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# Impact of exogenous proline or tyrosine on growth, some biochemical aspects and yield components of quinoa plant grown in sandy soil

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**Abstract:** A field experiment was conducted to evaluate the potential of foliar treatment of tyrosine or proline (50, 75 & 100 mg/l) on growth characters, photosynthetic pigments, seed yield quantity and quality and some biochemical aspects of quinoa plant under grown in sandy soil. Exogenous application of tyrosine or proline led to marked increases in growth characters (plant height, shoot, root fresh and dry weight) concomitantly with an increase in the levels of IAA, photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoids), phenol, free amino acid contents, carbohydrates content and yield components, as compared with the control. It could be concluded that foliar spray of tyrosine or proline was effective in improving quinoa performance by enhancing antioxidant compounds (phenolics), compatible osmolytes and antioxidant enzymes. All treatments increased seed yield and its components, also a marked increase in nutritional values of the yielded seed (carbohydrate %, protein%, flavonoids and antioxidant activity). It is noticed that tyrosine followed proline at 100 mg/l are more pronounced in increasing most of the tested parameters of quinoa plant.
**Key words:** Antioxidant enzymes, Phenol, Proline, Quinoa, Tyrosine.

## Introduction

Quinoa (*Chenopodium quinoa* Willd) is an original food crop can replenish part of foodstuff gap. It is a food crop recently introduce in Egyptian lands. [1]Repo-Carrasco *et al.*, reported that quinoa can be utilized for human food, flour products and animal feedstock because of its high nutritive value seeds. Quinoa could be used in bread in combination or substitution of with wheat and other seed products[2]. Moreover, quinoa is considered as a multipurpose crop because of the high-quality protein seeds, especially rich in essential amino acids, minerals, carbohydrates, antioxidant compounds as carotenoids, flavonoids, vitamin C and dietary fiber compared to that of cereals such as corn, oat, rice and wheat [3]. In addition, [4] illustrated that, quinoa seeds have enormous potential in the food industry as being gluten-free and highly nutritious did not contain anti-nutritional factors. It is recommended as useful essential food industries for formulations of baby gluten-free foods[5].

As quinoa can tolerate water stress and other abiotic stresses of arid and semiarid regions and can grow in sandy soil of which reduce crop production[6]. In these regions there is a need to increase yields of important economic crops like cereal without use of excessive fertilization. Use of natural products like amino acids, cheap and biodegradable chemicals. A foliar application of amino acid has been shown to increase agronomic performance and yield of newly cultivated crops. Amino acids are considered as precursors and constituents of proteins which are important for stimulation of cell growth[7]. Amino acids help to maintain favorable pH value within the plant cell due to its contain both acid and basic groups and act as buffers[8]. Amino acids can influence the physiological activities in plant growth and development, directly or indirectly via increasing of photosynthesis, endogenous hormones, ion uptake, nucleic acid and protein synthesis[9]. [10]Shiraishi et al., found that, exogenous application of amino acids adjusted the growth, yield and biochemical quality of squashe and garlic plants. L-Tyrosine used for the synthesis of proteins and served as an important precursor of natural products, including pigments, alkaloids, and some hormones. Many of these compounds are bioactive as well as playing important roles in plant defense against biotic and abiotic stresses[11]. [12]Refaat & Naguib, found that application of tyrosine increased total carbohydrate content of peppermint (*Mentha piperita* L.) leaves. Compatible solutes (osmoprotectants) like proline are low molecular weight, highly soluble organic compounds that are usually non-toxic at high cellular concentrations. These solutes provide protection to plants from stress by contributing to cellular osmotic adjustment, ROS detoxification, protection of membrane integrity and enzymes/protein stabilization[13]. The use of osmoprotectants as a foliar spray can be an economically viable strategy to enhance stress tolerance under adverse environmental conditions [14]. [15]Ali et al., observed that, foliar applications of proline have also been shown to have beneficial effects on plants exposed to water stress.[13] Hozayn et al., illustrated the foliar application of proline improve its endogenous level and therefore, encourage growth, antioxidant defense system also yield and its components.

