Amino Acids and its Role in Plant Nutrition and Crop Production. A review

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ABSTRACT
The importance of important amino acids in increasing crop yield and overall quality is well understood. Amino acid helps in auxin synthesis stimulant for plant growth, stimulates photosynthesis and plays an important role in the early maturity, resistance the stress conditions such as heat, cold, drought and salinity. Also increasing the growth, yield and proper ripening of fruits. In addition, increases the speed of biological processes within the plant, and disease resistance. Amino acids have been shown in studies to affect the physiological processes of plants, either directly or indirectly. Amino acid foliar nutrition improved grain wheat yield by 0.24-0.43 t ha\(^{-1}\) and grain protein content by 0.63-0.74 percentage points. In addition, grain wet gluten value by 5.5 \% and sedimentation volume increased by 11.3 \%. However, tomato yield increased by 27\%, fruit setting by 28\%, plant height 41\%, leaf area 24\% and total chlorophyll content by 44\% due to amino acid foliar feeding, the same trend was observed on pepper yield which reached to 76\% increment. Foliar application with tryptophan increased orange fruits yields by 30\%, number of fruits 3\%, fruit weight 50\% and fruit size 46\%. Drought, salinity, chilling, freezing, and high temperatures are all common adverse growth conditions for plants. These stresses can stall growth and development, lowering productivity. Plants receive amino acids relevant to stress physiology when amino acids are applied before, during, and after stress conditions, which has a preventing and recovering effect.

Keywords: Amino acids, stress conditions, plant nutrition, crop production.

Introduction
Agricultural production requires a lot of labor and is correlated with higher quality and yield, which contributes to higher profitability. However, no integrated and balanced fertilizer programs are available to achieve this goal with further technological growth. Now is the time to look at the biochemical aspects of plants in order to meet the goals of growers.

It is known that there are two types of amino acids: L- and D-amino acids. These plant-made proteins contain only L-amino acids, which have a low metabolic activity. The need for amino acids as important traits in a plant is a well-known way to boost yield and overall quality. According to Bradley, the first amino acid chelate fertilizers were developed by American chemists to increase plant nutrient supply. (Bradley, 2010).

Amino acids are important components of protein synthesis and have been shown to affect plant physiological processes directly or indirectly in studies. Plants contain around 20 important amino acids that are involved in various processes and functions. Amino acids are well-known biostimulants that encourage plant and crop growth and significantly reduce abiotic stress-related injuries (Kowalczyk & Zielony 2008). Saeed et al., (2005) discovered that plants treated with amino acids increased soybean growth parameters such as fresh and dry weight as well as pod yield. LIU Xing-quan et al., (2008) found that leaf use with the amino acid mixture from radish plants increased the nitrogen content in the buds, while the NO\(_3\) content decreased by 24-38\%, which improved its health quality. El-Zohiri & Asfour (2009) found that spraying amino acids significantly increased the vegetative growth of potatoes.
in terms of plant height and dry weight of plants. According to Abo Sedera et al. (2010) spraying strawberry plants with amino acids resulted in a significant increase in total nitrogen, phosphorus, and potassium in the leaves, as well as total yield, TSS, vitamin C, and total sugar content of the fruits, when compared to the control method. According to Julia and Claudia (2012) plants are regularly exposed to unfavorable growth conditions such as drought, salinity, cold, freezing, and high temperatures. These pressures may cause plant growth and development to be slowed, productivity to be reduced, and, in extreme cases, plant death. As a consequence, adding amino acids before, during, and after stressful conditions provides plants with amino acids that have a direct effect on preventing and recovering from the negative physiological effects of stress.

This review article focuses on elucidating the amino acids, their role and uses in plant nutrition.

**Definition and molecular structure of amino acids**

Amino acids are biologically essential organic compounds made up of the functional groups amine (-NH₂) and carboxylic acid (-COOH) as well as a side chain unique to each amino acid. Carbon, hydrogen, oxygen, and nitrogen are the four principal elements of an amino acid Fig.1.

![Molecular structure of amino acids](image)

**Fig.1:** Molecular structure of amino acids.

It is estimated that approximately 500 amino acids can be categorized in various ways. According to the positions of the functional groups, they can be categorized as alpha- (α-), beta- (β-), gamma- (γ-), or delta- (δ-). Other categories include polarity, acid/base/neutrality, and side chain group sort (including: aliphatic, cyclic, hydroxyl or sulfur containing, aromatic).

Nitrogen is initially consumed in plants as an organic compound in the form of glutamate, which consists of alpha-ketoglutarate and ammonia in the mitochondria. The plant uses transaminases to move the amino group to another alpha-keto-carboxylic acid in order to produce other amino acids. Amino transferase aspartate, for example, transforms glutamate and oxalo acetate to alpha-ketoglutarate and aspartate.

**Classification of Amino Acids**

While there are various classification schemes for amino acids, these molecules can be classified into six major groups based on their structure and the general chemical properties of their R groups. Table 1.

