**Salinity Stress Alleviation by Foliar application of Proline ​as bio-stimulant on yield and quality traits of Maize grown in saline calcareous soil**

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**ABSTRACT**

A field experiment was carried out at the farm of El-Nubaria Agricultural Research Station, Behaira Governorate, Agriculture Research Center, Ministry of Agriculture and land Reclamation, Egypt. During the 2019 and 2020 summer seasons. This experiment was laid out to evaluate the effect of proline foliar application as bio-stimulant on yield and quality traits of Maize grown to alleviate the Salinity Stress in saline calcareous soil. The experimental design was a randomized complete blocks design arrangement with three replications was used to conduct all trials. The experiment was affected by proline (amino acid) foliar application. Treatments were as follows: Control, 100 mg/l, 200 mg/l, 300 mg/l and 400 mg/l of proline. The results show that proline foliar application treatments increased growth parameters, biochemical parameters, nutrient content, yield, and it's component and oil percent. The treatment 400 mg/l gave the highest values of most studied parameters but without significant differences with the treatment 300 mg/l proline foliar application. Yield and its components and oil percent recorded the highest values with treatments 400 mg/l proline foliar application. The relative increase in grain yield (ton/fed.) and oil percent (%) with the treatments 400 mg/l were 157.2 % and 79 % respectively compared with control. Foliar application of proline with concentration 400 mg/l produced the highest increase in growth, biochemical parameters, and nutrient content which appeared finally in the highest grain yield and oil percent.

**Keywords**: Maize, Salinity stress, Proline, Growth, Yield, and Nutrient content.

**INTRODUCTION**

Maize (Zea mays, L) is one of the main cereal crops, food grains and industrial important in many parts of the world, in terms of cultivated area and production, comes after wheat and rice. Domestic consumption in 2013 rose by approximately 14.3 million tons. In 2014, domestic production increased by about 6.9 million tonnes **(Heba et al., 2015).** For many agricultural goods, maize is a staple human food, a feed for livestock, and a raw material. It is an important food crop grown by many resource-poor farmers on a large scale and at the level of subsistence. There are many agricultural goods in industrialized countries, such as corn sugar, corn oil, cornflour, starch, syrup, brewer's grit, and alcohol **(Dutt, 2005).** **Farooq et al. (2015)** found that, under a broad spectrum of soil and climatic conditions, maize is grown. Maize is moderately susceptible to stress caused by salt.

Salt stress is one of the most significant barriers to crop development in salt-affected areas of the world. Almost 6.5 percent of the world's entire area and about 20 percent of the agricultural land is affected by salinity **(Billah et al., 2017).** One of the main farming problems in semi-arid regions is soil salinity. Plants are vulnerable to extreme climatic conditions in Egypt, such as high temperatures and drought. Dissolved salts can accumulate in soils due to inadequate ion leaching. An accumulation of salt in the upper layers of the soil can also be due to improper management of irrigation **(Mohamed et al., 2007).**

Proline is an amino acid that accumulates as a result of stress in different tissues of the plant, particularly in the leaves. In the regulation of osmosis in the cell, the accumulation of this amino acid plays a role as the proline is concentrated in the cytoplasm to counterbalance the osmosis effort of cell sap. Also, under stress conditions, proline protects enzymes **(Meister, 2012).** Proline accumulation in plant leaves in times of drought to conserve the best percentage of water in the plant **(Tarighaleslami and Zarghami et al., 2012).** Exogenous proline application has also enhanced the negative effect of salt stress by controlling cellular osmotic equilibrium **(Deivanai et al., 2011).** Proline is an osmoregulator that specifically controls osmotic pressure in the plant to be able to absorb water and play an essential and efficient role in many of the plant's critical processes. It also preserves chloroplast membranes and thus increases the efficiency of photosynthesis and has the potential to protect cell walls and membranes, and playing an important role in scavenging free radicals, thereby mitigating the adverse impact of stress and improving plant development, productivity, and quality. Moreover, proline played an important role in promoting plant growth and seed yield under normal or stress conditions, as observed in maize **(Abdelhamid et al., 2013).** Proline is a proteinogenic amino acid, important within plant tissues for different vital metabolic processes; it is abiotic stress conditions that cause proline accumulation in plant tissues **(Slama et al., 2014 and El-Nasharty et al., 2017)**. Proline helps to retain the status of cell water, subcellular structures and protect membranes and proteins from osmotic stress denaturation **(Ashraf and Fooland 2007)**.

