Role of amino acids as plant bio-stimulants (Review)

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Abstract: The world's agricultural systems require two balanced needs: 1. raising food productivity per unit area of farmland for supporting the progressive increase in people increase, and 2. improving the production system to reduce the unfavorable effect on human health and environment. To recognize such two targets, farmers and scientists present many of sustainability methods, one of them using natural components known a sbiostimulants that able to promote plant growth and development. Biostimulants defined as substances that in few quantities promote plant growth and stress recovery. There are many definitions depending on the role of these constituents. Biostimulants was classified to different categories namely; humic acid substances, complex organic substances, beneficial chemical substances, inorganic salts, sea weed extracts, derivatives of chitosan and chitin, anti-transpirants, products containing hormones, free amino acids, small peptides and other nitrogenous compounds. In this year, global market of biostimulants reached to2, 241million$, with 12.5% annual growth from 2013-2018.

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Introduction

Bio-stimulants defined as substances that in few quantities promote plant growth and stress recovery **(Zhang and Schmidt, 1999)**. Bio-stimulants are safe environmental substances that reduced the consumption of chemical fertilizers and improved plant growth **(Tejada and Gonzalez, 2004)**.

Amino acids constituted the proteins and play many important functions in plant physiology as sources of secondary plant metabolites and as nitrogen carrier between different plant parts **(Dinkeloo et al., 2017)**. Also, amino acids have many roles as biostimulants of growth, yield and stress recovery of plants (**Kowalczyk and Zielony, 2008**). The role of amino acids as bio-stimulants may be returned to their importance in biosynthesis of IAA **(Hashimoto and Yamada, 1994)**, or to their direct and indirect effects on plant growth and development (**Boras et al., 2011**). Moreover, amino acids can induce plant defense and improve plant tolerance against different environmental and oxidative stresses **(Ertani et al., 2013; Calvo et al., 2014; Bakry et al., 2016)**.

This review summarizes the role of amino acids as bio-stimulants in plant physiology and stress recovery.

Role of amino acids in plant metabolism

1. Amino acids as basic units for protein synthesis

The primary plant metabolites are protein, carbohydrate and lipid. Protein is formed from L-amino acids by conjugation of amino acids by peptide linkage.

2. Amino acids as precursors for plant hormones and other plant metabolites

Amino acids act as precursors of different types of molecules that have diverse biological functions. Amino acids are involved in the biosynthesis of a large variety of phytohormone, growth substances, secondary metabolites, i.e. lignins, flavonoids, alkaloids, terpenoids and non-protein nitrogenous materials, i.e. coenzymes, vitamins, pigments, pyrimidine and purines bases **(Ibrahim et al., 2010).** However, examples are given in the following:

Arginine is the precursor of polyamines that are produced by decarboxylation of arginine through arginine decarboxylase to form putrescine **(Bouchereau et al., 1999).** Polyamines and their precursor arginine have been implicated as stimulator for different physiological and developmental processes in higher plants **(Galston and Kaur-Sawhny, 1990)**.

Tryptophan is the precursor of growth substances i.e. indoleacetic acid and indolebutyric acid **(Marschner, 1995)**. In addition, melatonin (N-acetyl-5-methoxytryptamine; MEL) is derived from tryptophan and contains an indole ring and two side chains, namely, 5-methoxy group and 3-amide group. Recently, several number of reports have indicated that relatively high levels of tryptophan-derived compounds: indole acetic acid (IAA), serotonin (prozac) (5HT:5-hydroxytryptamine) besides melatonin, are found in different plant sources **(Dalin et al., 2008)**.

Cysteine is the primary organic compound that contains reduced sulfur synthesized by the plant

(Takahashi et al., 2011). Cysteine acts not only as amino acid in the synthesis of protein but also as a precursor for some important biochemicals. It is an abundant and ubiquitous thiol group that furnishes disulfide bridges which are essential for structure and folding of protein as well as their function and satiability **(Haag et al., 2012)**. Another role of the thiol groups of cysteine their being located at the active sites of enzymes, acting as reaction modulators **(Richau et al., 2012)**. In addition, cysteine is the source molecule for important metabolites containing sulfur that are necessary for development such as the amino acid methionine, vitamins and cofactors **(Wirtz and Droux, 2005)**. The most important product of cysteine is glutathione (GSH) which has crucial function in cell defense and protection, principal antioxidant of cell, involved in reactive oxygen species (ROS) detoxification, and protein protectant against denaturation during stress **(Noctor et al., 2012)**.