**Functions of amino acids**

It is well known that all amino acids do not have the same importance in the plants & that they are required in different quantities. For example, Lysine, Tryptophan & Methionine are needed in an extremely low concentration. Glutamic acid Aspartic acid by transmutation gives rise to the rest of the
amino acids. The most amino acids found in plants are Glycine, Proline & Arginine. Nevertheless, they are all essential & interdependent in such a way that the excess or absence of one of them block the synthesis of other. Table 2 shows the functions of amino acids in plant.

**Table 1: Classification of amino acids.**

| Class                              | Name of the amino acids |
|------------------------------------|-------------------------|
| Aliphatic                          | Glycine, Alanine, Valine, Lucien, Isoleucine: |
| Hydroxyl or Sulfur-containing      | Serine, Cysteine, Threonine, Methionine |
| Cyclic                             | Proline |
| Aromatic                           | Phenylalanine, Tyrosine, Tryptophan |
| Basic                              | Histidine, Lysine, Arginine |
| Acidic and their Amide             | Aspartate, Glutamate, Asparagine, Glutamine |

Source: Tymoczko, John L. (2012)

**Table 2: Functions of amino acids in plant.**

| No. | Amino acid          | Role in plant                                                      |
|-----|---------------------|-------------------------------------------------------------------|
| 1   | Glycine             | Stimulate photosynthesis and raise its efficiency and stress tolerance |
| 2   | Alanine             | Affect the speed of growth positively                              |
| 3   | Valine              |                                                                   |
| 4   | Methionine          | Accelerates fruit ripening because it enters in the life cycle of ethylene |
| 5   | Isoleucine          |                                                                   |
| 6   | Lucien              | Increased vegetative growth and early maturity                     |
| 7   | Lysine              |                                                                   |
| 8   | Glutamic            |                                                                   |
| 9   | Hydroxy Lysine      | An increase in the growth, yield, early maturity and helps in proper ripening of fruits |
| 10  | Histidine           |                                                                   |
| 11  | Serine              | Increases the potential of strength plants to disease resistance   |
| 12  | Ceonine             |                                                                   |
| 13  | Threonine           |                                                                   |
| 14  | Cysteine            | Increases the speed of biological processes within the plant and disease resistance |
| 15  | Aspartic            | Disease resistance in general                                      |
| 16  | Arginine            | Resistance difficult conditions such as heat, cold, drought and salinity |
| 17  | Proline             |                                                                   |
| 18  | Hydroxyproline      |                                                                   |
| 19  | Phenylalanine.      | Improve plant cells                                                |
| 20  | Tryptophan          | Helps to auxin synthesis stimulant for plant growth and plays an important role in the early maturity |
| 21  | Selenocysteine      | Rare amino acids that are cotranslationally inserted into proteins |
| 22  | Pyrrolysine         |                                                                   |

Source: Arun K. Sharma (2009)

**Chelating process of amino acids**

Amino acid chelate fertilizers are made by chelating (i.e., binding) a nutritional element required by a plant (e.g., calcium) with one or more amino acids to create a new molecule that is readily absorbed by plants and efficiently delivers the nutrient, according to Bradley (Bradley, 2010). There are twenty-two amino acids found in nature, each with its own structure made up of nitrogen, oxygen, carbon, and hydrogen. They're the basic "building blocks" of proteins, and they're present in all living things. The simplest amino acid, glycine, is shown in Figure 2. As shown in Fig. 3, an atom of magnesium has been chelated with two molecules of Glycine.

Chemical bonds are represented by the red lines, which form two "ring" structures, with magnesium in the centre. The fact that the magnesium atom is bound together by four chemical bonds is one of the keys to the success of amino acid chelates. They form two ionic (electrically charged) bonds since the magnesium ion has two positive charges and each glycine molecule has a negative charge. The nitrogen atom of each amino acid, on the other side, exchanges two electrons with the magnesium to form two new covalent bonds. These four bonds chelate the magnesium and tie it more closely than two ionic bonds alone, allowing it to pass through many physical and chemical barriers.
inside a plant before reaching the cell interior, where it is needed. Salts or clusters are used instead of chelates where only two ionic bonds are involved. Figures 3 and 4 show magnesium chelated with two amino acid molecules, but any number of amino acid molecules from one to four can be used (at least 1 is required to be called an amino acid chelate). A convenient graphic representation of amino acid chelates is shown in Figure 4.

Fertilizers containing amino acids

Fertilizers containing amino acids differ from each other depending on the content of the ratio of free amino acids, macro and micronutrients as well as the content of organic substances, vitamins and seaweed extracts and can be divided as follows:

| Kind of Fertilizers                                      | Example                                                                 |
|----------------------------------------------------------|-------------------------------------------------------------------------|
| Free amino acids                                         | Glycine, Alanine, Proline, Tryptophan Hydroxyproline, Aspartic….etc.   |
| Amino acids + macronutrients                             | Pepton 85/16, Aminocat, Aminocal Star, Amino-green, Biomax….etc.       |
| Amino acids + micronutrients                             | Microcat Iron, Microcat Zinc, Amino power…. etc.                       |
| Amino acids + micronutrients + macronutrients            | Calmag Amino+ TE (F5) 8/8/8 AMINO +TE, Hi K Amino + TE, Florone. Amino Mix, Razormin…… etc. |
| Amino acids + macronutrients+ micronutrients + Seaweed extract | Razormare…… etc.                                                     |
| Amino acids +macronutrients+ micronutrients + Vitamins   | Amino Vit Plus, Amino Vit 2, etc.                                       |
Applying amino acid chelate fertilizers to foliage