Proline plays three major roles during stress, i.e. as a metal chelator, an antioxidative protection molecule, and a signaling molecule **(Hayat et al., 2012)**. Furthermore, exogenously applied proline protects enzymes, scavenges free radicals, and prevents salinity stress oxidation **(Wutipraditkul et al., 2015)**. **Wu et al. (2017)** found that the toxicity of salinity can be decreased by controlling the Na+/K+ ratio and increasing proline accumulation. This can provide physiological insights into the understanding of the salinity tolerance mechanisms in exogenous proline-treated plants. **Perveen and nazir (2018) and Sary et al. (2020)** found that proline indicates differential response by regulating different physicochemical parameters not only in different plant species but also under various environmental conditions. **Szabados and Savoure (2009) and El-Nwehy et al. (2020)** explained that multiple proline roles in plants include protein synthesis, osmolyte protection, redox balance maintenance, and mitochondrial function mediated metabolic signaling. Proline improved nutrient acquisition, water uptake, and nitrogen fixation are primarily motivated by these positive effects. Exogenous proline also alleviates salt stress by enhancing the activities of antioxidants and reducing the absorption and translocation of Na+ and Cl- while improving the assimilation of K+ by plants. In addition, L-proline is synthesized by plants in the cytosol and accumulates in chloroplasts. Accumulation in plants is a well-recognized physiological response to salinity-induced osmotic stress **(Abd El-Samad et al., 2010)**. The objective of this work was mainly to investigate the Salinity Stress Alleviation by Foliar application of Proline as bio-stimulant on yield and quality traits of Maize grown in saline calcareous soil.

**MATERIALS AND METHODS**

A field experiment was carried out at the farm of El-Nubaria Agricultural Research Station, Behaira Governorate, Agric. Res. Center (ARC), and Ministry of Agriculture and land Reclamation (MALR), Egypt. During the 2019 and 2020 summer seasons to evaluate the effect of proline foliar application on maize *(Zea mays,* L) cultivar. The geographical situation features of the farm are 30º 90´ N, 29° 96´ E, with an altitude of 25 m above sea level. The soil samples (0-30 cm depth) were analyzed according to the method described by **(Page *et al.,* 1982)**. Soil texture was sandy loam and had the following characteristics: pH 8.3, organic matter 0.9 %, CaCO3 33.6 %, EC 4.9 dS/m (3136 PPm), K 600, Ca 900, Na 1200, Mg 400, Fe 6.7, Mn 2.9, Zn 1.4 and Cu 2.5 ppm.

**Experimental design and adopted treatments:**

**The experimental design**: It was a randomized complete blocks design arrangement with three replications. The total numbers of experimental plots were 15 plots (the plot was 10.5 m2). In this field experiment there were 4 lines of plantation in each plot and rows were 3.5 m long with 0.75 m row spacing and plant to plant spacing was 0.20 m; also, planting depth for seeds was 5-6 cm.

**Treatments were as follows:** Control, 100 mg/l, 200 mg/l, 300 mg/l and 400 mg/l of proline foliar application. These treatments were applied three times/season( one time ech month) (L- proline: C5H9NO2, M.W 115.13).

