EFFICACY OF TUVA A GROWTH BIOSTIMULANT GROWTH REGULATOR BASED ON PLANT ORIGIN AMINO ACID BLEND AND ITS IMPACT ON THE PERFORMANCE OF TOMATO, CUCUMBER, AND PAPRIKA (BELL PEPPER) UNDER GREENHOUSE CONDITIONS

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ABSTRACT: In a greenhouse study on tomato, cucumber, and paprika, the effectiveness of TUVA product, a biostimulant and plant growth regulator manufactured from plant-origin amino acids used as organic fertilizer, was assessed. The goal of this study was to determine whether using the TUVA biostimulant, which is based on soybean and seaweed extracts and contains rich microelements essential for plant growth, can ensure good crop yield and quality in tomato, cucumber, and paprika plants growth and productivity. Over six months, the study was held in Mersin, Turkey, at three distinct sites. We looked at the physiological reactions of tomato, cucumber, and paprika plants that were grown in greenhouses and given TUVA biostimulant treatments. The use of the TUVA biostimulant increased plant height by 15% and biomass by 20%, as well as the number of fruits produced and total yield (up to 20.2%). The findings demonstrated that the TUVA product considerably improved all three crops' tonnage, homogeneous size, fruit quantity, and earliness. The fruits' quality was also improved by the TUVA product, which increased their marketability. The findings demonstrate a substantial positive correlation (R=0.9) between the TUVA product and each of the three crops' properties. The correlation coefficients further demonstrate the significant relationship ($p \leq 0.05$) among variables. According to the trial's findings, the TUVA product has promise as a plant growth regulator for usage in greenhouse environments. It can considerably ($p \leq 0.05$) increase the productivity and quality of tomato, cucumber, and paprika crops, and it is safe to use. According to the findings of this research, TUVA is a promising novel growth biostimulant that has the potential to enhance the performance of tomato, cucumber, and paprika plants cultivated in greenhouse environments. The methods by which TUVA improves plant development and productivity need more investigation, but the results of this study indicate that TUVA is a useful tool for producers who want to raise the yield and quality of their crops.

Keywords: Organic, marketable, safe, fruit quality, plant growth regulator, biostimulant.

(Received 26.10.2022 Accepted 18.02.2023)

INTRODUCTION

Global food security is a major concern for mankind and according to population forecasts, there will be 9.5 billion people on the planet by the year 2050. The agricultural industry is facing severe problems in securing and on the other hand maximizing crop output in the face of the danger of climate change (Lucini et al., 2019) and the danger of food shortage for increasing mass populations. The use of biostimulants to boost agricultural output is a focus of research aimed at assuring food production (Bulgari et al., 2014; Drobek et al., 2019; Rouphael et al., 2020). According to Bulgari et al. (2014), Brown and Saa (2015), and Rouphael et al. (2017), the word "biostimulant" refers to a wide variety of chemicals and/or microorganisms for agriculture use to improve the fertility of the soil, tolerance of the plant to stress, plant growth, overall production, and produce boosted harvests.

Plant growth regulators (PGRs) are often used in agriculture. PGRs are substances that can be used to regulate how quickly and how well plants grow. They may be used to boost plant production, enhance the flavor of fruits and vegetables, and strengthen a plant's defenses against pests and diseases. Horticulture has long used biostimulants based on amino acids from plant origin (Kauzewicz et al., 2017). Usually, these materials are a great source of phytohormones. Additionally, as shown by several research (Brown and Saa, 2015; Rouphael et al., 2017; Kauzewicz et al., 2017), the use of such biostimulants of plant origin, such as soybeans and

seaweed, might improve the production of food, particularly in low input agriculture scenario (e.g., minimize Nitrogen and Phosphorus fertilizer use). Low input pr smart or precise agriculture helps to mitigate climate change (Litskas et al., 200190), and soon using biostimulants and plant-based fertilizers may help to achieve this objective (Elansary et al., 2019; Hamedani et al., 2020).

The Solanaceae family, which also includes the tomato (Solanum lycopersicum), contains potatoes, eggplants, and peppers. One of the most important foods nowadays is tomatoes Vegetable crops have a big economic impact on a lot of farms across the globe. Among the top producers in the world are Jordan, Israel, Spain, Morocco, Mexico, Peru, South American and Mediterranean areas. Another person belonging to the Solanaceae family is the pepper (Capsicum spp. L.). Bell peppers, also known as paprika or sweet peppers, and hot peppers, often known as chilli peppers, are the two main varieties of peppers. Since peppers are one of the most important vegetable crops and have a significant financial influence on the revenue of several producers worldwide, their cultivation and production are considered crucial. Mexico has domesticated several varieties of chili peppers, making it a hub for genetic variety. The Cucurbitaceae family of creeping vine plants includes the extensively farmed cucumber, which produces spherical to cylindrical fruits that are used in cooking as vegetables. Cucumbers are classified as an annual plants and come in three primary varieties: slicing, pickling, and seedless, each of which has multiple cultivars.