Fertilizers should be applied to the foliage rather than the soil because plants absorb them very quickly through the leaves. Foliar fertilizers, on the other hand, must be of a form that can deliver nutrients with a high degree of efficiency and a low risk of phytotoxicity in order to be useful. The first obstacle that a foliar fertilizer could overcome is solubility (Fig. 5). Water solubility is required for any foliar fertilizer. Plant nutrition chelates of today are water-based and fully soluble. The leaf's cuticle, a waxy layer made up of fatty acids, is the next barrier to overcome. Both foliar fertilizers must move through the cuticle, which can be seen on both the upper and lower surfaces of the stems, as well as within the stomatal crypts (cavities). Electrical neutrality is the most important property of a nutrient molecule in this context. Since fatty acids have a negative electrical charge, they attract species that have a positive charge (Bradley, 2010).

![Fig. 5: Traditional mineral fertilizer applied to leaves. Source: (Bradley, 2010)](image)

Amino acid chelates, on the other hand, do not disassemble: the molecule stays intact and electrically neutral, allowing it to move along with minimal interference. This is seen in Figures 6 and 7. Since the chelate molecule does not break up and become charged, there is no risk of phytotoxicity.

![Fig. 6: Amino acid chelates applied to leaves. Source: (Bradley, 2010)](image)

The amino acid chelate must penetrate a complex ecosystem of cells and intercellular spaces after passing through the cuticle. The value of molecular size here cannot be overstated. In general, the smaller the molecule, the easier it is to diffuse through this atmosphere and penetrate the leaf. Glycine is used as a chelating agent in modern plant nutrition since it is the lightest amino acid and penetrates the leaf quickly. According to studies, the amino acid chelate has penetrated the leaf essentially completely within 2-3 hours of application.
The amino acid chelate may be absorbed and used by cells in the soil after diffusing through the leaf, or it may join the phloem: a vascular channel used by plants to transfer photosynthates and other high value materials to areas of the plant most in need: typically, fast growing regions such as new leaves, seeds, fruit, and so on. When the amino acid chelate enters the phloem, the nitrogen component of the amino acid is detected, the molecule is considered useful by the plant, and it is transported across the phloem to the plant's quickly expanding areas where it is most needed. As a result, amino acid chelates are highly mobile in plants and are transferred to the locations where they are most needed figure 7.

![Diagram of Penetration of Amino Acid Chelates Through Leaf and Phloem](image)

**Fig. 7:** Penetration of amino acid chelates through leaf and phloem. Source: (Bradley, 2010)

The mobility of amino acid chelates in plants is a huge benefit when it comes to adding those elements. Calcium, for example, is plentiful in soils, but calcium is contained in leaves in a state that is highly mobile, resulting in deficiency in quickly developing tissues (even despite leaf analysis indicating sufficient calcium).

The calcium ion (Ca++) is not transported into the phloem, which contributes to this. The phloem, on the other hand, transports calcium chelated with amino acids to the tissues that need it. Before a mineral can be used inside a cell, it must be able to overcome external barriers. The cell wall must first be torn down.

Plant cell walls are made up of complex fibrous structures and binding substances. Nutritional elements that are charged (ionic) displace calcium in the cell wall, causing it to become bound and inaccessible (Fig.8).

Since amino acid chelates are small and electrically neutral, they move through the cell wall with little resistance.

The mineral must travel through the cell membrane after penetrating the cell wall before entering the cell's interior. Cell membranes are bilayers of lipid (fat) that contain complex protein complexes, some of which transport nutrients into cells.

Some of these transport mechanisms recognize amino acid chelates as a supply of valuable organic nitrogen and transport them quickly into the cell.

Synthetic chelating agents, such as EDTA, are not accepted by these transport pathways and may not be transported to the cell's interior (Fig. 9).

Instead, EDTA must "swap" the nutrient for a calcium ion, which depletes calcium and can cause phytotoxicity, as seen in figure 9. When within the plant cell, enzymes break down the chelate, freeing the mineral for use.
Amino acids effects on crops

Exogenous amino acid application has been documented to modulate crop growth, yield, and biochemical quality by directly or indirectly influencing physiological activities in plant growth and development (El-Shabasi et al., 2005; Abd El-Aal et al., 2010; Shiraishi et al., 2010).

Effects of amino acids on wheat

Dromantiene et al., (2009) investigated the effects of amino acid-containing fertilizers on winter wheat grain yield and technical properties. Girdling increased grain yield by 0.24-0.43 t ha⁻¹, according to their findings (Fig. 10). Amino acids have also been shown to increase the consistency of winter wheat yields. Under the effect of amino acids, grain protein content increased by 0.63-0.74 percentage points Fig. 11.
Fig. 10: The relationship between winter wheat grain yield (y, t ha\(^{-1}\)) and amino acids concentrations in fertilizer (%) applied at winter wheat booting, heading and milk maturity stages. Source: (Dromantiene et al., 2009).