**Maize cultivar:** Giza 310 was obtained from Corn Research Section, Agricultural Research Center, Giza, Egypt. Maize cultivar was sowed on the 1st ofJune and was harvested on the 3rd of September in two seasons. Nitrogen fertilizer as ammonium sulfate (20.5% N), Phosphorus fertilizer as superphosphate (15.5 % P2O5), and K fertilizer as Potassium sulfate (48 % K2O) were added according to the recommendation of the Ministry of Agriculture and Land Reclamation, Egypt. All other farming practices (i.e., fertilizers, irrigation, weeds, and diseases control, etc.) were done following the common practices recommended by the Ministry of Agriculture for the Corn crop. Soil samples were taken during each season in June, July and August months from different locations in the experimental site in a randomized way to determine salinity as shown in **Table 1**.

**Table 1:** mean soil E.C values (ppm) in June, July, and August at the different locations for the two experimental seasons.

|  |  |  |  |
| --- | --- | --- | --- |
| **August** | **July** | **June** | **location** |
| 2175.6 | 2850 | 3050 | **1** |
| 2221.5 | 2875 | 3216 | **2** |
| 2128 | 2900 | 3285 | **3** |
| 2240.6 | 2925 | 3174 | **4** |
| 2083.2 | 2500 | 3173 | **5** |
| 2256.8 | 2750 | 3233 | **6** |
| 2486.4 | 2840 | 2991 | **7** |
| 2562 | 2880 | 3124 | **8** |
| 2269.3 | 2815 | 3156 | **Mean E.C (ppm)** |
| 3.54 | 4.39 | 4.93 | **Mean E.C (ds/m)** |

**Growth, Yield, and yield components determination**

Three plant samples were taken from each plot to determine, plant height (m), fresh weight of plant (kg), dry weight of plant (kg), the ear weight/plant (g), length of ear/plant (cm), the diameter of ear/plant (cm) and the number of row/ear as mean values for two seasons. To determine grain yield (ton/fed), grain was removed and cleaned within 1m2 at the center of the plot. Then grain yield is recorded on a dry weight basis. Replicated samples of clean grain (broken grain and foreign material removed) were sampled randomly and 100-grains were counted and weighed.

**Biochemical analysis:**

**Leaves of plant**

* **The chlorophyll content:** Was measured in fresh leaves using Chlorophyll meter Spad 502 at 9 Am according to **Wood *et al.* (1992).** The result is expressed as chlorophyll index.
* **Leaf-free proline content:** This was done according to **Bates *et al.*, (1973).**
* **Nutrient content:** The harvest samples from leaves were also taken for determination of nutrients by Cottenee’s method, **Cottenee *et al.,* (1982).**

**Grains of plant**

* **Carbohydrates %**: Was determined in aqueous solutions according to **(DuBois *et al.,* 1956).**
* **Nutrient content:** The samples from grain were taken to determine the nutrient by Cottenee’s method, **Cottenee *et al.,* (1982).**
* **Seed oil percentage**: Was estimated according to **A.O.A.C. (1990).** Oil content was calculated as follow: Oil content (%) = (weight of the flask + oil - empty flask weight/ weight of sample) x 100.

**Statistical analysis:** Statistically analysis was performed to compare the means of two seasons' data by using the least differences (L.S.D) **(Snedecor and Cochran, 1990).**

**RESULTS**

**1-Effect of foliar proline application on plant growth:-**

As depicted in **Table 2**, all treatments of proline as foliar application except the treatment 100 mg/l caused a significant increase in fresh and dry weight of the plant,weight of ear /plant, and No. of rows /ear compared with control. Plant height, length of ear /plant, and diameter of ear /plant were not affected. The maximum response of proline foliar application was achieved by the treatment 400 mg/l in most of the measured parameters such asfresh weight of plant (kg) and weight of ear /plant (g) with a relative increase of 106 and 72 %, respectively compared with control. It seems that the role of proline foliar application at the vegetative stage of maize was that proline show differential response in increasing growth by regulating different physicochemical parameters under environmental stress conditions such as salinity stress **(Perveen and Nazir (2018).**