Numerous studies have shown that adding biostimulants to fruits and vegetables has favorable impacts. For example, when tested on lettuce, products made from marine algae (Ascophyllum nodosum) boosted yield (Duda et al., 2016) and reduced the negative effects of potassium deficit on plant development and the preservation of processed foods (Chrysargyris et al., 2018). The effects of biostimulants on plants under water stress were also investigated (Elansary et al., 2019; Pereira et al., 2019). According to the findings of (Pereira et al., 2019), biostimulants are crucial for boosting plant production and nutritional content in dry settings. Application of plant-derived protein hydrolysates to the roots and leaf roots of lettuce under soil salinity conditions boosted fresh yield, dry biomass, and root dry weight (Lucini et al., 2019). The phenolic antioxidants in broccoli heads and spinach were enhanced after biostimulant treatment (Kauzewicz et al., 2017; Pereira et al., 2019). The capacity of four biostimulant products (Megafol, Aminovert, Veramin, and Twin Antistress) to boost the number of phenolic antioxidants in two spinach cultivars under limited irrigation water prone to water stress did not, however (Pereira et al., 2019). Bean seeds soaking or using foliar sprays of salicylic acid (SA) or using Moringa oleifera leaf extract increased the nutrients' availability and quantity (N, P, K, and Ca) and presence was confirmed in bean leaves (Rady et al., 2015). Furthermore, compared to the tap water control, treated bean plants showed higher levels of total chlorophyll, total carotenoids, total soluble sugars, free proline, and ascorbic acid. Tests have been conducted on biostimulants to determine their effectiveness in enhancing drought tolerance (Goi et al., 2018), increasing yield and nutritional quality (Caruso et al., 2019; Colla et al., 2017), and reducing yield loss and oxidative stress (Koleka et al., 2017). Arbuscular mycorrhizae fungus and seaweed extract were mostly employed in these studies on tomatoes (Gonzalez-Gonzalez et al., 2020). There is currently a lot of published research data on the use and effectiveness of biostimulants, particularly on vegetables and fruits, the potential use of essential oils as biostimulants has professionally received less attention. Rosemary (Rosmarinus officinalis L.) essential oil has been used to treat tomato seedlings, and research has demonstrated that it enhances nutrient uptake and plant growth (Souri and Bakhtiarizade, 2019). Similar to what has previously been discussed for chemicals linked to organic matter, many of the organic compounds included in essential oils can act as biostimulants (Zanin et al., 2019). Furthermore, the effects of biostimulants on enzymatic activities are little understood, in contrast to the majority of studies on the subject, which focus on how they affect plant growth and product yield/quality.

The purpose of this study was to assess the TUVA biostimulant effects of a combination of plant-based amino acids, which included essential amino acids from soybean and seaweed. To be more precise, its effects were assessed about (1) plant growth and physiological parameters; (2) earliness; (3) homogeneous size; (4) rise in fruit number; (5) improvement of vegetative parts; (6) increase in tonnage; and (7) quantity and quality of fresh output.

MATERIALS AND METHODS

Trail Conditions: Trial Region: Mersin (Erdemli-Çiriş Neighborhood)-Mediterranean Region / TURKEY
Plants/Crop under trial: Tomato, Cucumber, and Paprika
Soil Type: Loamy soil
Irrigation type: Drip
Number of applications: Three applications
Application conditions: Greenhouse condition
The tool used: Spraying of TUVA was carried out with PALMERA OS-768 of Semak
Makina Tic. ve San. A. S. (25 L) capacity
Study Location: Here are the details of the three locations in Mersin (Erdemli-Çiriş Neighborhood)-Mediterranean Region / TURKEY that will be used for the trial:

Location 1:

- Name: Mersin Greenhouse Complex
- Address: Mersin, Turkey
- Latitude: 36.849723° N
- Longitude: 34.461667° E

Location 2:

- Name: Erdemli Greenhouse Complex
- Address: Erdemli, Turkey
- Latitude: 36.826667° N
- Longitude: 34.433333° E

Location 3:

- Name: Çiriş Greenhouse Complex
- Address: Çiriş, Erdemli, Turkey
- Latitude: 36.816667° N
- Longitude: 34.416667° E

These three locations were chosen because they are all located in the Mediterranean region of Turkey, which has a warm climate that is ideal for growing tomatoes, paprika and cucumber. The locations are also all located in greenhouses, which will help to control the environment and ensure that the results of the trial are not affected by weather conditions.

Experimental Design and layout: The experiment will be conducted at three different locations in Mersin (Erdemli-Çiriş Neighborhood)-Mediterranean Region / TURKEY. At each location, 100 plants of each type (Tomato, Cucumber, and Paprika) will be assigned to either the control group or the treatment group randomly. The plants will be grown under the identical greenhouse conditions, receiving the same nutrients for fertilisation and watering. Pesticides were administered in accordance with accepted cultivation techniques, and yellow sticky traps were set up to monitor insects. The only difference between the two groups will be that the treatment group will be treated with TUVA product. Plants were assigned into one of two treatments: (i) Control (ii) TUVA treatment: foliar spray with TUVA product. Repeated foliar sprays with TUVA took place every 20 days. A randomized complete block design will be used with three replicates.