Proline is an important amino acid that plays different roles in plant. In addition, to its role in protein synthesis, it can protect plants from environmental stresses as well as singlet oxygen and free radicals **(Smirnoff and Gumbes, 1989)**. It acts as an intercellular structure (**Van-Rensburg et al., 1993)** and conserves enzymes as well as membranes **(Solomon et al., 1994)**. Moreover, it promotes the stability of some enzymes **(Nash et al., 1982)**. Accumulation of proline was also found in non-stressed condition as this amino acid provides energy for production need program of plant and plays role in flowering and development as a metabolite and a signal molecule **(Mattioli et al., 2009)**. According to **Hess (1981)**, proline and tyrosine are the starting materials for the synthesis of beet root pigments, betacyanins and betaxanthins.

Methionine is converted to S-adenosylmethionine (SAM) by S-adenosylmethionine synthase. SAM serves as a methyl donor in transmethylation reactions and is a precursor for the synthesis of ethylene, biotin, and polyamines **(Amir, 2010)**. Methionine is important for the biosynthesis of growth regulating substances, e. gcytokinins, auxins and brassinosteroids **(Gross et al., 2002)**.

Asparagine and glutamine connect the carbon and nitrogen cycles in plants and therefore influence both sugars and proteins metabolic pools. Aspartate is the precursor to several amino acidsin plantsasisoleucine, threonine, methionine **(Abd-elhady et al., 2011)**. Glutamic acid is important for the synthesis of the auxin and fruit set **(Taiz and Zeiger, 2002)**.

Phenylalanine amino acid is the precursor of all phenolic compounds i.e. flavonoids, lignin, stilbenes, lignans through cinnamic acid that are synthesized within the shikimic acid pathway **(Shirley, 1996)**. Phenylalanine is related to defense responses in the plant against herbivores, antibacterial and antifungal activities as well as other stress impacts (**Helenoa et al., 2015, Edreva et al., 2015)** and food sources of phenolics are important for human health and protection **(Lin et al., 2016)**.

Effect of exogenous application of amino acids on plants

1. Impact of amino acids application on quality and quality of plants

Amino acids play an important role as bio-stimulant which has positive effects on quality and quantity of plant as well as significantly mitigate the harmful effects of abiotic stresses **(Kowalczyk and Zielony, 2008)**. In this respect, **Yunsheng et al. (2015 a, b)** mentioned that foliar spraying snap bean with glutamine or asparagine at 25 ppm increased growth parameters, yield of snap bean and some biochemical constituents of the yielded pods (protein, free amino acids and phenolic contents). In addition, priming faba bean seeds with L-cysteine or proline at the rates 20 and 40 mgL^{-1} induced significant increments in growth parameters, photosynthetic pigments content of leaves as well as N, P, K in the shoots accompanied by significant increases in seed yield/feddan and total carbohydrate, protein, P and K contents of the yielded dry seeds. Moreover, the ratio of essential amino acids /non-essential amino acids was increased in the seeds yielded by the treated plants. Treatment with 20 or 40 mgL^{-1} proline showed the highest significant effect followed by L-cysteine at the rate of 20 mgL^{-1}as reported by **El-Awadi et al. (2016)**.

Shafeek et al. (2012) found that treated onion with glutamine and arginine at 150 ppm produced the highest total yield. In addition, both amino acids at 200ppm enhanced N %, protein %, TSS %, and dry matter %. In a study conducted by **El-Awadi and Abd-El Wahed (2012)** they found that foliar application of cysteine, methionine and glutathione at 25, 50 and 75 mgL^{-1} significantly promoted the growth criteria of green onion and some biochemical contents of bulb (fixed oil, free amino acids, total protein, flavonoids, phenolic compound, and indoles). A similar enhancement effect on green onion via L-tryptophan treatments (25, 50 and 75 mgL^{-1}) was reported by **Abd El-Wahed et al. (2016)** who indicated that the increase in growth criteria was concomitant with increases in photosynthetic pigments, oil percentage, total nitrogen, total protein, total free amino acids and indole contents.