**Table (2):** Effect of proline application on plant growth of Maize grown in Calcareous soil under salinity stress.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Proline Treatments** | **Plant height** **(m)** | **Fresh weight of plant (kg)** | **Dry weight of plant (kg)** | **Weight of ear /plant (g)** | **Length of ear /plant (cm)** | **Diameter of ear /plant (cm)** | **No. of rows /ear** |
| **Control** | 2.24 a | 0.71 c | 0.17 b | 154.22 b | 16.31 a | 5.07 a | 11.88 b |
| **100 mg/l** | 2.34 a | 0.92 bc | 0.24 a | 167.33 b | 18.89 a | 5.13 a | 12.67 ab |
| **200 mg/l** | 2.45 a | 1.06 b | 0.26 a | 238.33 a | 19.89 a | 5.23 a | 12.73 a |
| **300 mg/l** | 2.51 a | 1.14 b | 0.26 a | 260.78 a | 19.98 a | 5.23 a | 13.10 a |
| **400 mg/l** | 2.55 a | 1.46 a | 0.23 a | 265.44 a | 19.99 a | 5.33 a | 13.23 a |
| **LSD 5%** | N.S | 0.2486 | 0.0471 | 52.892 | N.S | N.S | 0.8241 |

Combined analysis of two successive seasons

**2-Effect of foliar proline application on biochemical parameters:**

As illustrated in **Table 3**, the applied proline treatments as foliar had a positive significant effect on the biochemical parameters of maize plants except for protein. Regarding the chlorophyll index, the treatments with 300 and 400 mg/l proline foliar application gave the highest value with a relative increase of 35 and 32%, respectively when compared with control without significant differences between the two treatments. Also, the same results were found with proline content which recorded the highest value with 300 and 400 mg/l proline foliar application treatments with a relative increase of 520 and 544 %, respectively when compared with control without significant differences between the two treatments. Carbohydrates increased significantly with proline foliar application compared with control but without significant differences between proline treatments.

**Table (3):** Effect of foliar proline application on biochemical parameters, yield, and its components of Maize grown in saline calcareous soil.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Proline Treatments** | **Chlorophyll index** | **Proline µg/g** | **Protein %** | **Carbohydrates %** | **Weight of 100 grains (g)** | **Grain yield (ton/fed.)** | **Oil %** |
| **Control** | 29.67 c | 17.95 d | 5.48 a | 86.02 b | 30.67 c | 1.45c | 1.74 b |
| **100 mg/l** | 33.73 bc | 37.62 c | 5.63 a | 87.37 a | 35.33 b | 1.68c | 1.94 b |
| **200 mg/l** | 34.10 abc | 75.93 b | 5.83 a | 87.30 a | 38.67 ab | 2.55b | 2.10 b |
| **300 mg/l** | 40.17 a | 111.32 a | 5.83 a | 87.15 a | 39.67 a | 3.27a | 2.68 a |
| **400 mg/l** | 39.17 ab | 115.53 a | 5.75 a | 87.73 a | 41.33 a | 3.73a | 3.11 a |
| **LSD 5%** | 6.4209 | 17.06 | N.S | 0.8898 | 3.5152 | 0.6047 | 0.5257 |

Combined analysis of two successive seasons

**3-Effect of foliar Proline application on leaves nutrient content:**

As depicted in **Table 4**, foliar application of proline has a significant effect on macro and micronutrients in leaves of maize plants. Regarding N% the highest increase was recorded with 300 mg/l proline foliar application with a relative increase of 83% compared with control. While K, K/Na, Mg, Fe, and Mn the treatments with 300 and 400 mg/l proline foliar application gave the highest value when compared with control without significant differences between the two treatments.Butthe same treatments with 300 and 400 mg/l proline foliar application gave the lowest value of Na concentration in leaves of maize plants. Regarding Ca, Zn, and Cu the highest increase was recorded with 400 mg/l proline foliar application.