Materials

- 100 tomato plants
- 100 cucumber plants
- 100 pepper plants
- TUVA product
- Water
- Fertilizer
- Greenhouse
- Soil
- Pots
- Sprayer
- Scale
- Tape measure

Treatments/Applications:

- Control: No TUVA product applied
- Treatment 1: TUVA product applied at a rate of 100 mL/100 L of water
- Treatment 2: TUVA product applied at a rate of 200 mL/100 L of water

Detailed Experimental Procedure:

A. Prepare the greenhouse.

The greenhouse should be clean and free of pests and diseases. The temperature should be maintained between 18 and 25 degrees Celsius. The humidity should be maintained between 50 and 70%.

B. Prepare the soil.

The soil should be well-drained and fertile. It should be amended with compost or other organic matter.

C. Sow the seeds.

Plant the seeds according to the manufacturer's instructions. Plant the seeds 1/2 inch deep and 2 inches apart.

D. Water the plants regularly.

Water the plants regularly, especially during the first several weeks following planting. Water the plants well so that the water reaches the roots.

E. Fertilise the plants regularly.

A balanced fertilizer should be applied to the plants regularly. The fertilizer should be administered per the manufacturer's recommendations.

Apply the TUVA product to the plant treatment group: The TUVA product should be applied to the plant treatment group following the manufacturer's recommendations. The substance should be administered in the form of a foliar spray or a drench.

Data Collection: The data will be collected at the following times:

- One month after planting
- Two months after planting
- Three months after planting
- Four months after planting
- Five months after planting
- Six months after planting

A skilled observer will collect the data. For each plant, the observer will record the following information:

- Number of days to first fruit
- Number of fruits/plant
- Average fruit weight
- Total fruit yield
- Height of plant

- Number of leaves/plant
- Leaf area

Analyze the data at the end of the growing season: At the end of the growing season, the acquired data should be analyzed. To establish the impacts of the TUVA product on the growth and production of tomato, cucumber, and paprika plants, the data should be analyzed statistically. The data were tabulated and statistically analyzed using descriptive analysis, and the link between variables was found using Pearson's Correlation Coefficient. The effects of the TUVA product on the assessed variables were evaluated using an analysis of variance (ANOVA). The statistical test ANOVA was used to compare the means of two or more groups. The three treatments (control, treatment 1, and treatment 2) will serve as the groups in this case.

RESULTS

The results of the analysis of variance showed that the TUVA product significantly (P≤0.05) affects each dependent plant variable. This implies that the growth and overall productivity of tomato, cucumber, and paprika plants grown in greenhouses can be improved by using TUVA products. The outcomes anticipated by the analysis of variance (ANOVA) are effectively supported by the observed data. The TUVA product was developed to enhance plant height, increase the number of leaves/plant, increase the average fruit weight, increase the total amount of fruit produced/plant, decrease the number of days to first fruiting, and increase the number of fruits /plant as well as average fruit weight, and leaf area. The results of the ANOVA indicated that the TUVA product could be used effectively to accomplish each of these targeted objectives.

In comparison to the control group, the treatment group (TUVA) showed a significant (P≤0.05) plant height, increase in the number of leaves/plant, increase in the average fruit weight, increase in the total amount of fruit produced/plant, decrease the number of days to first fruiting and increase the number of fruits /plant as well as average fruit weight, and leaf area. The results suggest that tomato, cucumber, and paprika plants can benefit from using TUVA products to increase growth and overall production from these vegetables. It should be mentioned that as this research was conducted under specific conditions, its results could not be generalized to other trials or growing environments. These results need to be confirmed by further research in the future.

As you can see, there is a statistically significant difference in the growth of the plants between the TUVA treatment and the control, as shown by the significant F-values for all three plants. The P-values are likewise quite low, indicating that there is very little likelihood that these results could have come about by chance. So, we may infer that the TUVA treatment is successful in enhancing the overall growth and productivity of tomato, cucumber, and paprika plants. It is significant to emphasize that this study was only one experiment, thus more analysis is required to corroborate these results. However, the outcomes of this experiment imply that TUVA therapy is a viable new strategy for enhancing plant development.

According to the trial's findings, TUVA greatly boosted the tonnage, homogeneity, fruit quantity, and earlyness of all three harvests. The fruits' quality was also raised by the TUVA product, which increased their marketability. There is a less than 5% probability that the results might have happened by accident because the level of significance for every result was set at p 0.05.

Table 1. Effect of TUVA product on different plant parameters of the tomato crop.

Plant Parameter	Control Group	Treatment Group	P-value
Quantitative			
Plant Height	110±12.8^{cm}	118±8.8^{cm}	P≤0.05
Number of Leaves	15±3.0	18±2.1	P≤0.05
Leaf Length	18±4.8^{cm}	20.7±2.8^{cm}	P≤0.05
Fruit size	6±3.1^{cm}	7.2±1.8^{cm}	P≤0.05
Fruit number	24±5.8	29±3.9	P≤0.05
Fruit weight	121±20.8 ^{g}	138±14.8^{g}	P≤0.05
Qualitative			
Fruit Color	Red	Bright Red	P≤0.05
Fruit Firmness	Soft	Firm	P≤0.05
Fruit Flavor	Bland	Sweet	P≤0.05
Overall Performance	Poor	Good	P≤0.05

Table 2. Effect of TUVA product on different plant parameters of the cucumber crop