Therefore, the present study investigates the ability of quinoa plant's grown sandy soil conditions in Egypt. To study the possible role of L-Tyrosine or proline in improving growth, some biochemical aspects, yield and nutritional values of the yielded of quinoa seeds.

## Materials and Methods

**Plant material and growth conditions:**

A field experiment was conducted at the Experimental Station of National Research Centre, Nubaria district Beheira Governorate, Egypt, during two successive seasons. The soils of both experimental sites were reclaimed sandy soil where mechanical and chemical analysis is reported in Table (1) according to[16].

**Table 1: Mechanical and chemical analysis of the experimental soil sites.**

**A. Mechanical analysis:**

| Sand | | Silt 20-0µ% | Clay < 2µ% | Soil texture |
|---|---|---|---|---|
| Course 2000-200µ% | Fine 200-20µ % | | | |
| 47.46 | 36.19 | 12.86 | 4.28 | Sandy |

**B. Chemical analysis:**

| pH | EC $dSm^{-1}$ | $CaCO_3$ | OM % | Soluble Cations meq/l | | | | Soluble anions meq/l | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $Na^+$ | $K^+$ | $Mg^+$ | $Ca^{++}$ | $CO_3^{--}$ | $HCO_3^-$ | $Cl^-$ | $SO_4^{--}$ |
| 7.60 | 0.13 | 5.3 | 0.06 | 0.57 | 0.13 | 0.92 | 1.0 | 0.0 | 1.25 | 0.48 | 0.89 |

**Available nutrients**

| Macro element ppm | | | Micro element ppm | | | |
|---|---|---|---|---|---|---|
| N | P | K | Zn | Fe | Mn | Cu |
| 52 | 12.0 | 75 | 0.14 | 1.4 | 0.3 | 0.00 |

Seeds of quinoa (*Chenopodium quinoa* Willd.) were obtained from Agricultural Research Centre Giza, Egypt. The experimental design was in randomized complete block with four replications, quinoa seeds were sown on November in rows 3.5 meters long, and the distance between rows was 20 cm apart. Plot area was 10.5 m2 (3.0 m in width and 3.5 m in length). The recommended agricultural practices of growing quinoa were applied. Pre-sowing, 150 kg/feddan of calcium super-phosphate (15.5% P2O5) was applied to the soil. Nitrogen was applied after emergence in the form of ammonium nitrate 33.5% at a rate of 75 Kg/feddan in five equal doses before the 1st, 2nd, 3rd, 4th and 5thirrigation. Potassium sulfate (48.52 % K2O) was added in two equal doses of 50 kg/feddan, before the 1st and 3rdirrigations. Irrigation was carried out using the new sprinkler irrigation system where water was added every 5 days.

The plants were sprayed twice with L-Proline or L-Tyrosine at different concentrations (50, 75 and 100 mg/l), while control plants were sprayed with distilled water during vegetative growth at 45 and 60 days after sowing. Data Recorded two weeks after the second spraying at 75 days from sowing plant samples were collected to determine plant height; fresh and dry weight of shoot and root/plant as well as some biochemical parameters in leaves photosynthetic pigments, indole acetic acid contents, total phenol contents, proline, total free amino acid, carbohydrate constituents (total soluble sugars, polysaccharides, total carbohydrates) and some antioxidant enzymes activity.

At harvest, the following items were estimated: plant height, Fruiting branches number /plant, weight of seeds/ plant, weight of shoot/ plant. Air dried seeds were ground into fine powder and kept in desiccators for analysis. Some chemical parameters are measured in the yielded grains as proteins %, carbohydrates %, flavonoids and antioxidant activity.