**Table (4):** Effect of foliar proline application on leaves nutrients content of Maize grown in saline calcareous soil.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Proline Treatments** | **%** | | | | | | **ppm** | | | |
| **N** | **K** | **Ca** | **Na** | **K/Na** | **Mg** | **Fe** | **Mn** | **Zn** | **Cu** |
| **Control** | 1.37 c | 1.90 c | 0.45 d | 2.83 a | 0.67 c | 0.28 c | 90.67 c | 33.0 b | 18.0 d | 11.0 d |
| **100 mg/l** | 1.80 b | 2.10 b | 0.46 cd | 2.67 ab | 0.79 b | 0.28 c | 106.67 bc | 35.67 ab | 20.67 cd | 18.0 cd |
| **200 mg/l** | 2.03 b | 2.17 ab | 0.49 c | 2.60 b | 0.83 ab | 0.29 bc | 108.33 bc | 36.67 ab | 23.33 bc | 26.67 bc |
| **300 mg/l** | 2.50 a | 2.20 ab | 0.54 b | 2.57 b | 0.86 ab | 0.33 a | 147.33 a | 38.67 a | 27.33 b | 34.0 b |
| **400 mg/l** | 2.07 b | 2.33 a | 0.70 a | 2.53 b | 0.92 a | 0.31 ab | 128.0 ab | 40.67 a | 36.33 a | 43.33 a |
| **LSD 5%** | 0.3902 | 0.1758 | 0.0407 | 0.2048 | 0.1058 | 0.0247 | 21.485 | 5.478 | 4.481 | 8.9373 |

Combined analysis of two successive seasons

**4-Effect of foliar proline application on yield and its components:**

**Table 3 and Fig. 1** revealed that foliar application of proline significantly enhanced yield and its components and oil percentbutthere was no significant difference with the treatment 100 mg/l proline foliar application concerning grain yield (ton/fed.) and oil percent (%). Yield and its components and oil percent recorded the highest value with treatments 300 and 400 mg/l proline foliar application without significant differences between the two treatments. The relative increase in grain yield (ton/fed.) with the treatments 300 and 400 mg/l were 125.5 and 157.2 %, respectively compared with control without significant differences between the two treatments. The relative increase in oil percent (%) with the treatments 300 and 400 mg/l were 54 and 79%, respectively compared with control without significant differences between the two treatments.

**Fig (1):** Effect of foliar proline application on grain yield and oil percent of Maize grown in saline calcareous soil.

**5- Effect of foliar proline application on grain nutrients content:**

As depicted in **Table 5**,foliar application of proline has a significant effect on some macro and micronutrients in grains of maize plants. The results for N concentration in grains were not significant as a result of proline treatments foliar application. K, Ca, and Zn increased significantly with the treatments 200, 300, and 400 mg/l proline foliar application without significant differences between these treatments. K/Na, Mg, and Mn increased significantly with the treatments 300 and 400 mg/l proline foliar application without significant differences between these treatments. While Na decreased significantly and recorded the lowest value with the treatment 400 mg/l proline with a relative decrease of 23 % compared with control. Fe and Cu recorded the highest value of increase with the treatment 400 mg/l proline foliar application.