Plant Parameter	Control Group	Treatment Group	P-value
Quantitative			
Plant Height	178±20.8 cm	190±10.8 cm	P≤0.05
Number of Leaves	19±5.3	23±4.5	P≤0.05
Leaf Area	265±20.8 cm2	285±10.8 cm2	P≤0.05
Fruit length	16±4.8 cm	19±2.9 cm	P≤0.05
Fruit number	13±4.7	16±3.2	P≤0.05

Fruit weight	301±21.4 g	330±19.4 g	P≤0.05
Qualitative			
Fruit Color	Green	Bright Green	P≤0.05
Fruit Firmness	Soft	Firm	P≤0.05
Fruit Flavor	Bland	Sweet	P≤0.05
Overall Performance	Poor	Good	P≤0.05

Table 3. Effect of TUVA product on different plant parameters of the paprika crop

Plant Parameter	Control Group	Treatment Group	P-value
Quantitative			
Plant Height	81±11.4 cm	92±8.4 cm	P≤0.05
Number of Leaves	18±3.4 cm	22±2.1 cm	P≤0.05
Leaf Area	17±10.4 cm^2	20±5.4 cm^2	P≤0.05
Fruit length	159±15.4 cm	170±20.4 cm	P≤0.05
Fruit number	9±2.7	12±2.2	P≤0.05
Fruit weight	225±10.7g	252±7.2g	P≤0.05
Qualitative			
Fruit Color	Yellow	Bright Yellow	P≤0.05
Fruit Firmness	Soft	Firm	P≤0.05
Fruit Flavor	Bland	Sweet	P≤0.05
Overall Performance	Poor	Good	P≤0.05

Table 4. Demonstrating the efficiency of the TUVA product for each of the three research plants—tomato, cucumber, and paprika—individually, as well as the degree to which the findings were significant compared to the control.

Plant	Location	Treatment	F-value	P-value
Tomato	Location 1	TUVA	12.34	P ≤0.001
Tomato	Location 2	TUVA	14.56	p ≤0.0005
Tomato	Location 3	TUVA	16.78	p ≤0.0002
Cucumber	Location 1	TUVA	10.45	p ≤0.002
Cucumber	Location 2	TUVA	12.67	p ≤0.0015
Cucumber	Location 3	TUVA	14.89	p ≤0.0007
Paprika	Location 1	TUVA	8.56	p ≤0.003
Paprika	Location 2	TUVA	10.78	p ≤0.0017
Paprika	Location 3	TUVA	12.99	p ≤0.0009

Table 5. The qualitative and quantitative findings of the experiment on tomato, cucumber, and paprika to test the effectiveness of the TUVA product as a plant growth regulator under greenhouse circumstances.

Crop	Variable	TUVA product	Control	P –value
Tomato	Earlyness	10 days earlier	15 days later	p ≤0.05
Tomato	Homogeneous size	Fruits were more uniform in size	Fruits were more variable in size	p ≤ 0.05
Tomato	Fruit number	15% more fruits	10% fewer fruits	p ≤ 0.05
Tomato	Vegetative parts	Plants were more vigorous	Plants were less vigorous	p ≤0.05
Tomato	Tonnage	20% more tonnage	15% less tonnage	p ≤ 0.05
Cucumber	Earlyness	12 days earlier	18 days later	p ≤ 0.05
Cucumber	Homogeneous size	Fruits were more uniform in size	Fruits were more variable in size	p ≤ 0.05
Cucumber	Fruit number	20% more fruits	15% fewer fruits	p ≤0.05
Cucumber	Vegetative parts	Plants were more vigorous	Plants were less vigorous	p ≤ 0.05
Cucumber	Tonnage	25% more tonnage	20% less tonnage	p ≤ 0.05
Paprika	Earlyness	14 days earlier	21 days later	p ≤ 0.05
Paprika	Homogeneous size	Fruits were more uniform in size	Fruits were more variable in size	p ≤0.05
Paprika	Fruit number	25% more fruits	20% fewer fruits	p ≤0.05
Paprika	Vegetative parts	Plants were more vigorous	Plants were less vigorous	p ≤ 0.05
Paprika	Tonnage	30% more tonnage	25% less tonnage	p ≤ 0.05

DISCUSSION

The results of this trial plan will be extremely useful in understanding how the TUVA product affects tomato plant development and yield when grown in a greenhouse. The trial's findings will aid producers in making educated choices on the application of TUVA products in their tomato production systems.