EL-Sherbeny and Da Silva (2013) concluded that beetroot growers could effectively use proline and tyrosine at 100 and 200 mgL^{-1}as a foliar application to increase beetroot yield for edible purposes and to increase pigments for use in coloring and medicinal industries. **Nishanthi and Sutharsan (2015)** also found that tryptophan at 10^{-4}M increased the radish tuber yield per plant (157%), tuber length (112%) and diameter (76%) under the recommended fertilizer rate. Moreover, an improvement in radish tuber yield and yield criteria was observed in plants treated with 10^{-3}M tryptophan (as a phytohormone precursor) at half recommended fertilizer rate. Foliar application of L-cysteine, L-methionine and amino-acid-bearing fertilizer at 100 and 200 mgL^{-1} on transplants of broccoli (*Brassica oleracea* var. italica) enhanced growth criteria and nitrogen contents **(Shekari and Javanmardi, 2017)**. Using glycine at 75ppm or methionine at 150 ppm or tryptophan at 300 ppm either as a presoaking or foliar spraying treatment resulted in a significant increase in most of the studied parameters of gladiolus (vegetative growth, flower characteristics, corms and cormels production and some chemical components). Moreover, tallest spikes were shown by the plants that have been treated with glycine at 450ppm, methionine at 600ppm, or tryptophan at 900ppm (**Khattab et al., 2016**).

Foliar spray of tryptophan (25-100mgL^{-1}) significantly increased yield and yield components of lupine plants at harvest stage. High concentration promoted the seeds contents of nitrogen, phosphorus, potassium, crude protein, sugars, free amino acids and oil (**Amin et al., 2014**). **El-Hosary et al. (2013)** revealed that foliar application of L-tryptophan (100ppm) and L-cysteine (150ppm) significantly increased grain and straw yield as well as yield components of wheat plant. Amino acid applications (serine, alanine, glutamine and arginine) each at 0.5mM increased the regeneration rate and regenerate length with varying degrees in *Triticum durum* Desf. “Ç-1252” and “Kunduru 1149” and *Triticumaestivum* L. “Bolal” and “İkizce 96” cultivars (**Duran et al., 2013**). In addition, **Abbas et al. (2013)** showed that L-tryptophan at 10^{-3}M improved the crop vegetative and reproductive growth that consequently increased pod weight of chickpea. **Teixeira et al. (2017)** reported that the application of cysteine, glutamate, glycine and phenylalanine to soybean seed, leaves or both increased the activity of anti-oxidant enzymes (peroxidase, catalase, and superoxide dismutase) and resistance enzymes (polyphenol oxidase and phenylalanine ammonia-lyase) accompanied by a reduction of lipid peroxidation.

The beneficial effects of amino acids on growth, yield and quality of grapevines cvs were also emphasized by the findings of **Al-Khawaga (2014)**, **Faissal et al. (2014, 2015)**. Three amino acids (methionine, glutamic acid and arginine) at a rate 500ppm were used as a spray application on the vines for three times at growth start (when shoots length reached about 40 - 50cm), after fruit set and 2 weeks after fruit set as attempts to improve growth, physical and chemical properties of flame seedless grapevines (**Belal et al., 2016**). Exogenous application of tryptophan at 10^{-5}M, 10^{-4}M or 10^{-3}Mconsiderably enhanced periwinkle plant growth at successive developmental stages (**Talaat et al., 2005)**. These effects were most pronounced with 10^{-3}M tryptophan. Tryptophan at 10^{-4} or 10^{-3}M also increased gibberellic acid (GA_3), IAA and ABA contents, whereas a decrease was obtained in response to treatment with the lowest concentration (10^{-5}M).