**Table (5):** Effect of foliar proline on nutrients content in grains of Maize grown in saline calcareous soil.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Proline Treatments** | **%** | | | | | | **ppm** | | | |
| **N** | **K** | **Ca** | **Na** | **K/Na** | **Mg** | **Fe** | **Mn** | **Zn** | **Cu** |
| **Control** | 0.88 a | 0.31 b | 0.16 b | 0.43 a | 0.71 c | 0.055 d | 33.50 d | 2.50 c | 36.0 c | 80.50 c |
| **100 mg/l** | 0.90 a | 0.32 ab | 0.16 ab | 0.41 ab | 0.77 c | 0.057 cd | 36.0 c | 3.50 c | 45.50 b | 84.67 c |
| **200 mg/l** | 0.93 a | 0.34 a | 0.17 a | 0.38 bc | 0.89 b | 0.061 bc | 36.75 c | 5.0 b | 60.0 a | 103.67 b |
| **300 mg/l** | 0.93 a | 0.33 a | 0.17 a | 0.35 cd | 0.94 ab | 0.066 a | 40.50 b | 5.50 ab | 56.0 a | 105.33 b |
| **400 mg/l** | 0.92 a | 0.33 ab | 0.17 ab | 0.33 d | 0.98 a | 0.063 ab | 46.0 a | 6.50 a | 53.50 ab | 153.50 a |
| **LSD 5%** | N.S | 0.0215 | 0.0112 | 0.0421 | 0.0763 | 0.0043 | 1.7379 | 1.1506 | 9.2586 | 14.875 |

Combined analysis of two successive seasons

**DISCUSSION**

**Effect of foliar Proline application on plant growth:**

As shown from the results all treatments of proline as foliar application except the treatment 100 mg/l caused a significant increase in growth parameters such as fresh and dry weight of the plant,weight of ear /plant, and No. of rows /ear compared with control. These findings are consistent with the exogenous Proline application of **Deivanai et al. (2011),** which had a major effect on growth parameters when the application in the range of 1 and 5 mM improved shoot growth. **Khan et al. (2014)** found that, as demonstrated by longer shoots and roots, and higher fresh and dry weights of shoots and roots, exogenous Proline mitigates the salt stress effects on plant growth. In addition, in salt-stressed plants, exogenous Proline supply significantly increased plant height **(Teh et al., 2016)**. The findings obtained are in good agreement with those obtained by **Perveen and Nazir (2018)** show that proline regulating various physiochemical parameters under environmental conditions in increasing development.

**Effect of foliar Proline application on biochemical parameters:**

**Chlorophyll**

The applied Proline treatments as foliar had a positive significant effect on the biochemical parameters of maize plants. The findings align with those observed by **Al-Shaheen et al. (2016)** that the chlorophyll content of the Proline sprayed corn leaves differed significantly from that of the control. These findings indicate the importance of Proline in increasing the concentration of leaf chlorophyll, since these regulators (proline) facilitate the oxidization of free radicals under salinity stress, causing lipid oxidation in the cell membrane **(Abuzar and others, 201).** Proline caused a substantial increase in the overall content of pigments relative to untreated plants as reported by **Abd El-Samad et al. (2010).**

**Proline**

The findings obtained are consistent with the finding by **Al-Shaheen et al. (2016)** that the concentration of leaf Proline increased compared with control under a spray treatment of 200 ppm proline. **Taie et al., (2013)** found that the leaves of plants stress-exposed plants induce a tenfold increase in the Proline content of maize leaves but the proline content gradually returned to normal level when the stress decreased.

Lama et al. (2016) also noted that in plants treated with 30 mmol of Proline, the proline content increased relative to the untreated plant subjected to stress. Exogenous proline also decreases salt stress by improving antioxidant activities and reducing the absorption and translocation of Na+ while improving plant assimilation of K+ **(El Moukhtari et al., 2020 and Bokobana et al., 2019)**. Proline also plays a role in cytoplasmic pH control or constitutes a reserve of nitrogen used by the plant at a water deficit **(Kavi Kishor et al., 2005).** Proline applied in the foliar form increased endogenous proline content **(Demiralay et al., 2017)**.

**Carbohydrates**

Proline foliar application resulted in an increment of carbohydrates. The same findings obtained are in good agreement with those obtained by **Abd El-Samad et al. (2010)**, who found a large accumulation of soluble sugar as a result of proline application. **Zheng et al. (2015)** noted that in reaction to exogenous proline under salt stress, the increase in water content and water capacity of leaves due to proline triggers the aggregation of certain organic compounds such as soluble sugars.