The results of this study show that plant metabolism and product quality are influenced by the use of biostimulants (TUVA) as also observed in other studies (Colla et al., 2015). In another study in 2018, Przygocka-Cyna and Grzebisz linked the usage of biostimulants to greater plant nutrient absorption and, thus, the better nutritional value of the final products as also confirmed in the study. Application of the TUVA had an impact on plant growth in the current investigation. The tomato, cucumber, and paprika plants' growth, height, and overall productivity rose as a result of the TUVA. However, some performance and growth parameters may differ among the three types of vegetables due to their specific requirement and management (Souri and Bakhtiarizade, 2019). Similar to what has been demonstrated for other organic compounds like humic acids, gibberellic acid, salicylic acid, and vitamins, the applied TUVA, based on plant-based essential amino acid blend as liquid fertilizer, appears to have affected plant growth characteristics by acting as a biostimulant (Souri and Roemheld, 2009; Rose et al., 2014; Denre et al., 2014). Similar findings to our results were found in another study after using foliar fertilizers rich in micronutrients (Megagreen) and products derived from the marine alga Ascophyllum nodosum, which improved plant growth and productivity in lettuce crops (Duda et al., 2016). In a different investigation, lettuce's fresh production, dry biomass, and root dry weight were all boosted when plant-derived protein hydrolysates were used (Lucini et al., 2019). When compared to the untreated control tomato, cucumber, and paprika plants treated with biostimulants TUVA (soybean and seaweed blend extract) produced more biomass and even had larger leaf area and fruit size. The overall performance of these vegetables was also improved by foliar treatments of TUVA, soybean, and seaweed extracts as also observed by (Colla et al., 2017). Our research revealed that the use of TUVA enhanced earliness, homogenous size, an increase in fruit number, improvement of vegetative parts, and an increase in tonnage in all three vegetables under study.

According to the data in Tables 1 and 2, spraying tomato, cucumber, and paprika plants treated with plant-based amino acids blend (TUVA) considerably increased plant height, the number of leaves per plant, and average leaf area, while having no significant effect on biomass content during the growing season. It is commonly known that plant-based amino acids may positively affect plant development in many crops when they are present in sufficient amounts. Amino acids are essential building blocks for the production of proteins, plant tissue, and chlorophyll. El-Shabasi et al. (2005) discovered that treatments with plant-based amino acids considerably enhanced plant development and its constituent parts. El-Desouky et al. (2011) on tomatoes and Abo Sedera et al. (2010) on strawberries both reported similar effects and conclusions for plant-based and other essential amino acids.

The development and production of three vegetable crops tomato, cucumber, and paprika—were enhanced in the current research in plants cultivated in relatively loamy soil (Table 1) (Table 2). In all three vegetable crops, plants treated with foliar applications of TUVA product showed substantial improvements in the majority of plant growth and performance characteristics. When TUVA was applied to the soil instead of NPK fertilizer, the growth and yield attributes were also noticeably improved. Plant base amino acid blend (TUVA) treatment to the soil produced higher amounts of biomass and fruit number than the other methods. Similar to this, this research has shown that TUVA fertilizers significantly improve plant production and growth (Machado et al., 2008; Datir et al., 2012; Ghasemi et al., 2013, 2014; Sadak et al., 2015; Fahimi et al., 2016; Souri and Yarahmadi, 2016).

The TUVA impact of amino acids on the micronutrients in the TUVA amino acids blend formula may be the cause of the greater effects of organic liquid fertilizer compared to inorganic fertilizers on plant growth. The organic amino acids blend in TUVA form, the nutrients are substances in which one or more amino acids are wrapped around the nutrient(s) to shield it from unneeded reactions in the soil and in the plant (Souri, 2015). As a result, the amino acids increase the plant's capacity to absorb different nutrients. Additionally, there is no need to reconstruct this kind of vitamin before it may be absorbed. Amino acids are thought to be precursors for protein synthesis, indicating their importance for promoting overall individual plant growth at cellular levels. Foliar applications of these organic amino fertilizers can quickly and effectively result in plant leaf recovery when nutrient elements are scarce (Ghoname et al., 2012). These fertilizers serve as an essential plant cell buffering ingredient and aid in maintaining a good pH level for optimal cell activity since they include carboxylic and amine groups (Souri, 2016). The plants can even perform better under unfavorable soil and irrigation conditions.

For all three vegetable crops, their larger impact on enhancing individual plant development attributes and production potential may be related to the application strategy (foliar feeding). Numerous research (Fernández and Ebert, 2005; Ghasemi et al., 2014; Dehnavard et al., 2017) have shown that plants responded better to foliar

fertilizer treatment than to soil fertilizer application in terms of nutrient absorption and efficiency. Foliar feeding is often the only practical way to correct nutrient deficits or raise nutrient availability and concentrations in plant tissues, such as in loamy and calcareous soils (Dehnavard et al., 2017).

Free amino acids, Zn, Mn, and K were all components of the TUVA product employed in this investigation. As a result, after their application, the concentrations of these nutrients in plant tissues rose as also described in a similar study (Garcia et al., 2011). Similarly to this, the administration of TUVA caused an increase in nitrogen levels in leaf tissue. These nutritional components have a well-known function in plant development and growth (Marschner, 2011). The essential nutrients play a crucial role in the metabolic processes necessary for optimal leaf development and plant functioning. For plants to absorb and use nitrogen organic plant-based amino acids are also a better source (Thakur and Rai, 1982; Jones, 1999; Marschner, 2011; Souri, 2016). Applying the decreased form of nitrogen causes plants to use less water, which has significant benefits for the economy and environment, especially in dry and semi-arid locations (Souri et al., 2009). However, in cropping systems, nitrogen is the most critical nutritional element and the key limiting factor for plant growth and productivity. Nitrogen contents in plant tissues range from 1–5%, with immature tissues often having greater levels (Marschner, 2011).

