5	9.6	10.2
Mean	1.0.1	10.3	10.8	10.7	
Root (R)	0.96ns				
Foliar (F)	0.92ns				
R × F interaction	1.99ns				

* $p<0.05$, ns – not significant
The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

tion, macro-and micronutrients uptake, signaling processes, energy production (Hildebrandt et al. 2015, Santi et al. 2017, Souri, Hatamian 2019). Plants have the ability to take up and use amino acids as a nitrogen source, and N concentrations

Table 7

Effects of different doses of amino acid root and foliar applications on the calcium and magnesium concentration of the leaves

Calcium (g kg^{-1})						Magnesium (g kg^{-1})				
foliar (ml 100 L^{-1})						foliar (ml 100 L^{-1})				
Root	F1	F2	F3	F4	Mean	F1	F2	F3	F4	mean
R1	28.6	31.1	30.1	28.4	29.5	5.7	5.8	5.8	5.6	5.7
R2	29.9	27.9	27.4	27.1	28.1	6.2	5.2	5.4	5.5	5.6
R3	29.1	28.0	28.5	28.9	28.6	5.4	5.7	5.4	5.6	5.5
R4	27.9	28.4	29.2	25.7	27.8	5.5	5.8	5.4	5.5	5.6
Mean	28.9	28.8	28.8	27.5	-	5.7	5.7	5.5	5.5	
Root (R)		0.53ns				0.22ns				
Foliar (F)		0.40ns				0.28ns				
R × F interaction		0.30ns				0.50ns				

* p<0.05, ns – not significant

The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

of leaves increase with amino acid applications (Chapin et al. 1993, Matsumoto et al. 2000, Zewail 2014, Shehata et al. 2011).

The effects of different doses of amino acid root, foliar and R×F applications on the micronutrient concentrations in the leaves of tomato were found to be statistically significant. R3 (1000 ml da^{-1}) and R4 (2000 ml da^{-1}) doses in root applications, F3 (100 ml L^{-1}) doses in foliar applications, and R1×F3 and R4×F4 applications were determined as the ones leading to the highest iron concentration (Table 8).

Root and foliar applications were found to be statistically significant in the manganese concentration of tomato leaves, the highest manganese values were determined from R4 (2000 ml da^{-1}) root application, and all foliar application doses increased Mg content compared to control (Table 9).

Root and foliar applications of amino acid applications did not result in differences in zinc and copper concentrations of tomato plants (Table 10). In general, applications of amino acids had a positive effect on micronutrients. The soluble sources of Fe available to plants in the rhizosphere are mainly a mixture of complexes between this microelement and organic ligands from plant roots or microorganisms (Bityutskii et al. 2004). The increase in the leaf Fe concentration of plants owing to amino acid applications may have raised the transport of Fe in the xylem and phloem translocation by helping the formation of Fe-phytosiderophore complexes (Robin et al. 2008). Amino acid applications have a positive effect on the manganese concentration in the plant (Fawzy et al. 2012).

Table 8

Effects of different doses of amino acid root and foliar applications on the iron concentration of the leaves

Iron (mg kg^{-1})	Foliar application (ml 100 L^{-1})				
Root application (ml da^{-1})	F1	F2	F3	F4	mean
R1	22.2*de*	25.5*bcde*	43.4*a*	21.9*e*	28.3*B*
R2	21.1*e*	23.3*cde*	35.4*ab*	36.5*ab*	29.1*B*
R3	34.3*abc*	35.1*ab*	34.5*abc*	33.5*abcd*	34.4*A*
R4	31.9*abcde*	37.4*ab*	35.6*ab*	41.0*a*	36.5*A*
Mean	27.4(*C*)	30.3(*BC*)	37.2(*A*)	33.21(*AB*)	
Root (R)	5.138**				
Foliar (F)	5.646**				
R × F interaction	3.013**				

** $p<0.01$, ns – not significant
The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

Table 9

Effects of different doses of amino acid root and foliar applications on the manganese concentration of the leaves

Manganese (mg kg^{-1})	Foliar application (ml 100 L^{-1})				
Root application (ml da^{-1})	F1	F2	F3	F4	mean
R1	111.1	113.1	126.2	121.1	117.9*AB*
R2	111.5	132.3	108.3	128.2	120.2*A*
R3	105.6	107.9	114.0	113.1	110.1*B*
R4	110.2	122.0	124.5	126.5	120.8*A*
Mean	109.6(*B*)	118.8(*A*)	118.3(*A*)	122.2(*A*)	
Root (R)	2.880*				
Foliar (F)	3.502*				
R × F interaction	1.467ns				