### Chemical analysis:

Photosynthetic pigments: Total chlorophyll a and b and carotenoids contents in fresh leaves were estimated using the method of[17]**.** Total soluble sugars (TSS), were extracted by the method of[18]**.** TSS was analyzed by[19]**.** Determination of total carbohydrates was carried out according to[20]. Indole acetic acid content were extracted and analyzed by the method of [21]. Total phenol content, the extract was extracted as IAA extraction, and then measured as described by [22]. The antioxidant enzyme (Superoxide dismutase. (SOD, EC 1.12.1.1) activity was spectrophotometrically assayed at 560 nmby nitro-blue-tetrazolium(NBT) reduction method[23]. Catalase. (CAT, EC 1.11.1.6) activity was determined spectrophotometrically by following the decrease in absorbance at 240 nm[23]. Peroxidase. (POX, EC 1.11.1.7) activity was spectrophotometrically assayed by the method of[24]. Total protein concentration of the supernatant was determined according to the method described by[25]**.** Total flavonoids were determined using the method reported by[26]**.** The antioxidant activity (DPPH radical scavenging) was determined using the method of [27]**.**

### Statistical analysis:

The data were statistically analyzed on complete randomized design system according to [28]**.** Combined analysis of the two growing seasons was carried out. Means were compared by using least significant difference (LSD) at 5% levels of probability.

## Results

### Change in Growth parameters

The growth parameters of quinoa plants in response to foliar application treatment with different concentrations of proline or tyrosine (50, 75 & 100 mg/l) on quinoa plant grown in sandy soil are represents in Table (2). Results are reveal that, using tyrosine or proline at different concentrations increased shoot length, shoot fresh and dry weight as well as root fresh and dry weight of quinoa plant as compared with control plant. While, the highest plant fresh and dry weight (shoot, root) were recorded at 100 mg/l tyrosine. In addition, as the percentage of increases in response to 100mg/l tyrosine reached to 58% & 63 % in fresh and dry weights of shoots and 139% & 191% in fresh and dry weights of roots as compared to the untreated plants.

**Table 2: Effect of proline or tyrosine on morphological parameters of quinoa plant at 75 days after sowing grown in sandy soil.**

| Material | | Shoot length (cm) | Shoot FW (gm) | Shoot DW (gm) | Root FW (gm) | Root DW (gm) |
|---|---|---|---|---|---|---|
| Control | | 15.00±0.204 | 30.87±0.342 | 7.30±0.088 | 1.77±0.162 | 0.65±0.068 |
| Proline (mg/l) | 50 | 17.37±0.387 | 30.90±0.188 | 5.40±0.076 | 3.33±0.234 | 1.13±0.091 |
| | 75 | 19.20±0.753 | 37.70±0.321 | 8.77±0.121 | 3.50±0.214 | 1.12±0.110 |
| | 100 | 21.87±0.133 | 48.01±0.221 | 10.65±0.233 | 3.43±0.115 | 1.01±0.085 |
| Tyrosine (mg/l) | 50 | 20.01±0. 513 | 36.75±0.542 | 5.90±0.098 | 2.80±0.066 | 1.27±0.050 |
| | 75 | 21.93±0.554 | 40.95±0.213 | 7.25±0.115 | 3.97±0.149 | 1.75±0.057 |
| | 100 | 24.09±0.312 | 48.88±0.654 | 11.93±0.312 | 4.23±0.215 | 1.89±0.067 |
| LSD 5% | | 2.05 | 3.35 | 1.23 | 1.04 | 0.75 |

**Change in photosynthetic pigments:**

The effect of different concentrations of proline or tyrosine foliar application (50, 75 & 100 mg/l) on photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments) of quinoa plant grown in sandy soil are shown in Table 3. proline or tyrosine gradual significant increased chlorophyll a chlorophyll b, total carotenoids and consequently total pigments with increase the concentrations of both proline or tyrosine. The maximum increases of the photosynthetic pigments were obtained by foliar application with tyrosine (100 mg/l) followed by proline (100mg/l). As compared to the untreated plants the percentage of increases in chlorophyll a reached to 63 & 60 %, chlorophyll b 130% & 122%, carotenoids 155% &135% and total pigments 88% & 81% in response to 100mg/l tyrosine or proline respectively.