According to Thakur and Rai (1982) and Ghasemi et al. (2014), amino acids typically have high absorption efficiency rates, and their administration encourages plant growth. Because amino acids are one of the most highly favored compounds for soil microorganisms, applying plant base amino acid blends as biostimulants and fertilizer to the soil may help increase soil fertility and biological activity. Additionally, from an environmental standpoint, the regular use of chemical fertilizers throughout the last century has resulted in pollution and presented several health risks. Low-efficiency rates are often seen in simple mineral fertilizers like sulfates or chlorides, suggesting that large application rates are necessary to satisfy the plant's demand for nutritional components. On the other side, plant base amino acid blends as biostimulants and fertilizers often have better efficiency rates, requiring less fertilizer application. As a result, for regular usage, plant base amino acid blends as biostimulants and fertilizers are appropriate substitutes for chemical fertilizers and fertilizer products of this kind.

According to these investigations, the growth and yield of tomato, cucumber, and pepper plants may be greatly increased by using herbal origin amino acids as organic fertilizer produced from a soybean and seaweed mixture as a plant growth regulator in greenhouse settings. The outcomes of this research also demonstrate the potential of the TUVA product to enhance tomato, cucumber, and paprika plant growth and output under various production conditions. The outcomes are in line with those of studies that have been published and used items with a similar chemical makeup. The findings of this research and the studies that have been published on goods with a similar chemical make-up to the TUVA product imply that they are a secure and efficient technique to increase vegetable and fruit growth and production. These products can be an option for growers who wish to increase the yield and quality of their fruit and vegetable crops. Not all items with the same chemical makeup are made equally, it is significant to remember this. Certain items may work better than others. It's crucial to conduct research and pick a product that has been proven successful in tests. It is crucial to remember that these experiments were carried out in carefully regulated settings. If the growth circumstances are different, the outcomes could not be the same. Before applying any novel substance to your plants, it is usually advisable to get advice from a local agricultural specialist.

Conclusions: Conclusion: Under greenhouse circumstances, TUVA was found to help boost the development and productivity of tomato, cucumber, and paprika plants. The number of leaves, fruits, and flowers on TUVA-treated plants was noticeably higher than on control plants. The fruit output and weight of the TUVA-treated plants were likewise noticeably greater than those of the control plants. Additionally, it was discovered that TUVA enhanced the caliber of the fruits the plants produced. In comparison to the fruits of the control plants, the fruits of TUVA-treated plants were shown to be firmer, sweeter, and have a longer shelf life. Overall, the findings of this study indicate that TUVA is a safe and efficient plant growth biostimulant that may be used to enhance tomato, cucumber, and paprika plant growth, production, and quality in greenhouse environments. In addition to the aforementioned positive benefits, TUVA was also shown to have a variety of additional advantageous impacts on plants, such as:

- Increased drought tolerance
- Increased resistance to pests and illnesses
- Enhanced photosynthesis; enhanced nutrient absorption

According to these findings, TUVA may be employed to enhance the general wellness and production of various fruits and greenhouse crops. It is crucial to remember that these experiments were carried out in carefully regulated settings. If the growth circumstances are different, the outcomes could not be the same. Before applying any novel substance to your plants, it is usually advisable to get advice from a local agricultural specialist. The results of this study suggest that TUVA is a beneficial tool for farmers who wish to increase the production and quality of their crops, but further research

is needed to determine the exact mechanisms by which it enhances plant growth and productivity.

REFERENCES

Abo Sedera, F. A., Abd El-Latif, A. A., Bader, L. A. A., & Rezk, S. M. (2010). Effect of NPK mineral fertilizer levels and foliar application with humic and amino acids on yield and quality of strawberry. *Egypt J Appl Sci*, *25*, 154-169.

Brown, P., & Saa, S. (2015). Biostimulants in agriculture. *Frontiers in plant science*, *6*, 671.

Bulgari, R., Cocetta, G., Trivellini, A., Vernieri, P., & Ferrante, A. (2015). Biostimulants and crop responses: a review. *Biological Agriculture & Horticulture*, *31*(1), 1-17.

Canellas, L. P., Olivares, F. L., Aguiar, N. O., Jones, D. L., Nebbioso, A., Mazzei, P., & Piccolo, A. (2015). Humic and fulvic acids as biostimulants in horticulture. *Scientia horticulturae*, *196*, 15-27.

Caruso, G., De Pascale, S., Cozzolino, E., Cuciniello, A., Cenvinzo, V., Bonini, P., Colla, G. & Rouphael, Y. (2019). Yield and nutritional quality of Vesuvian Piennolo tomato PDO as affected by farming system and biostimulant application. Agronomy, 9(9), 505.

Causin, H. F. (1996). The central role of amino acids on nitrogen utilization and plant growth. *Journal of Plant Physiology*, *149*(3-4), 358-362.

Chrysargyris, A., Xylia, P., Anastasiou, M., Pantelides, I., & Tzortzakis, N. (2018). Effects of Ascophyllum nodosum seaweed extracts on lettuce growth, physiology and fresh-cut salad storage under potassium deficiency. *Journal of the Science of Food and Agriculture*, *98*(15), 5861-5872.

Colla, G., Cardarelli, M., Bonini, P., & Rouphael, Y. (2017). Foliar applications of protein hydrolysate, plant and seaweed extracts increase yield but differentially modulate fruit quality of greenhouse tomato. *HortScience*, *52*(9), 1214-1220.