In addition, wheat grain wet gluten value and sedimentation volume was increased by 5.5 % and 11.3 %, respectively Tables 3 & 4.

Table 3: The effect of liquid amide nitrogen fertilizers containing amino acids on winter wheat grain wet gluten value.

| Concentration of amino acids (factor A) | Fertilization timing (factor B) | Average of factor A |
|----------------------------------------|--------------------------------|--------------------|
|                                        | Booting stage BBCH 32-35 | Heading stage BBCH 51-56 | Milk maturity stage BBCH 71-75 |
| Control (without amino acids)           | 28.3                        | 29.6                | 29.1                        | 29.0                        |
| Amino acids 0.5%                        | 30.2                        | 31.3                | 30.3                        | 30.6                        |
| Amino acids 1.0%                        | 30.1                        | 31.3                | 29.9                        | 30.4                        |
| Amino acids 1.5 %                       | 30.4                        | 30.7                | 29.8                        | 30.3                        |
| Amino acids 2.0%                        | 30.6                        | 30.7                | 30.4                        | 30.6                        |
| Amino acids 2.5%                        | 30.6                        | 30.5                | 30.4                        | 30.5                        |
| Amino acids 3.0 %                       | 30.8                        | 30.1                | 30.1                        | 30.3                        |
| Average of factor B                     | 30.1                        | 30.6                | 30.0                        | -                            |

LSD\(_{0.05}\) A = 0.63; LSD\(_{0.05}\) B= 0.41; LSD\(_{0.05}\) AXB= 1.09. Source: (Dromantiene et al., 2009)

Fig. 11: The relationship between winter wheat grain protein content (y, t ha\(^{-1}\)) and amino acids concentrations in fertilizer (%) applied at winter wheat booting, heading and milk maturity stages. Source: (Dromantiene et al., 2009)
Table 4: The effect of liquid amide nitrogen fertilizers containing amino acids on grain sedimentation volume.

| Concentration of amino acids % (factor A) | Fertilization timing (factor B) | Average of factor A |
|-----------------------------------------|---------------------------------|---------------------|
|                                         | Booting stage (BBCH 32-35)      |                     |
|                                         | Heading stage (BBCH 51-56)      |                     |
|                                         | Milk maturity stage (BBCH 71-75)|                     |
| Control (without amino acids)           | 39                              | 42                  |
| Amino acids 0.5%                        | 42                              | 45                  |
| Amino acids 1.0%                        | 43                              | 45                  |
| Amino acids 1.5%                        | 45                              | 45                  |
| Amino acids 2.0%                        | 45                              | 45                  |
| Amino acids 2.5%                        | 46                              | 45                  |
| Amino acids 3.0%                        | 44                              | 45                  |
| Average of factor B                     | 43                              | 45                  |

LSD<sub>0.05</sub> A = 1.15; LSD<sub>0.05</sub> B= 0.75; LSD<sub>0.05</sub> AxB= 1.99

Source: (Dromantiene et al., 2009)

Effects of amino acids on some vegetable’s crops

Tomato

Tantawy et al., (2009) discovered that all growth parameters, including plant height, leaf area, and total chlorophyll, as well as tomato yield and fruit environment, reacted significantly to an increase in amino acid levels Table 5, with the highest values obtained at a rate of 3 gm/L from amino acids.

Table 5: Effect of levels amino acids on plant height, leaf area and total chlorophyll at 70 days after transplanting and fruit setting and total yield of tomato plants.

| Treatments                     | Plant height (cm) | Leaf area (cm²) | Total Chlorophyll Content (SPAD unit) | Fruit setting (%) | Total yield (g)/Plant |
|--------------------------------|------------------|----------------|--------------------------------------|-------------------|----------------------|
| Amino Acids (0 gm/L)           | 41.58            | 68.56          | 44.45                                | 63.6              | 520.11               |
| Amino Acids (2 gm/L)           | 53.11            | 79.55          | 61.23                                | 72.38             | 643.34               |
| Amino Acids (3 gm/L)           | 58.45            | 85.21          | 64.16                                | 81.07             | 662.77               |
| LSD 5%                         | 1.21             | 5.26           | 2.18                                 | 4.98              | 12.65                |

Source: (Tantawy et al., 2009)

Pepper

Sarojnee et al., (2009) investigated the effects of two synthetic forms of naturally occurring amino acid stimulants (Perfectos Powder and Perfectos Liquid) on hot pepper plants at two doses. When Perfectos TM Powder was added at 0.45g and 0.27g/plant in the first and second fertilizer dressings, respectively, plant height, canopy width, number of branches, shoot dry matter, fruit weight, fruit diameter, percent fruit dry matter content, ascorbic acid content, and marketable yield all improved dramatically. At 27 and 40 days after transplanting, shot dry matter obtained in the Perfectos Powder (0.45g/plant) treatment was 54.9 and 54.1 percent higher than in the untreated control treatment, respectively.