* $p<0.05$, ns – not significant
The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

CONCLUSIONS

The present study evaluated the effects of different doses of amino acid applied via the root and foliar applications on the yield, growth and mineral

Table 10

Effects of different doses of amino acid root and foliar applications on the zinc and copper concentrations of leaves

Zinc (mg kg^{-1})						Copper (mg kg^{-1})				
foliar (ml 100 L^{-1})						foliar (ml 100 L^{-1})				
Root	F1	F2	F3	F4	mean	F1	F2	F3	F4	mean
R1	39.4	44.2	38.2	37.9	39.9	11.6	8.2	10.2	7.7	9.4
R2	33.9	49.5	37.7	45.5	41.7	9.1	9.4	9.1	9.0	9.2
R3	34.5	39.8	41.6	37.1	38.3	9.0	10.4	7.8	9.3	9.1
R4	39.9	43.4	37.9	37.8	39.8	9.7	10.0	14.3	8.4	10.6
Mean	36.9	44.2	38.9	39.6	-	9.9	9.5	10.3	8.6	-
Root (R)	0.35ns					0.63ns				
Foliar (F)	1.73ns					0.69ns				
R × F	0.56ns					0.96ns				

* $p<0.05$, ns – not significant

The values followed by uppercase letters indicate a difference between the root application of amino acid. The values followed by uppercase letters in parentheses indicate a difference between the foliar application of amino acid.

nutrient content of greenhouse tomato. The treatments with amino acids affected the yield, growth and some nutrient concentrations positively. Generally, the efficiency of the 3rd and 4th doses was found to be higher in both root and foliar amino acid treatments. In addition to basic fertilization, it has been revealed that significant increases in productivity parameters can be achieved with amino acid root and foliar applications. As a result of the study, it was determined that amino acid treatments provide an important contribution to and can be used in plant production.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to the Scientific Fund of Akdeniz University (Project No: FYL-2019-5082).

REFERENCES

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.* Potr S J F Sci, 13(1): 831-839.

Aslan Y. 2019. *Humik-fulvik asit ile amino asit'in kıvırcık yapraklı baş salatanın verim ve kalitesi üzerine etkisi.* Yüksek lisans tezi, Gaziosmanpaşa Üniversitesi Fen Bilimleri Enstitüsü Bahçe Bitkileri Ana Bilim Dalı, Tokat, 46 s. (in Turkish)

Basanth N., Mahesh G. 2018. *Bioefficacy of Nova Nutri Boost for yield and yield components in paddy (Oryza sativa* L.*).* Int J Curr Microbiol Appl Sci, 7(10): 2250-2253.

Bityutskii N.P., Davydovskaya E.N., Malyuga E.A., Yakkonen K.L. 2004. *Mechanisms under-*

lying iron and zinc transport to axis organs in grain during early seedling development of maize. J Plant Nutr, 27: 1525-1541. DOI: 10.1081/PLN-200025996

Boras M., Zidan R., Halloum W. 2011. *Effect of amino acids on growth, production and quality of tomato in plastic greenhouse*. Tishreen Univ. J Res. and Sc Studies. Biolog Sci Series, 33(5): 229-238.

Bremner J.M. 1965. *Total nitrogen*. In: *Methods of soil analysis*. Eds. C.A. Black, 1149-1178, Agronomy No. 9, Part 2. Madison, WI, American Society of Agronomy.

Calvo P., Nelson L., Kloepper J.W. 2014. *Agricultural uses of plant biostimulants*. Plant Soil, 383: 3-41. DOI: 10.1007/s11104-014-2131-8

Chapin F.S., Moilainen L., Kielland K. 1993. *Preferential use of organic nitrogen by a non-mycorrhizal arctic sedge*. Nature, 361: 150-53. DOI: 10.1038/361150a0

Denli Z., Arabaci G. 2014. *Investigation of the effect of amino acids on peroxidase enzymes from kiwano (Cucumis metuliferus)*. SAU J Sci, 18(2): 105-109.

El-Razek E.A., Laila F.H., Abd-El-Migeed M.M.M., El-Hady E.S. 2018. *Combined effects of soil applications of humic acid and foliar spray of amino acids on yield and fruit quality of Florida Prince peach trees under calcareous soil conditions*. Biosci Res, 15(4): 3270-3282.

Fawzy Z.F., El-Shal Z.S., Yunsheng L., Zhu O., Sawan O.M. 2012. *Response of garlic (allium sativum L.) plants to foliar spraying of some bio-stimulants under sandy soil condition*. J Appl Sci Res, 8(2):770-776.