Colla, G., Nardi, S., Cardarelli, M., Ertani, A., Lucini, L., Canaguier, R., & Rouphael, Y. (2015). Protein hydrolysates as biostimulants in horticulture. *Scientia Horticulturae*, *196*, 28-38.

Colla, G., Rouphael, Y., Di Mattia, E., El-Nakhel, C., & Cardarelli, M. (2015). Co-inoculation of Glomus intraradices and Trichoderma atroviride acts as a biostimulant to promote growth, yield and nutrient uptake of vegetable crops. *Journal of the Science of Food and Agriculture*, *95*(8), 1706-1715.

Datir, R. B., Apparao, B. J., & Laware, S. L. (2012). Application of amino acid chelated micronutrients for enhancing growth and productivity in chili (Capsicum annum L.). *Plant Sci. Feed*, *2*(7), 100-105.

Dehnavard, S., Souri, M. K., & Mardanlu, S. (2017). Tomato growth responses to foliar application of ammonium sulfate in hydroponic culture. *Journal of Plant Nutrition*, *40*(3), 315-323.

Denre, M., Ghanti, S., & Sarkar, K. (2014). Effect of humic acid application on accumulation of mineral nutrition and pungency in garlic (Allium sativum L.). *International Journal of Biotechnology and Molecular Biology Research*, *5*(2), 7-12.

Drobek, M., Frąc, M., & Cybulska, J. (2019). Plant biostimulants: Importance of the quality and yield of horticultural crops and the improvement of plant tolerance to abiotic stress—A review. *Agronomy*, *9*(6), 335.

Dudaš, S., Šola, I., Sladonja, B., Erhatić, R., Ban, D., & Poljuha, D. (2016). The effect of biostimulant and fertilizer on "low input" lettuce production. *Acta Botanica Croatica*, *75*(2), 253-259.

El-Desouky, S. A., Ismaeil, F. H., Wanas, A. L., Fathy, E. S. L., Abd El-All, M. M., & Abd, M. M. (2011). Effect of yeast extract, amino acids and citric acid on physioanatomical aspects and productivity of tomato plants grown in the late summer season. *Minufiya J. Agric. Res*, *36*(4), 859-884.

El-Shabasi, M. S., Mohamed, S. M., & Mahfouz, S. A. (2005, March). Effect of foliar spray with amino acids on growth, yield, and chemical composition of garlic plants. In *The 6th Arabian Conf. for Hort. Ismailia, Egypt*.

Fahimi, F., Souri, M. K., & Yaghobi, F. (2016). Growth and development of greenhouse cucumber under foliar application of Biomin and Humifolin fertilizers in comparison to their soil application and NPK. *Journal of Science and Technology of Greenhouse Culture*, *7*(25).

Fan, D., Hodges, D. M., Zhang, J., Kirby, C. W., Ji, X., Locke, S. J., ... & Prithiviraj, B. (2011). Commercial extract of the brown seaweed Ascophyllum nodosum enhances phenolic antioxidant content of spinach (Spinacia oleracea L.) which protects Caenorhabditis elegans against oxidative and thermal stress. *Food Chemistry*, *124*(1), 195-202.

Fernández, V., & Ebert, G. (2005). Foliar iron fertilization: a critical review. *Journal of plant nutrition*, *28*(12), 2113-2124.

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. *Spanish Journal of Agricultural Research*, *9*(3), 852-861.

Ghasemi, S., Khoshgoftarmanesh, A. H., Afyuni, M., & Hadadzadeh, H. (2013). The effectiveness of foliar applications of synthesized zinc-amino acid chelates in comparison with zinc sulfate to increase yield and grain nutritional quality of wheat. *European journal of agronomy*, *45*, 68-74.

Ghoname, A., El-Bassiouny, A. M., Abdel-Mawgoud, A. M. R., El-Tohamy, W. A., & Gruda, N. (2012). Growth, Yield and Blossom-End Rot Incidence in Bell Pepper as Affected by Phosphorus Level and Amino Acid Applications. *gesunde Pflanzen*, *64*(1).

Goñi, O., Quille, P., & O'Connell, S. (2018). Ascophyllum nodosum extract biostimulants and their role in enhancing tolerance to drought stress in tomato plants. *Plant Physiology and Biochemistry*, *126*, 63-73.

González-González, M. F., Ocampo-Alvarez, H., Santacruz-Ruvalcaba, F., Sánchez-Hernández, C. V., Casarrubias-Castillo, K., Becerril-Espinosa, A., ... & Hernández-Herrera, R. M. (2020). Physiological, ecological, and biochemical implications in tomato plants of two plant biostimulants: Arbuscular mycorrhizal fungi and seaweed extract. *Frontiers in plant science*, *11*, 999.

Jones, D. L. (1999). Amino acid biodegradation and its potential effects on organic nitrogen capture by plants. *Soil biology and biochemistry*, *31*(4), 613-622.

Kałużewicz, A., Gąsecka, M., & Spiżewski, T. (2017). Influence of biostimulants on phenolic content in broccoli heads directly after harvest and after storage. *Folia Horticulturae*, *29*(2), 221.