2. Positive role of amino acids application on the impact of stress

It is estimated that yield losses in agricultural crops due to different abiotic stresses include 15% due to low temperature, 17% due to drought, 20% due to salinity, 40% due to high temperature, and 8% due to other environmental factors **(Ashraf et al., 2008)**. The application of different amino acids can increase plant tolerance to a variety of abiotic stresses **(Ertani et al., 2013; Calvo et al., 2014; Bakry et al., 2016)**. The role of amino acids in alleviating the impact of different stresses is discussed in the following:

A. Osmotic stress

Salinity and drought are the most important environmental factors that limit crop productivity, mainly due to alterations in water relations, ionic imbalance, metabolic perturbations, generation of reactive oxygen species (ROS) and tissue damage **(Bartels and Sunkar, 2005)**. Many reports indicated that exogenous application of proline, at low concentrations, enhanced tolerance to osmotic stress of various plant species **(Slama et al., 2015; Teh et al., 2016)**. For example, **Dawood et al. (2014)** mentioned that foliar application of proline at 25 mM partially mitigated the toxicity of diluted seawater (3.13 and 6.25 ds m^{-}1) on growth and anatomy **(Figure1)** of faba bean plants, where the recovery effect was accompanied by changing in the levels of total carbohydrates, total soluble sugars, free amino acids, endogenous proline and phenolic contents as well as the activity of two antioxidant enzymes; peroxidase and polyphenol oxidase**.**

Meanwhile, **Elewa et al. (2017)** concluded that proline foliar treatments (12.5mM and 25mM) improved growth parameters, relative water content of quinoa, quinoa yield, yield components and the nutritional values of the yielded seeds subjected to drought stress conditions by skipping two irrigation times. Additionally, **Rady et al. (2016)** attributed the positive effect of proline on growth, productivity and anatomy of lupine varieties under salt stress to the increase in carotenoids, chlorophylls, total soluble sugars and endogenous proline contents.

Regarding arginine, arginine treatments on sunflower plants grown under salinity showed positive effect on physiological processes that reflected on improving vegetative growth and active translocation of photosynthetic products from source to sink **(El-Bassiouny et al., 2008)**.