**Table 3: Effect of prolin or tyrosine on photosynthetic pigment contents µg/g fresh weight of quinoa plant at 75 days after sowing grown in sandy soil.**

| Material | | Chlorophyll a | Chlorophyll b | Carotenoids | Total pigments |
|---|---|---|---|---|---|
| Control | | 9.84±0.335 | 2.29±0.215 | 2.21±0.033 | 14.34±0.329 |
| Proline (mg/l) | 50 | 11.75±0.543 | 3.44±0.187 | 3.01±0.227 | 18.20±0.749 |
| | 75 | 12.39±0.423 | 4.42±0.133 | 4.23±0.435 | 21.04±0.432 |
| | 100 | 15.72±0.703 | 5.08±0.157 | 5.19±0.072 | 25.94±0.373 |
| Tyrosine (mg/l) | 50 | 13.83±0.342 | 3.77±0.237 | 4.50±0.312 | 22.1±0.239 |
| | 75 | 14.63±0.053 | 5.09±0.052 | 5.09±0.278 | 25.91±0.129 |
| | 100 | 16.02±0.185 | 5.28±0.130 | 5.65±0.316 | 26.95±0.815 |
| LSD 5% | | 0.6 | 0.13 | 0.2 | 2.04 |

**Change in sugar contents**

Data in (Table 4) show significant increases in total soluble sugars, polysaccharides and total carbohydrate contents of quinoa plant grown in sandy soil treated with proline or tyrosine (50,75 and 100 mg/l). Data also show gradual increased in sugar contents with increase the concentrations of amino acid. While application of tyrosine or proline (100 mg/l) caused the most effective changes in all carbohydrates fractions as they increased TSS by 42% & 36% , polysaccharides by 94% & 80% and total carbohydrates by 90% & 72 % respectively as compared with the untreated plant. Data indicated increases in carbohydrates constituents as affected by different concentrations of proline and tyrosine treatments followed the same trend obtained previously on vegetative growth and photosynthetic pigments.

**Table4: Effect of proline and tyrosine on total soluble sugars, polysaccharides and total carbohydrates (mg/g dry weight) of quinoa plant at 75 days after sowing grown in sandy soil.**

| Material | | Total soluble sugar | polysaccharides | Total carbohydrates |
|---|---|---|---|---|
| Control | | 28.12±1.078 | 120.94±1.130 | 149.06±1.569 |
| Proline (mg/l) | 50 | 30.89±0. 433 | 158.91±5.012 | 189.8±2.025 |
| | 75 | 33.51±0. 499 | 164.1±2.360 | 197.61±1.455 |
| | 100 | 38.35±0.229 | 218.76±1.526 | 257.11±3.127 |
| Tyrosine (mg/l) | 50 | 34.23±0. 352 | 174.67±4.207 | 208.9±1.329 |
| | 75 | 37.17±0.373 | 184.35±3.203 | 221.52±5.025 |
| | 100 | 40.01±0.815 | 234.11±2.127 | 274.12±2.316 |
| LSD at 5% | | 1.21 | 30.79 | 32.13 |

### Change in total IAA, phenol and free amino acid contents

Foliar application of quinoa plant with different concentrations proline or tyrosine (50, 75 or 100 mg/l) increased total IAA, phenol and free amino acids compared with the corresponding controls. Table 5 illustrate that with increasing the concentration of these compounds were significantly increased the concentration of the total IAA, phenol and free amino acid concentration of quinoa plant grown in sandy soil. Tyrosine at 100mg/l followed by proline at 100 mg/l were the most effective treatment on total IAA and phenol and free amino acid contents. Since it increased IAA by 90 % & 82%, phenol by 60% & 42% and free amino acid by 48% & 46% respectively. It is notice that the increase in auxin contents concurrent with the increase in growth rate as shown in Table (2).