Plants treated with Perfectos Powder (0.45g/plant) yielded a marketable yield of 16.5 t/ha, which was 75.9% higher than untreated control plants. In contrast to plants that were not processed, Plant height, canopy width, number of branches, shoot dry matter, fruit weight, fruit diameter, percent fruit dry matter content and ascorbic acid content all improved dramatically when Perfectos TM Liquid (1.6 mL/L) was used.

Broccoli

Shekari & Javanmardi (2017) indicated that foliar application of amino acid, at suitable concentrations, had positive effects on the physical and chemical properties of the Broccoli transplants.

Potato

Khaled et al., (2020) spraying plants with amino acids at a rate of 1000 ppm led to a significant increase in plant growth and tubers yield and improve their quality, as well as improve the nutrient balance in potato tuber.
Bean

Sadak et al., (2015) discovered that applying amino acids as a foliar spray greatly enhanced all of the reduced parameters caused by seawater stress. However, the highest amount of amino acid, 1500 mg L⁻¹, had the greatest effect in reducing the negative effects of seawater salinity tension.

Effects of amino acids on some fruit’s crops

Citrus

Citrus crops have a great importance either for the local market or export needs, where it is considered a source of the national income. So, improving citrus yield and fruit quality are concerned in many investigations. A lot of research done in Egypt has been carried out to improve the yield and fruit quality of citrus through selecting the best agricultural treatments, i.e., fertilization (foliar application with amino acids).

Hanafy et al., (2012) found that, foliar application with tryptophan improved growth characters (shoot length, shoot diameter, leaves number, and leaves area), yield and fruit quality of Valencia orange. Data in Tables 6 & 7 showed that, the increases of most of the studied characters were detected with increasing tryptophan foliar application rate, with some exceptions especially at the highest level of tryptophan (100 ppm) in which low values were obtained.

Furthermore, the results revealed that, significantly increases on most of the studied growth characters were obtained by the tree treated with any of the three different rates of tryptophan when compared with control.

Table 6: Effect of tryptophan on growth characters of Valencia orange trees

| Treatments     | Shoot length (cm) | Shoot Diameter (cm) | Leaves number/ shoot | Average leaf area (cm²)/shoot |
|----------------|-------------------|---------------------|----------------------|------------------------------|
| Control        | 7.00              | 0.17                | 5.60                 | 10.30                        |
| Tryptophan (25 ppm) | 8.45              | 0.17                | 5.60                 | 10.88                        |
| Tryptophan (50 ppm) | 8.65              | 0.19                | 6.23                 | 11.46                        |
| Tryptophan (100 ppm) | 8.30              | 0.20                | 7.10                 | 11.42                        |
| L.S.D (0.05)   | 1.128             | 0.003               | N. S                 | 1.218                        |

Source: Hanafy et al., (2012)

Table 7: Effect of tryptophan on yield and fruit quality of Valencia orange trees

| Treatments     | Tree yield (kg) | Number of fruits/trees | Fruit weight (g) | Fruit size (cm³) | Total sugars (mg/g f.w.) |
|----------------|-----------------|------------------------|------------------|------------------|--------------------------|
| Control        | 38.84           | 290.00                 | 120.12           | 122.33           | 2.800                    |
| Tryptophan (25 ppm) | 42.91           | 285.00                 | 150.67           | 153.12           | 3.920                    |
| Tryptophan (50 ppm) | 50.47           | 280.00                 | 180.33           | 178.33           | 4.110                    |
| Tryptophan (100 ppm) | 3.72            | 300.00                 | 139.45           | 139.51           | 4.320                    |
| L.S.D (0.05)   | 41.84           | 14.93                  | 12.00            | 6.60             | 1.06                     |

Source: Hanafy et al., (2012)

Grape

Abdel Aziz et al., (2017) and Mohamed (2017) showed that using amino acids were very effective in advancing grapes quality in different grape cvs.

El-Sese et al., (2020) found that, all the amino acid treatments tested on grapes significantly exceeded the yield/vine control with no major variations between them under salinity stress. Tyrosine at 500 ppm reported during the 1st season (9.47 kg/vine) was the most successful treatment in this regard. During the 2nd season, suggested that amino acid mixture, Glycin, Lysin and Tyrosine demonstrated the highest values. Glycin which recorded the highest values during the 3rd season.

Role of amino acids in tolerance of abiotic stresses

In their natural world, plants are subjected to a range of biotic and abiotic stresses. Abiotic and biotic stress can reduce average productivity by up to 75%. Abiotic stress conditions have a major impact on agricultural production around the world.
Abiotic factors influencing crop production include salinity, drought, submergence, and temperature extremes, including high and low temperatures.

In this regard, it has been projected that in order to meet the needs of an increasing population, plant productivity in developed countries must be increased by at least 20% and in developing countries by 60%.

Environmental stress can cause cellular structures to be disrupted and key physiological functions to be impaired (Larcher, 2003). The application of amino acids before, during, and after stress conditions provides amino acids related to stress physiology to the plants, which has a preventing and recovering effect. Accumulation of amino acids has been observed in many studies on plants exposed to abiotic stress (Kaplan et al., 2004; Brosche et al., 2005; Zuther et al., 2007; Kempa et al., 2008; Sanchez et al., 2008; Usadel et al., 2008; Lugan et al., 2010). This rise may be due to increased amino acid synthesis or stress-induced protein breakdown. Although overall amino acid accumulation during stress can suggest cell damage in some species (Widodo et al., 2009), increased levels of specific amino acids have a beneficial effect during stress adaptation.