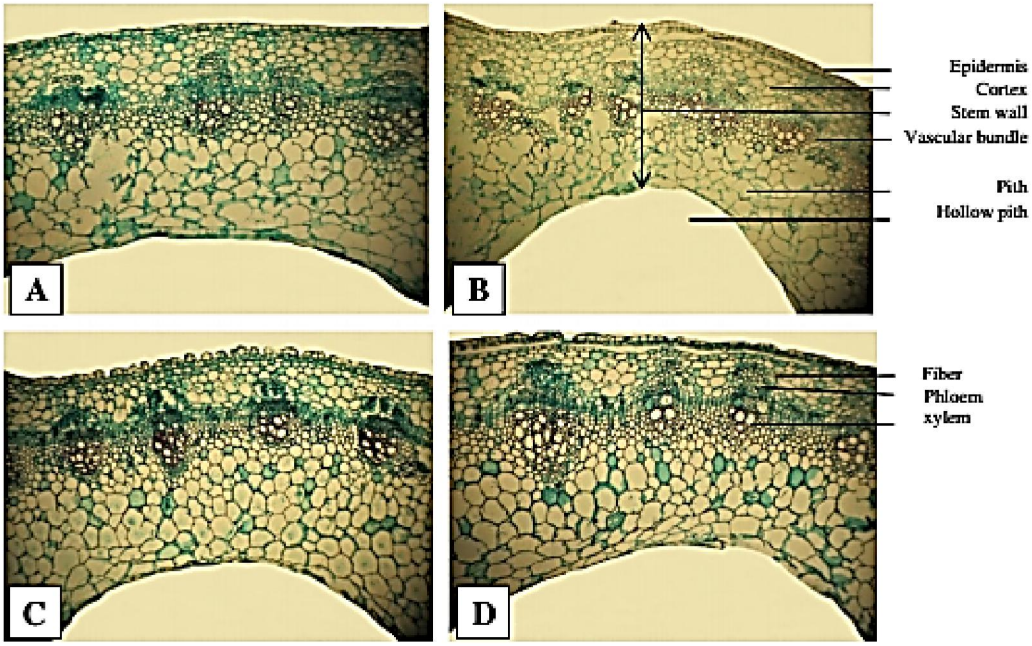

Figure 1: Changes in cross sections of the stem anatomy of faba bean plants grown under seawater stress and exogenous application of proline (×68). A: tap water without proline (0.23 dS m^{-1}); B: 6.25 dS m^{-1} seawater; C: tap water (0.23 dS m^{-1}) + 25 mM proline; D: 6.25 dS m^{-1} seawater + 25 mM proline **(Dawood et al., 2014)**.

Application of arginine at different concentrations on mung bean plants could alleviate the harmful effect of salinity on plant dry weight, yield and yield component as well as increased total carbohydrates and protein contents of the yielded seeds. The magnitude of increment was much pronounced by using 2.5mM arginine under all salinity levels (**Abdul Qados, 2010)**. Moreover, pre-soaking of mung bean seeds with arginine at 0.3mM mitigates the harmful effect of salinity via enhancement the growth, yield and yield components as well as nutritional value of yielded seeds **(Hozayn et al., 2013)**. Alleviation the harmful effects of salinity by arginine might be due to increased activity of catalase and ascorbate peroxidase in root and leaves of sunflower **(Nejadalimoradi et al., 2014)**.

L-tryptophan is precursor of auxins in higher plants and has more positive effect on plant growth and yield as compared to pure auxins **(Zahir et al., 1999)**. L-Tryptophan may act as an osmolyte, modulate stomatalopening, regulate ion transport and detoxify harmful effects of heavy metals **(Rai, 2002).** Exogenous application of tryptophan (50, 75 mg/L) led to marked increases in growth characters of quinoa (plant height, shoot, root fresh and dry weight) accompanied by an increase in the levels of IAA, phenol, free amino acid contents and yield components, as compared with the control with skipping irrigation (**Bakry et al., 2016**). Pretreatment of sunflower seeds with different concentrations of tryptophan (2.5 and 5.0mg/L) could improve the adverse effects of salinity stress by increasing the solute and antioxidant enzyme (**El-Bassiouny and Abdel-Monem,2016**).

Cysteine is considered as a sulphur containing amino acid. **Nasibi et al. (2016)** attributed the positive effect of0.01M cysteine on the growth of wheat plants that exposed to salinity or osmotic stress for 2 weeks to alleviation of oxidative damages through an increased activity of antioxidant enzymes, glutathione content, and decreased ion toxicity.

Khanna and Rai (1998) observed that exogenous application of the amino acids L-leucine, L-glutamic acid, L-alanine, and L-histidine alleviated osmotic stress in *Raphanu ssativus* L. seedling**s** through enhancement of endogenous proline levels. **Akladious and Abbas (2013)** reported that alleviation of the adverse effect of salinity in tomato plants by aspartic acid was assumed to take place through increased α-tocopherol, ascorbic acid, anthocyanin, enzymatic activities and endogenous amino acids.

B. Heavy Metals Stress

In plants, amino acids are considered as the most important components of antioxidant systems.

Rennenberg and Herschbach (2014); **Hildebrandt et al. (2015)** stated that amino acids involved in the reduction of free radicals and osmoprotection as well as play a key role in signaling stress response and secondary metabolism in plants.

Cadmium (Cd) contamination has negative effects on plant performance even at very low concentrations. Leaf concentrations ≥ 5-10 µg Cd/g dry matter (DM) is toxic to most plants **(White and Brown, 2010)**. Amino acids play a significant role in the mechanism of plant adaptation to Cd stress. Tryptophan side chain was found to interact with metal ions **(Li and Yang 2003)**. In this connection, **Sanjaya et al. (2008)** reported that increased tryptophan levels make Cd less available to the plant, decrease Cd transport and histidine reduce Cd accumulation. **Farooq et al. (2015)** showed that L-tryptophan enhanced plant height (12.54%), the number of tillers (25.53%), the number of panicles (19.04%), 1000 grain weight (19.28%), and the paddy yield (11.78%) in cadmium contaminated soil. They added that L-tryptophan increased the uptake of cadmium in rice straw and decreased the translocation of cadmium towards rice grains. **Zemanová et al. (2014)** indicated that methionine and histidine might be involved in Cd resistance and accumulation by reducing oxidative damage.