**Table 5: Effect of proline and tyrosine on IAA (µg/g fresh weight), total phenol (mg/100 g fresh weight) and free amino acid (mg/100 g dry weight) of quinoa plant at 75 days after sowing grown in sandy soil.**

| Material | | IAA | Phenol | Free amino acid |
|---|---|---|---|---|
| Control | | 29.18±0.279 | 177.0±1.667 | 237.7±2.043 |
| Proline (mg/l) | 50 | 33.14±0.099 | 206.2±1.416 | 304.3±1.112 |
| | 75 | 35.24±0.461 | 212.5±0.995 | 288.2±3.043 |
| | 100 | 53.21± 0.213 | 250.5±1.021 | 346.8±4.106 |
| Tyrosine (mg/l) | 50 | 45.14± 0.097 | 225.5±1.113 | 312.1±4.921 |
| | 75 | 48.13±0.209 | 237.4±1.328 | 333.9±3.014 |
| | 100 | 55.41±0. 036 | 281.3±0.451 | 352.1±4.90 |
| LSD at 5% | | 1.23 | 8.5 | 7.1 |

### Change in antioxidant enzymes activity

Superoxide dismutase, catalase and peroxidase activities were increased in response to application of different concentrations of proline and tyrosine (50, 75 or 100 mg/l) on quinoa plants as compared to those of untreated control plants (Table 6). The most effective treatment was detected with tyrosine at 100mg/l followed by treatment with proline at 100 mg/l since; it increased the activities of SOD by 83% & 75%, CAT by 22 % & 18% and POX by 48% and 25 % as compared to control plants.

**Table 6: Effect of proline and tyrosine on enzyme activities (µg/g fresh weight/hour) of quinoa plant at 75 days after sowing grown in sandy soil.**

| Material | | SOD | CAT | POX |
|---|---|---|---|---|
| Control | | 23.14±0.233 | 59.26±0. 880 | 30.09±0.408 |
| Proline (mg/l) | 50 | 33.98±0.798 | 63.42±0.408 | 31.57±1.022 |
| | 75 | 36.45±0.760 | 61.04±0.385 | 32.75±0. 884 |
| | 100 | 40.42±0.582 | 69.74±0.323 | 37.66±0.973 |
| Tyrosine (mg/l) | 50 | 37.87±0.360 | 65.88±0.591 | 33.27±0.068 |
| | 75 | 39.79±1.087 | 67.51±1.009 | 34.41±1.233 |
| | 100 | 42.45±1.019 | 72.43±0.429 | 44.48±0.126 |
| LSD at 5% | | 1.45 | 2.02 | 0.98 |

**Change in yield and yield components**

Data presented in (Table 7) show the effect of foliar application of proline or tyrosine (50, 75 & 100 mg/l) on yield parameters of quinoa plants grown under newly reclaimed sandy soil. Data clearly show that, application of different treatments increased significantly yield and yield components such as shoot length, fruiting branches number /plant, shoot weight and seed weight/ plant as compared with control plants. The maximum increases of the yield parameters were obtained by foliar application with tyrosine at 100 mg/l followed by proline at 100 mg/l. As the percentage of increases in response to 100 mg /l tyrosine reached to 86%, 70%, 76%, and 58% as shoot length, branches number /plant, shoot weight and seed weight/ plant as compared to the untreated plants, respectively.

**Table 7: Effect of prolin or tyrosine on yield components/plant of quinoa plant grown in sandy soil.**

| Material | | Shoot length (cm) | branches number /plant | Shoot weight (gm) | Seed weight (gm) |
|---|---|---|---|---|---|
| Control | | 24.83±0.077 | 12.33±0.113 | 18.73±0.401 | 13.33±0.181 |
| Proline (mg/l) | 50 | 32.37±0.125 | 16.33±0.301 | 20.55±0. 731 | 17.50±0.309 |
| | 75 | 34.73±0. 757 | 18.67±0.321 | 25.97±0.725 | 17.97±0.808 |
| | 100 | 41.67±0.545 | 20.33±0.631 | 29.97±0.012 | 19.43±0.109 |
| Tyrosine (mg/l) | 50 | 36.37±0.432 | 18.67±0.553 | 25.88±0.198 | 18.53±0.312 |
| | 75 | 38.50±0.455 | 20.33±0.321 | 26.77±0.624 | 18.67±0.509 |
| | 100 | 46.07±0.653 | 21.00±0.617 | 32.88±0.501 | 21.00± 0. 280 |
| LSD at 5% | | 1.32 | 0.99 | 1.98 | 2.01 |