Garcia A.L., Madrid R., Gimeno V., Rodriguez-Ortega W.M., Nicolas N., Garcia-Sanchez F. 2011. *The effects of amino acids fertilization incorporated to the nutrient solution on mineral composition and growth in tomato seedlings*. Span J Agric Res, 9(3): 852-861.

Geraldson C.M., Klacan G.R., Lorenz O.A. 1973. *Plant analysis as an aid in fertilizing vegetable crops, soil testing and plant analysis*. Soil Science of America Inc., Madison, Wisconsin, USA.

Hildebrandt T.M., Nunes Nesi A., Arau'Jo W.L., Braun H.P. 2015. *Amino acid catabolism in plants*. Mol Plant, 8: 1563-1579. DOI: 10.1016/j.molp.2015.09.005

Kacar B., Kovancı D. 1982. *Bitki, toprak ve gübrelerde kimyasal fosfor analizleri ve sonuçlarinin değerlendirilmesi*. Ege Üniv. Ziraat Fak. Yayınları No: 354, İzmir, Türkiye. (in Turkish)

Kavasoğlu A. 2018. *Aminoasit uygulamasının kınalı fasulye çeşidinin tarımsal özellikleri üzerine etkileri*. Selçuk Üniversitesi, Fen Bilimleri Enstitüsü, Tarla Bitkileri Anabilim Dalı, Yüksek lisans tezi, Konya, 36 s. (in Turkish)

Kacar B., İnal A. 2008. *Bitki Analizleri*. Nobel Yayın Dağıtım Ltd. Şti. Yayınları, Yayın No: 1241, Fen Bilimleri 63, Ankara. (in Turkish)

Koukounaras A., Tsouvaltzıs P., Sıomos A.I. 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.

Liu X.Q., Ko K.Y., Kim S.H., Lee K.S. 2008. *Effect of amino acid fertilization on nitrate assimilation of leafy radish and soil chemical properties in high nitrate soil*. Commun Soil Sci Plant Anal 39: 269-281. DOI: 10.1080/00103620701759301

Matsumoto S., Ae N., Yamagata M. 2000. *Possible direct uptake of organic nitrogen from soil by chingensai (Brassica campestris* L.*) and carrot (Daucus carota* L.*)*. Soil Biol Biochem, 32: 1301-1310. DOI: 10.1016/S0038-0717(00)00048-1

Moraditochaee M., Bidarigh S., Azarpour E., Danesh R.K., Bozorgi H.R. 2012. *Effects of nitrogen fertilizer management and foliar spraying with amino acid on yield of cowpea (Vigna unguiculata* L.*)*. Int J Agric Crop Sci, 4(20): 1489-1491.

Neeraja G., Reddy I.P., Gautham B. 2005. *Effect of growth promoters on growth and yield of tomato cv. Marutham*. J Res ANGRAU, 33(3): 68-70.

Robin A., Vansuyt G., Hinsinger P., Meyer J.M., Briat J.F., Lemanceau P. 2008. *Iron dynamics in the rhizosphere. Consequences for plant health and nutrition*. Adv Agron, 99: 183-225.

Sadak S.H.M., Abdelhamid M.T., Schmidhalter U. 2015. *Effect of foliar application of amino acids on plant yield and physiological parameters in bean plants irrigated with seawater.* Acta Biolo Colomb, 20(1): 141-152.

Salim B.B.M., Salama Y.A.M., Hikal M.S., Abou El-Yazied A., Abd El-Gawad H.G. 2021. *Physiological and biochemical responses of tomato plant to amino acids and micronutrients foliar application.* Egypt J Bot, 61(3): 837-848. DOI: 10.21608/ejbo.2021.54992.1600

Sahu B. 2016. *Differential responses of various amino acid-based growth substances on physiological parameters, dry matter partitioning, productivity and quality of soybean.* Master thesis. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur College of Agriculture, Jabalpur, 87. (in Hindi)

Santi C., Zamboni A., Varanini Z., Pandolfini T. 2017. *Growth stimulatory effects and genome -wide transcriptional changes produced by protein hydrolysates in maize seedlings.* Front Plant Sci, 8(433): 1-17. DOI: 10.3389/fp13.2017.00433

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

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.* Eur J Sci Res, 58(2): 257-265.

Souri M.K., Hatamian M. 2019. *Aminochelates in plant nutrition: A review.* J Plant Nutr, 42(1): 67-78. DOI: 10.1080/01904167.2018.1549671

Zewail R.M.Y. 2014. *Effect of seaweed extract and amino acids on growth and productivity and some bioconstituents of common bean plants.* J Plant Prod, 5(8): 1441-1453.