Role of amino acids in tolerance of salinity stress

Under saline conditions, amino acids increased plant growth and development. Amino acids, according to Neeraja et al., (2005), increased the number of flowers, fruit environment, and fruit yield of tomato plants.

Tantawy et al., (2009) demonstrated that all tomato growth parameters, including plant height, leaf area, yield, and some yield quality parameters, decreased as salinity increased Table 8. The application of amino acids, on the other hand, mitigates this effect, and the greatest effect was found with the application of the highest concentration of amino acids. The beneficial effects of amino acid application may be due to its cell-internal role as an osmo-regulatory agent and increasing protein content in the plant (Subotic et al., 2009), as it is very soluble in water and thus increases the concentration of cellular osmotic components.

Table 8: Effect of salinity levels, amino acids on plant height, leaf area and total chlorophyll at 70 days after transplanting, fruit setting and total yield of tomato.

| Salinity (ppm) | Amino acids(gm/L) | Plant height (cm) | Leaf Area (cm²) | Total Chlorophyll Content (SPAD unit) | Fruit setting(%) | Total yield (gm)/Plant |
|---------------|-------------------|-------------------|-----------------|--------------------------------------|-----------------|------------------------|
| 3000          | 0                 | 40.41             | 71.20           | 45.45                                | 65.09           | 534.64                 |
|               | 2                 | 54.22             | 81.45           | 60.33                                | 73.18           | 653.47                 |
|               | 3                 | 57.47             | 86.12           | 65.64                                | 80.58           | 671.69                 |
| 4000          | 0                 | 34.77             | 61.08           | 40.16                                | 56.35           | 471.50                 |
|               | 2                 | 50.49             | 74.41           | 53.14                                | 67.37           | 531.47                 |
|               | 3                 | 54.60             | 76.36           | 56.42                                | 71.41           | 561.35                 |
| 5000          | 0                 | 30.37             | 54.21           | 35.34                                | 49.32           | 404.65                 |
|               | 2                 | 47.39             | 69.96           | 48.97                                | 62.00           | 479.66                 |
|               | 3                 | 50.30             | 73.14           | 50.23                                | 66.47           | 491.71                 |
| LSD 5%        |                   | 1.64              | 6.94            | 2.64                                 | 6.68            | 12.47                  |

Source: Tantawy et al., (2009)

Role of amino acids in tolerance of drought stress

Water is becoming scarce not only in arid and drought-prone areas, but also in areas with abundant rainfall (Pereira et al., 2002). Many researchers have extensively published on the reduction of wheat grain yield and its components under water stress. (Gupta et al., 2001; Hassan, 2003; Shantha & Jagadish, 2002; Kokhmetova et al., 2003). Many plant species accumulate proline in response to various environmental stresses, including drought. Also, (Yousef Alaei, 2011) used 11 wheat genotypes to evaluate the impact of amino acids on leaf chlorophyll content in bread wheat genotypes under drought stress conditions at the germination point. The findings indicated that using aminoforth solution in irrigation conditions would help increase yield and resistance to drought stress. Sankar et al., (2007) investigated the impact of water scarcity on biochemical constituents and proline metabolism in five behind (Abelmoschus esculentus L.) plant varieties. They discovered that proline content and -
glutamyl kinase activity were significantly increased while proline oxidase activity was decreased. Drought stress increased the content of free amino acids and glycinebetaine.

**Role of amino acids in tolerance of temperature stress**

Wheat yields were reduced as a result of the shorter growing season caused by high temperatures (Abd El-Monem, 2007) and Mostafa et al. (2009).

Accelerated phase development, accelerated senescence, increased respiration, decreased photosynthesis, and inhibition of starch synthesis in developing kernels could all contribute to wheat yield reduction due to heat stress. Temperature variations during grain filling have been shown to allow dough properties to deviate from expectations (Hamam and Khaled, 2009).

The normal average temperature increases to 30°C or higher during anthesis, inducing pollen sterility. Furthermore, water stress caused by high temperatures as a result of climate change decreased wheat final grain yield by delaying wheat sowing dates at various plant growth stages (Ouda et al., 2005 and Mostafa et al., 2009).

Hozayn and Abd El-Monem (2010) discovered that delayed sowing reduced biological and economic yield by reducing spike length and weight, spike grain weight, spike no per square meter, and 1000-grains weight. The economic yield/fed was decreased by 10.39 and 41.22 percent, respectively, when wheat was sown on December 23rd and January 23rd. In comparison to untreated seeds, foliar applications of arginine at 2.5 and 5.0 mM on normal or delayed sowing wheat resulted in a significant improvement in yield and its components. The magnitude of the rises was even greater in reaction to 2.5 mM arginine, which induced increases in economic yield per feddan of 19.2, 20.5, and 25.5 percent at naturally, 30-, and 60-day delays, respectively. Furthermore, compared to plants sown late at 23/12, the 2.5 mM arginine treatment causes an 8.0 percent increase in grain yield, which may reduce the reduction percent in grain yield from 41.2 to 26.2 percent at the 23 Jan. sowing date. This research found that arginine, as an amino acid source, could help to offset the negative effects of climate change by allowing late wheat sowing and reducing the expected decrease in economic yield in semi-arid areas with irrigated agriculture.