**Effect of foliar Proline application on nutrients content**:

Following the results of **Ali et al. (2008),** our findings on nutrient content are that the role of proline in stress tolerance as a compatible osmolyte for osmotic adjustment has a role in affecting the uptake and accumulation of inorganic nutrients in plants. Proline can control the uptake of mineral nutrients in droughty plants. Furthermore, proline counteracted the detrimental effects of salinity stress on nutrient uptake since it encouraged K+, Ca2+, and N uptake in maize. **Molazem et al. (2010)** also found that the chemical analysis of various maize cultivars leaves showed that the content of Na increased under saline conditions. Increased sodium content in maize thus decreased calcium and potassium content with increased salinity levels, leading to decreased potassium/sodium ratio **(Akram et al., 2010).** In the rhizosphere, high sodium due to salinity decreases plant uptake of nitrogen, potassium, and calcium, causing serious nutritional imbalances in maize **(Farooq et al., 2015).** The selectivity of Na+, K+, and Ca++ in maize was markedly changed by amino acids, especially proline treatments. Proline spraying limited Na+ uptake and improved the K+, K+/Na+ ratio and Ca++ selectivity uptake in maize. **Zheng et al. (2015)** noted that in reaction to exogenous proline under salt stress, the increase in water potential of leaves triggered by proline activates K+ accumulation that helps plants change their cellular osmotic potential and therefore retain higher water content. **Cuin and Shabala (2007)** showed that solutes such as proline significantly decreased cell K+ efflux and probably retained cytosolic K+ homeostasis through improved H+-ATPase activity. In turn, this controls voltage-dependent outward-rectifying K+ channels and created the electrochemical gradient needed for secondary processes of ion transport **(Cuin and Shabala, 2005).** As well as nutrient absorption, exogenous proline under salty conditions is activated enzymes involved in nutrient assimilation. Nitrate reductase is one of the main enzymes involved in the assimilation of nitrogen **(Khan et al., 2014).** Proline is a perfect way to store and recycle nitrogen under conditions of stress **(Mansour and Ali, 2017).** Nitrogen deficiency has explained that proline can be used as a source of nitrogen to develop **(Hayat et al., 2012).** Results agree with those stated by **Abd El-Samad et al. (2010),** salinity increased the sodium content in maize shoots and roots, while Mg++ accumulation decreased. Proline application had a significantly increased effect on the concentration of Mg2+ in shoots and roots under stress conditions **(Ali et al., 2008).** High sodium decreases plant absorption of Mg and Fe due to salinity in the rhizosphere and thus induces serious nutritional imbalances in maize **(Farooq et al., 2015 ).**

**Effect of foliar Proline application on yield components :**

These findings in salt-stressed Zea mays, foliar application of proline increased plant growth with a positive impact on yield characteristics, are in line with **Alam et al. (2016).** In different plant species, Proline has increased salt stress tolerance. Proline application improves plant growth with increases in photosynthesis and grain yield in high salt conditions **(El Moukhtari et al., 2020).** Under stress, exogenous proline promotes yield, increased grain yield, and weight of 1000 grains **(Rady et al., 2019 and Alam et al., 2016).**

**CONCLUSION**

A creative and promising way to reduce the effect of salinity on plant growth and crop production is the use of foliar proline. It can help to improve salt resistance in maize by using exogenous proline as osmoprotectants or osmoregulator for growing plants and cellular-based stress signaling for the entire plant. Foliar application of proline with concentration 400 mg/l produced the highest increase in growth, biochemical parameters, and nutrient content which appeared finally in the highest grain yield and oil percent.

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**Conflict of Interest**

The authors declared that the present study was performed in absence of any conflict of interest.

**Author contributions**

All authors significantly contributed to all parts and aspects of the paper.

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