Other amino acids were found to induce plant tolerance to heavy metal toxicity. For example, **Wang *et al*. (2017)** investigated the exogenous application of three amino acids (glutamate, glycine, and cysteine) on rice seedlings exposed to 5.0µmol L^{-1} Cd. They stated that all applied treatments decreased lipid peroxidation, increased catalase, superoxide dismutase activities, and reduced glutathione contents. The three amino acids alleviated the damaging effects of oxidation to varying degrees while the effect of cysteine treatment was relatively better. The main reason may be attributed that cysteine represents the most important conceptual fragments of glutathione, which is the main precursor of the phytochelatins.

Exogenously applied aspartic acid was also effective in the reduction of Cd toxicity on different plants leading to improve plant quantity and quality. **Rizwan et al. (2017)** studied the effect of foliar application of aspartic acid (10, 15 and 20mg L^{-1}) on rice plant grown under soil contaminated with Cd (2.86 mg kg^{-1}). They found that aspartic acid increased the shoot height, dry weights of plants and photosynthesis. On the other hand, aspartic acid reduced the translocation of Cd from roots to shoots of rice seedlings and decreased the malondialdehyde content and electrolyte leakage which indicated that aspartic alleviated the oxidative stress and enhanced the Cd tolerance in rice seedlings.

The accumulation of proline decreased the metal toxicity on lipid peroxidation **(Mehta and Gaur 1999)**. The application of exogenous proline (10 and 20mM) alleviated the oxidative damage induced by Cd accumulation (0 and 30 mg $CdCl_2$ kg^1soil) via increasing plant growth, activities of antioxidant enzymes, photosynthetic activity, nutritional status, and oil content of olive fruit (**Zouari et al., 2016).**

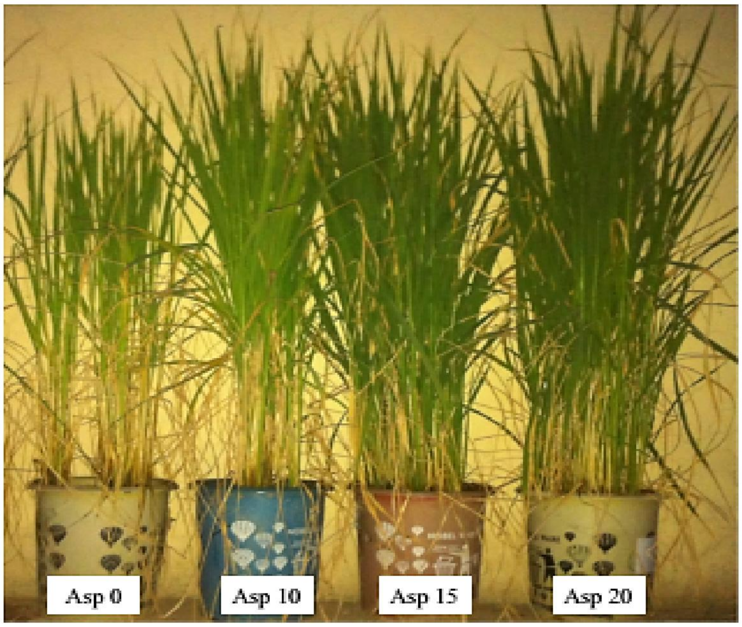

Figure2: Photos of rice seedlings taken before harvesting (75 days after sowing) grown in a historically Cd-contaminated soil with foliar application of increasing doses of aspartic acid **(Rizwan et al., 2017).**

Regarding alleviation of selenium toxicity, **Aggarwal et al. (2011)** indicated that the phytotoxic effects of selenium (1, 2, 4, and 6ppm) might occur due to increase in oxidative stress and depletion in levels of endogenous proline. They added that exogenous application of proline (50μM) reduced toxicity of selenium on bean via improving the photosynthetic pigments, elevating the leaf water content and endogenous proline content, and reducing the oxidative damage.