**Conclusion**

The current review concludes that it is critical to use amino acids to chelate metal cations to enhance mineral absorption from supplements, which may be needed to improve plant health or development and correct mineral deficiencies. Also, application of amino acids on different crops increases the productivity and quality as well as its resources to different abiotic stress conditions cause a major loss to the agricultural productivity such as, (drought, salinity, high and low temperatures.... etc.).

**References**

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

Abdel-Aziz, F.H., M.Kh. Uwakiem, and M.M. Ebrahiem, 2017. Promoting berries coloration, yield and quality of Flame seedless grapevines by using amino acids enriched with different nutrients. Assiut J. Agric. Sci., 98(13):145-157.

Abd El-Monem, A.A., 2007. Polyamines as modulators of wheat growth, metabolism and reproductive development under high temperature stress. PhD Thesis: Ain Shamas University (Cairo, Egypt).

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

Arun, K.S., 2009. Biofertilizer for sustainable agriculture.

Bradley, K., 2010. A Description of Amino Acid Chelate Fertilizers’ and Their Mode of Action. Modern Plant Nutrition Pty Ltd., 1 -8.

Brosche, M., B. Vinocur, and E.R. Alatalo, 2005. Gene expression and metabolite profiling of Populus euphratica growing in the Negev desert. Genome Biology, 6: R101.
Dromantiene, R., I. Pranckietiene, G. Šidlauskas, and V. Pranckietis, 2009. The effect of fertilizers containing amino acids on winter wheat grain yield and technological properties. Zemdirbyste (Agriculture) 96 (4): 97-109.

El-Sese, A.M., A.K.A. Mohamed, A. Eman, A. Abou-Zaid, and A.M.M. Abd-El-Ghany, 2020. Impact of foliar application with seaweed extract, amino acids and vitamins on yield and berry quality of some Grapevine cultivar. International Journal of Agricultural Science, 2 (1): 73-84.

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

El-Zohiri, S.S.M., and Y.M. Asfour, 2009. Effect of some organic compounds on growth and productivity of some potato cultivars. Annals of Agric. Sci. Moshtohor, 47 (3): 403 -415.

Gupta, N.K., S. Gupta, and A. Kumar, 2001. Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages. J. Agron. Crop Sci., 186: 55-62.

Hamam, K.A., and A.G.A. Khaled, 2009. Stability of wheat genotypes under different Environments and their evaluation under sowing dates and nitrogen fertilizer levels. In: Australian Journal of Basic and Applied Sciences, 3(1): 206-217.

Hanafy, A.A.H., M.K. Khalil, A.M. Abd El-Rahman, and N.A.M. Hamed, 2012. Effect of zinc, tryptophan and indole acetic acid on growth, yield and chemical composition of Valencia. Orange trees. Journal of Applied Sciences Research, 8(2): 901-914.

Hassan, R.K., 2003. Effect of drought stress on yield and yield components of some wheat and triticale genotypes. Ann. Agric. Sci., 48: 117-129.

Hozayn, M., and A.A. Abd El-Monem, 2010. Alleviation of the potential impact of climate change on wheat productivity using arginine under irrigated Egyptian Agriculture Options Méditerranéennes, no. 95, 2010 -Economics of drought and drought preparedness in a climate change context.

Julia, K., and J. Claudia, 2012. Drought, salt, and temperature stress-induced metabolic rearrangements and regulatory networks. Journal of Experimental Botany 1-16.

Khaled, M., M. Abd El-Rheem, S.S. El-Sawy, Heba Y. El-Batran, and A. El-Damarawy, 2020. Effect of foliar application of K-humate and amino acid on growth, yield and nutrient balance of potato plants. Med. J. Soil Sci., 1 (1): 18-27.

Kaplan, F., J. Kopka, D.W. Haskell, W. Zhao, K.C. Schiller, N. Gatzke, D.Y. Sung, and C.L. Guy, 2004. Exploring the temperature-stress metabolite of Arabidopsis. Plant Physiology 136: 4159–4168.

Kemap, S., J. Krasensky, S. Dal Santo, J. Kopka, and C. Jonak, 2008. A central role of abscisic acid in stress-regulated carbohydrate metabolism. PLoS One 3, e3935.

Kokhmetova, A., G. Sariyeva, and S. Kenjebayeva, 2003. Yield stability and drought resistance in wheat. Acta Botanica Hungarica, 45: 153-161.

Kowalczyk, K., and T. Zielony, 2008. Effect of amino plant and Asahi on yield and quality of Lettuce grown on rockwool. Conf.of biostimulators in modern agriculture, 7-8 February 2008, Warsaw, Poland.

Larcher, W., 2003. Physiological plant ecology, 4th ed. Springer.