**Change in carbohydrate %, protein% and oil contents in yielded seeds:**

Data in (Table 8) show that all used amino acids led to significant increase in carbohydrates%, protein % and flavenoids % of yielded seeds of quinoa. Data also show that application of proline or tyrosine increased significantly carbohydrates%, protein % and flavenoids% of quinoa yielded seeds as compared with the control. Moreover, the percentage of carbohydrate, protein and flavonoid, were gradually increased with increasing concentrations of proline and tyrosine from 50 to 100mg/l. Meanwhile, the most effective treatment on carbohydrate, protein and flavonoids, of the yielded quinoa seeds was obtained by 100 mg/l tyrosine as it reached to 37% for carbohydrate 46% for protein and 21% for flavonoid, 25% relative to control plant.

**Changes in Antioxidant activity in yielded grains:**

Data in (Table 8) showed that foliar application of amino acids (proline or tyrosine) increases in antioxidant activity (as DPPH- radical scavenging capacity) of quinoa plant as compared with untreated control. Data also show that amino acids with different concentrations (50, 75 and 100mg/l) caused gradual increases in antioxidant activity as compared with control plants. Higher content of antioxidant activity was obtained with 100 mg/l tyrosine application.

**Table 8: Effect of prolin or tyrosine on nutritive value and antioxidant substances of the yielded seeds of quinoa plant grown in sandy soil**.

| Material | | Carbohydrates % | Protein % | Flavenoids % | DPPH % |
|---|---|---|---|---|---|
| **Control** | | 50.01±0.052 | 12.87±0.089 | 61.22±0.364 | 41.23±0. 323 |
| **Proline (mg/l)** | **50** | 54.17±0.092 | 14.98±0.069 | 63.75±0.309 | 49.87±0.106 |
| | **75** | 56.47±0.218 | 14.03±0.254 | 65.14±0.023 | 53.35±0.173 |
| | **100** | 66.75±0.035 | 17.21±0.240 | 71.17±0.367 | 64.87±0.268 |
| **Tyrosine (mg/l)** | **50** | 61.95±0.038 | 15.75±0.344 | 67.14±0.067 | 58.88±0.231 |
| | **75** | 63.33±0.423 | 16.83±0.533 | 69.93±0.136 | 61.25±0.551 |
| | **100** | 68.44±0.124 | 18.85±0.450 | 74.33±0.038 | 66.35±0.383 |
| **LSD at 5%** | | 1.82 | 0.75 | 0.95 | 1.41 |

## Discussion

### The growth parameters

The growth parameters of quinoa plants in response to foliar application treatment with different concentrations of proline or tyrosine (50, 75 & 100 mg/l) on quinoa plant grown in sandy soil found that, using tyrosine or proline at different concentrations increased shoot fresh and dry weight as well as root fresh and dry weight of quinoa plant. Tyrosine or proline induced significant effects on various biological aspects in plants may act as growth stimulants. These amino acids played a role on metabolic activities relevant to growth through increasing the efficiency of water uptake and utilization as well as protecting the photosynthetic pigments (Table3), significantly higher levels of carbohydrates (Table 4) and increasing IAA contents (Table 5) which enhancing cell division and/or cell enlargement. In addition, the positive effect of amino acid (Tyrosine and Proline) may be due to that, amino acid are an acceptable nitrogen source for increased growth rate of shoots[29]. [30]El Bassiouny et al., pointed out that, amino acids may play an important role in plant metabolism and protein assimilation which necessary for cell formation and consequently increase fresh and dry mater.