In case of Ni contamination**, Nasibi et al. (2013)** mentioned that **a**rginine induced alleviation of Ni toxicity and accelerated transport by chelating Ni in plants directly or through production of polyamines.

Commercial amino acids

Source of commercial amino acids

Commercial amino acid was prepared by hydrolysis protein from the waste plants and animals **(Figure 3) (Colla et al., 2015)** by chemicals or enzymes **(Pasupuleti and Braun, 2010)**. Plant protein is usually hydrolysate by enzyme, and combined chemical and enzymatic hydrolysis is used to prevent the degradation of amino acids **(Niculescu et al., 2009)**. Acid and alkaline hydrolysis broke the peptide linkage between bounded amino acids in protein and produced free amino acids. Acid hydrolysis destroy many amino acids such as tryptophan, partially lost cysteine, serine and threonine and convert amide amino acids, asparagine and glutamine to acidic form **(Lisiecka et al., 2011)**. Protein hydrolysate (PHs) from animal and plant differ in their contents from amino acids ranging 1 to 85% (w/w) and 2–18% (w/w), respectively **(Calvo et al., 2014)**. Protein hydrolysate produced from animal protein contain higher amount of amino acids as compared with those obtained from plant **(Ertani et al., 2009)**. Protein hydrolysate obtained from collagen contain high amount of aspartic acid and glutamic acid and contains two non-protein amino acids, namely hydroxyproline and hydroxylysine **(Ertani et al., 2009; Chalamaiah et al., 2012; Ertani et al., 2013)**. Whereas, protein hydrolysate originated from casein contains high amounts from glutamic and proline.

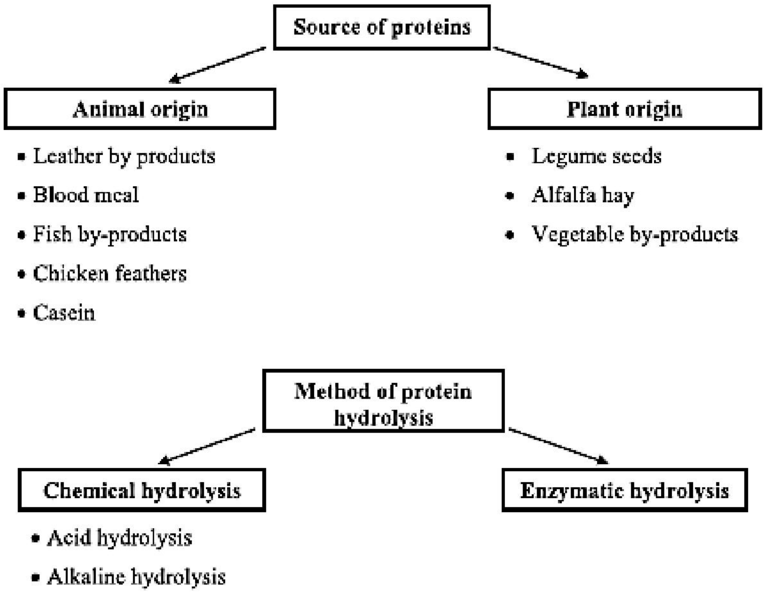

Figure 3: Source of commercial amino acids (**Colla et al., 2015**)

Foliar application of two commercial amino acids sources (amino-vitplus and amino-mix) at 500ppm and1000 ppm caused an enhancement effect on squash plant growth and its fruits yield **(Abd El-Aal et al., 2010)**. There were no significant differences between two commercial sources regarding to their effects on growth, yield and its parameters. **Shehata et al. (2011)** indicated that spraying the celeriac plants with amino acids at higher rate (750ppm) significantly increased plant height, fresh and dry weight of leaves, green yield (leaves) and NO_3 content of roots compared to control. **Abdel-Mawgoud et al. (2011)** stated that Amino-green (15 % amino acids) enhanced the vegetative growth parameters of *Phaseolus vulgaris* L. and pod quality, particularly its protein contents that responded more positively to Amino-green application.