Liu Xing, Q., H.Y. Chen, N. Qin-xue, and L.K. Seung, 2008. Evaluation of the Role of mixed amino acids in nitrate uptake and assimilation in leafy radish by using 15n-labeled nitrate. Agricultural sciences in China, 7(10): 1196-1202.

Lugan, R., M.F. Niogret, L. Leport, J.P. Guegan, F.R. Larher, A. Savoure, J. Kopka, and A. Bouchereau, 2010. Metabolome and water homeostasis analysis of Thellungiella salugineae suggests that dehydration tolerance is a key response to osmotic stress in this halophyte. The Plant Journal, 64: 215–229.

Mohamed, M.M.E., 2017. 'Promoting the yield quantitatively and qualitatively of Flame seedless Grapevines by using some amino acid enriched with different nutrients', M.Sc. Thesis, Fac. of Agric. Minia Univ., Egypt.

Mostafa, H.A.M., R.A. Hassanein, S.I. Khalil, S.A. El-Khawas, H.M.S. El-Bassiouny, and A.A. El-Monem, 2009. Effect of arginine or putrescine on growth, yield and yield components of late sowing wheat. In: J. of Applied Sci. Res.
Neeraja, G., I.P. Reddy, and B. Gautham, 2005. Effect of growth promoters on growth and yield of tomato cv. Marutham. Journal of Research-ANGRAU., 33(3): 68-70.

Ouda, S.A., S.M. El-Marsafawy, M.A. El-Kholy, and M.S. Gaballah, 2005. Simulating the effect of water stress and different sowing dates on wheat production in South Delta. In: Journal of Applied Sciences Research, 1(3):268-276.

Pereira, L., S.T. Oweis, and A. Zairi, 2002. Irrigation management under water scarcity. Agric. Water Manage., 57: 175-206.

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

Saeed, M.R., A.M. Kheir, and A.A. Al-Sayed, 2005. Suppressive effect of some amino acids against Meloidogyne incognita on Soybeans. Agric. Sci. Mansoura Univ., 30 (2): 1097 – 1103.

Sanchez, D.H., M.R. Siahpoosh, U. Roessner, M. Udvardi, and J. Kopka, 2008. Plant metabolomics reveals conserved and divergent metabolic responses to salinity. Physiologia Plantarum, 132: 209–219.

Sankar, B., C.A. Jaleel, P. Manivannan, A. Kishorekumar, R. Somasundaram, and R. Panneerselvam, 2007. Drought-induced biochemical modifications and proline metabolism in Abelmoschus esculentus L. Acta Bot. Croat. 66(1): 43-56.

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

Shantha, N., and R. Jagadish, 2002. Relationship of simulated water stress using senescing agent with yield performance of wheat genotypes under drought stress. Ind. J. Plant Physiol., 7: 333-337.

Shekari, G., and J. Javanmardi, 2017. Effects of Foliar Application Pure Amino Acid and Amino Acid Containing Fertilizer on Broccoli (Brassica oleracea L. var. italic) Transplant. Advances in Crop. Science and Technology, 5 (3): 1-4.

Shiraishi, M., H.F. Hiroyuki, and H.H. Chijiwa, 2010. Evaluation of table grape genetic resources for sugar, organic acid, and amino acid composition of berries. Euphytica, 174: 1–13.

Subotić, A., S. Jevremović, and D. Grubišić, 2009. Influence of cytokinins on in vitro morphogenesis in root cultures of Centaurium erythraea—Valuable medicinal plant. Scientia Horticulturae, 120 (3): 386-390.

Tantawy, A.S., A.M.R. Abdel-Mawgoud, M.A. El-Nemr, and Y.G. Chamoun, 2009. Alleviation of salinity effects on tomato plants by application of amino acids and growth regulators. European Journal of Scientific Research, 30 (3): 484-494.

Tymoczko, L.J., 2012. Biochemistry. New York: W. H. Freeman and company, 28-31. ISBN 9781429229364.

Usadel, B., O.E. Blasing, Y. Gibon, F. Poree, M. Hohne, M. Gunter, R. Trethewey, B. Kamla, H. Poorter, and M. Stitt, 2008. Multilevel genomic analysis of the response of transcripts, enzyme activities and metabolites in Arabidopsis rosettes to a progressive decrease of temperature in the non-freezing range. Plant, Cell and Environment, 31: 518–547.

Widodo, P.J.H., E. Newbigin, M. Tester, A. Bacic, and U. Roessner, 2009. Metabolic responses to salt stress of barley (Hordeum vulgare L.) cultivars, Sahara and Clipper, which differ in salinity tolerance. Journal of Experimental Botany, 60: 4089–4103.

Yousef, A., 2011. The effect of amino acids on leaf chlorophyll content in bread wheat genotypes under drought stress conditions. Middle East Journal of Scientific Research, 10 (1): 99-101.

Zuther, E., K. Koehl, and J. Kopka, 2007. Comparative metabolome analysis of the salt response in breeding cultivars of rice. In: Jenks MA, Hasegawa PM, Jain SM, eds: Advances in molecular breeding toward drought and salt tolerant crops. Netherlands: Springer, 2