L-Tyrosine used for the synthesis of proteins and served as an important precursor for natural products, including pigments, alkaloids, and hormones[11] which are act as bio-stimulators for plant growth and development. [31]El-Sherbeny and Teixeira da Silva found that, treatment with tyrosine improved plant growth in red beet plant. Ali et al., (2007) reported that the exogenous application of proline alleviated the adverse effects generated by water stress in *Zea mays* and enhanced growth and yield characteristics.

### Photosynthetic pigments:

The effect of different concentrations of proline or tyrosine foliar application (50, 75 & 100 mg/l) on photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments) of quinoa plant grown in sandy soil are shown in Table 3., These results were confirmed by the findings of **[31]** on red beet (*Beta vulgaris* L. subsp. cicla) **.** These increases could be attributed to the proline application depends on the scavenging of reactive oxygen species by increasing the antioxidant enzyme activity (Table 6) and promoting photosynthesis, maintaining enzyme activity [32,33]. [15]Ali et al., reported that, the useful effect of proline applied was due to its promotive effects on photosynthetic capacity by overcoming stomata limitations, enhancing biosynthesis of photosynthetic pigments. Foliar application of mixture of amino acids at different growth stages significantly improved leaf chlorophyll contents in celeriac, grapevines and Radish plants[34, 35]. [29]Abdallah et al., reported that, amino acids help to increase in chlorophyll this lead to the increase in different growth criteria (Table 2).

Moreover, it is noticed that, carotenoids content was significantly higher in quinoa plants under treatment with tyrosine or proline. Carotenoids play a role as a free radical scavenger which, enhance their capacity to reduce the damage caused by ROS, which in turn increased chlorophyll content of such plants[36].

## Change in sugar contents

Data in (Table 4) show significant increases in total soluble sugars, polysaccharides and total carbohydrate contents of quinoa plant grown in sandy soil treated with proline or tyrosine (50,75 and 100 mg/l). Our results indicated that the application of amino acids as a foliar spray caused increases in the contents of total carbohydrates and polysaccharides of plants. These results are in agreement with the finding of other studies on onion and wheat plants[37,29] respectively. There is positive correlation between photosynthesis rates and nitrogen contents in leaves. A high rate of photosynthesis, because of a high nitrogen supply, results in higher biomass production[38]. [31]El-Sherbeny and Teixeira da Silva added that application of tyrosine increased total carbohydrate content of red beet.

[39]Ali et al., illustrated that, the increase in TSC content may be responsible for providing carbon skeleton and improvement of photosynthetic pigments (Table 3) that lead to the better dry mater production (Table 2). Moreover, [40] reported that, the accumulation of total soluble sugars in wheat plant under water stress via increasing endogenous levels of certain phytohormones (Table 5).

## Changes in total IAA, phenol and free amino acid contents

Foliar application of quinoa plant with different concentrations proline or tyrosine (50, 75 or 100 mg/l) increased total IAA, phenol and free amino acids compared with the corresponding controls Table 5. Higher plants have a patent effect to synthesise secondary metabolites, such as phenols, and IAA which have an anti-oxidative role in scavenging ROS[41]. The increases in IAA, content in shoot tissues treated with amino acid parallel with the increase in growth rate (Table 2) could be attributed to the stimulation in cell division and / or cell enlargement[42].

Phenolic compounds play a key role as protective components of plant cells and protect cells from potential oxidative damage; increase the stability of cell membranes[43]. This increase may be due to total phenols role to play a significant mechanism in regulation of plant metabolic processes[29]. [44,45]Abdallah et al. and Hussien et al confirmed this result in quinoa plant. [11]Maeda & Dudareva reported that, L-Tyrosine, used as an important precursor for natural products, including hormones.

Proline or tyrosine application caused significant increases of free amino acids as compared with control plant (Table 5). These obtained results are in harmony with those obtained by[46] who reported that, amino acid treatment enhanced the levels of total amino acids.