With regard to foliar application of amino acid (Amino Green II) on onion, the results indicated the positive promoting effects of amino acids on growth, yield and its quality as well as all biochemical composition **(Fawzy et al., 2012)**. **El-Abagyet al. (2014**) also, studied the application of three commercial amino acids on onion; namely: Superbiomine, Pepton and Amino-power (0, 0.5, 1, 2), (0, 0.5, 1, 1.5) and (0, 0.5, 1, 1.5), respectively. They showed that the growth, productivity and quality of onion plants were enhanced by the applied commercial amino acids. Foliar application of amino mixture (1.2mlL^{-1}) enhanced garlic yield and quality of bulb **(Shalaby and El-Ramady, 2014).**

When radish plants treated with mixture of amino acids, the N content of shoots increased whereas, NO_3 content was reduced by 24-38% **(Liu et al. 2008).** Moreover, spraying radish plants with amino acids at higher rate had a significant effect on fresh and dry weights of shoot and root, root diameter, as well as nutrient content **(Abo Basha and El-Aila, 2015).**

Hadi et al. (2011) mentioned that treated chamomile at the flowering stage with amino acid mixture (Fosnutren), enhanced plant height, flower head diameter, fresh and dry weights and essential oil content. In field experiment, **Hendawy et al. (2012)** reported that application of Amino-AT on *Nigella sativa* and *Nigella damascena* plants had significant effects on the growth, fixed oil and fatty acid contents. **Ardebili et al. (2012)** indicated that foliar application of commercial amino acids (Aminol-Forte at 0.05, 0.1 and 0.15% (v/v) had stimulating effects on the content of secondary metabolites, antioxidants and antioxidant activity in *Aloe vera*. Under Egyptian conditions, **Hendawy et al. (2015)** observed that application of amino spot fertilizer (Algae extract), had a significant effect on *Menthapi perita* growth characters. The results of **Tarraf et al. (2015)** indicated that application of amino acids mixture (1.25g/L) enhanced the vegetative growth, total nitrogen, essential oil percentage and yield of fenugreek plants cultivated in either clay soil or sandy soil. **Azza and Yousef (2015)** revealed that foliar application of amino acids (HCl hydrolysis defatted soya flour) specially at 1.5ml/L enhanced the vegetative growth parameters of basil plant, seed yield components and the chemical constituents of leaves (total soluble sugars, protein, soluble amino acids and antioxidants activity, as well as chemical composition of volatile oil).

The results of **Abd El-Razek and Saleh (2012)** indicated that foliar and/or soil application of amino acids (Pepton 85/16) at 0.5% for both had positive effect on productivity and fruit quality, leaf mineral contents and chlorophyll contents of peach. Also, **Abo Sedera et al. (2010)** revealed that spraying strawberry plants with pepton at 0.5 and 1.0 g/L significantly increased total nitrogen, phosphorus and potassium in plant foliage as well as total yield, TSS, vitamin C and total sugars content of fruits, compared to control treatment.

Subbarao et al. (2015) observed a positive effect of protein hydrolysate (Siapton, carob enzymatic extract) on plant growth and yield of rice finger millet and cowpea. Soil application was more effective than foliar application including root and shoot length, leaf area, total chlorophyll content, photosynthetic rate, and yield.

The results of **Sultan et al. (2016)** showed that maximum fresh and dry fodder yields as well as seed yield, crude protein and oil % of Fahl Egyptian clover were obtained as a result of spraying plants with 10ml/L amino acids mixture.

Sadak and Abdelhamid (2015) emphasized the potential of application of commercial amino acids mixture in sustainable agriculture in arid and semiarid regions. The foliar application of amino acid mixture (500, 1000 or 1500 mg L^{-1}) significantly improved all the reduced parameters due to seawater stress and the most promising treatment was amino acids mixture at 1500mg L^{-1}.

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