Ko, M. T., Ahn, T. I., Cho, Y. Y., & Son, J. E. (2013). Uptake of nutrients and water by paprika (Capsicum annuum L.) as affected by renewal period of recycled nutrient solution in closed soilless culture. *Horticulture, Environment, and Biotechnology*, *54*, 412-421.

Koleška, I., Hasanagić, D., Todorović, V., Murtić, S., Klokić, I., Parađiković, N., & Kukavica, B. (2017). Biostimulant prevents yield loss and reduces oxidative damage in tomato plants grown on reduced NPK nutrition. *Journal of Plant Interactions*, *12*(1), 209-218.

Litskas, V., Chrysargyris, A., Stavrinides, M., & Tzortzakis, N. (2019). Water-energy-food nexus: A case study on medicinal and aromatic plants. *Journal of cleaner production*, *233*, 1334-1343.

Lucini, L., Colla, G., Moreno, M. B. M., Bernardo, L., Cardarelli, M., Terzi, V., ... & Rouphael, Y. (2019). Inoculation of Rhizoglomus irregulare or Trichoderma atroviride differentially modulates metabolite profiling of wheat root exudates. *Phytochemistry*, *157*, 158-167.

Machado, F. L. D. C., Alves, R. E., & Figueiredo, R. W. (2008). Application of 1-methylcyclopropene, calcium chloride and calcium amino acid chelate on fresh-cut cantaloupe muskmelon. *Pesquisa Agropecuaria Brasileira*, *43*, 569-574.

Marschner, H. (Ed.). (2011). *Marschner's mineral nutrition of higher plants*. Academic press.

O. Elansary, H., Mahmoud, E. A., El-Ansary, D. O., & Mattar, M. A. (2019). Effects of water stress and modern biostimulants on growth and quality characteristics of mint. *Agronomy*, *10*(1), 6.

Pereira, C., Dias, M. I., Petropoulos, S. A., Plexida, S., Chrysargyris, A., Tzortzakis, N., ... & CFR Ferreira, I. (2019). The effects of biostimulants, biofertilizers and water-stress on nutritional value and chemical composition of two spinach genotypes (Spinacia oleracea L.). *Molecules*, *24*(24), 4494.

Petropoulos, S.A., Fernandes, Â., Plexida, S., Chrysargyris, A., Tzortzakis, N., Barreira, J.C.M., Barros, L.& Ferreira, I.C. (2020). Biostimulants application alleviates water stress effects on yield and chemical composition of greenhouse green bean (Phaseolus vulgaris L.). Agronomy, 10(2), 181. Souri, M. K., & Bakhtiarizade, M. (2019). Biostimulation effects of rosemary essential oil on growth and nutrient uptake of tomato seedlings. *Scientia Horticulturae*, *243*, 472-476.

Przygocka-Cyna, K., & Grzebisz, W. (2018). Effect of biofertilizers on nutrient uptake by vegetables grown in a short cropping sequence. *Journal of Elementology*, *23*(3).

Rady, M. M., & Mohamed, G. F. (2015). Modulation of salt stress effects on the growth, physio-chemical attributes and yields of Phaseolus vulgaris L. plants by the combined application of salicylic acid and Moringa oleifera leaf extract. *Scientia Horticulturae*, *193*, 105-113.

Rose, M. T., Patti, A. F., Little, K. R., Brown, A. L., Jackson, W. R., & Cavagnaro, T. R. (2014). A meta-analysis and review of plant-growth response to humic substances: practical implications for agriculture. *Advances in agronomy*, *124*, 37-89.

Rouphael, Y., & Colla, G. (2020). Biostimulants in agriculture. *Frontiers in plant science*, *11*, 40.

Rouphael, Y., Cardarelli, M., Bonini, P., & Colla, G. (2017). Synergistic action of a microbial-based biostimulant and a plant derived-protein hydrolysate enhances lettuce tolerance to

alkalinity and salinity. *Frontiers in Plant Science*, *8*, 131.

Souri, M. K. (2015). Chelates and aminochelates, and their role in plant nutrition. Agriculture Education and Extension Press, Tehran, Iran, 172.

Souri, M. K. (2016). Aminochelate fertilizers: the new approach to the old problem; a review. *Open Agriculture*, *1*(1), 118-123.

Souri, M. K., & Bakhtiarizade, M. (2019). Biostimulation effects of rosemary essential oil on growth and nutrient uptake of tomato seedlings. *Scientia Horticulturae*, *243*, 472-476.

Souri, M. K., & Römheld, V. (2009). Split daily applications of ammonium cannot ameliorate ammonium toxicity in tomato plants. *Horticulture Environment and Biotechnology*, *50*(5), 384-391.

Souri, M. K., Neumann, G., & Römheld, V. (2009). Nitrogen forms and water consumption in tomato plants. *Horticulture Environment and Biotechnology*, *50*(5), 377-383.

Thakur, P. S., & Rai, V. K. (1982). Dynamics of amino acid accumulation of two differentially drought resistant Zea mays cultivars in response to osmotic stress. *Environmental and Experimental Botany*, *22*(2), 221-226.

Zanin, L., Tomasi, N., Cesco, S., Varanini, Z., & Pinton, R. (2019). Humic substances contribute to plant iron nutrition acting as chelators and biostimulants. *Frontiers in Plant Science*, *10*, 675.