## Change in antioxidant enzymes

Superoxide dismutase, catalase and peroxidase activities were increased in response to application of different concentrations of proline and tyrosine (50, 75 or 100 mg/l) on quinoa plants as compared to those of untreated control plants (Table 6). _Plants continuously synthesize the reactive oxygen species (ROS) as a byproduct of various metabolic pathways. [47]Foyer and Harbinson, demonstrated that, ROS play a significant role in providing protection against harmful stress. However, excessive levels of ROS result in oxidative damage to plants, e.g., nucleic acid damage, oxidation of proteins and lipids and degradation of chlorophyll pigments. The proposed functions of accumulated amino acid are osmoregulation, maintenance of membrane and protein stability, growth, seed germination while carbon and nitrogen serve as an energy store [48]. [49]Shabala reports indicate that proline is responsible for scavenging the ROS and other free radicals. [50]Öztürk & Demir reported that, proline application plays a regulatory role in activity of the enzymes catalase, peroxidase and polyphenol oxidase in plant cells and in their sharing in development of metabolic responses to environmental factors. Moreover, [51] reported that exogenous application of proline significantly enhanced the activities of antioxidative enzymes catalase, peroxidase and superoxide dismutase in tobacco suspension cultures exposed to salinity stress.

## Change in yield and yield components

Foliar application of proline and tyrosine (50, 75 & 100 mg/l ) increased significantly yield and yield components of quinoa plants grown under sandy soil. The obtained results are in good agreement with those obtained by[52] and [53]. The overall improvement in plant yield due to application of amino acids may be due to providing with pleasure source of growing substances which form the constitutes of protein in the living tissues. Also, the positive effects of amino acids application may be brought as osmo-regulatory [29] since it is very soluble in water therefore increase the concentration of cellular osmotic components. [54]Raza et al., reported that, proline as osmoprotectants promotes plant growth and yield under normal or stress conditions due to its osmoprotective effect on photosynthetic machinery and regulation of ion homeostasis as well as improving CO2 assimilation in plants under stress[55]. [31]El-Sherbeny and Teixeira da Silva revealed that application of tyrosine increased total carbohydrate contents of peppermint plant and in sequentially yield and its components. [56]Dromantienė et al. and [57]Mohamed et al found that the application of a mixture of amino acids on common wheat (*Triticum aestivum* L.) improved yield components.

**Change in carbohydrate %, protein% and oils contents in yielded seeds:**

The different treatments of all used amino acids led to significant increase in carbohydrates%, protein % and Flavenoids % of yielded seeds of quinoa (Table 8). Similar finding were obtained in response to amino acids application [29], who found that, total carbohydrate, and protein concentrations were increased in glutamic acid application on wheat plant. [30] concluded that, there is a close relationship between the effect of amino acids and the stimulated of the photosynthetic output (soluble sugars, polysaccharides and total carbohydrates) of wheat plant. These results might increase the efficiency of solar energy conversion which maximized the growth ability of quinoa plant and consequently increased its productivity. Moreover, [31]reported that plants treated with proline and tyrosine contained higher carbohydrate content in roots of red beet.

**Change in Antioxidant activity in yielded grains:**

Data in (Table 8) showed that foliar application of amino acids (proline and tyrosine) increases in antioxidant activity (as DPPH- radical scavenging capacity) of quinoa plant as compared with untreated control. These findings are in a good agreement with [29] who mentioned that amino acid foliar application increased antioxidant activity (as DPPH). The increase in the antioxidant activity can be considered an advantage of treatment used[58]. The increases in total phenols and total flavonoids lead to antioxidant activity increase [59, 60]**.**

## Conclusion

The growth enhanced by foliar application of proline or tyrosine, which stimulating growth regulators level (IAA) and involved in protecting the photosynthetic apparatus and consequently increasing the photosynthetic ,growth and yield components of quinoa plant . Foliar spray of tyrosine or proline was effective in improving quinoa performance by enhancing antioxidant compounds (phenolics), compatible osmolytes and antioxidant enzymes. Moreover, quinoa plant gave higher nutritional value of carbohydrate%, protein%, total flavonoids, and antioxidant activity in yielded seeds.

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