



## Research Paper

# Influence of different calcium sources foliar spray on growth, yield and some biochemical changes of eggplant

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## ABSTRACT

The impacts of the individual foliar spray with different calcium sources, such as calcium superphosphate, calcium sulphate, calcium nitrate and calcium chloride at 2 g/l for each source equal 3.96, 5.81, 6.1 and 9.09 mM Ca<sup>+2</sup>, respectively at 40 and 50 days from transplanting, on the growth, yield and some biochemical changes of eggplant (*Solanum melongena* L.) cultivated during the summer seasons of 2017 and 2018 were studied. The results indicated that foliar application with calcium treatments significantly stimulated the most of the vegetative growth characteristics, super oxide dismutase (SOD) activity, improved photosynthetic pigments (chlorophyll a, b, total chlorophylls and total carotenoids) and increased the total fruits yield as compared with the control plants. In contrast, spraying different calcium sources reduced the concentration of total soluble proteins and free amino acids in eggplant leaves as compared with the check plants. The superiority of foliar spray with calcium superphosphate (3.96 mM Ca<sup>+2</sup>) gave the highest values of plant height, number of leaves and branches per plant, leaf area, leaf fresh and dry weights, fruit length, fruit diameter, fruits number per plant, fruits yield per plant and fruits yield per feddan as well as recorded the highest values of total carbohydrates, SOD activity, Cu concentration in leaves, N, P, Mg, Ca, Fe, Mn, Cu and Zn concentration in fruits as compared with the check plants and other calcium sources.

B. B. M. Salim<sup>1\*</sup>, M. S. Hikal<sup>2</sup>, Y. A. M. Salama<sup>3</sup>,  
A. Abou El-Yazied<sup>4</sup> and H. G. Abd  
El-Gawad<sup>4</sup>

<sup>1</sup>Department of Agricultural Botany, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

<sup>2</sup>Department of Biochemistry, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

<sup>3</sup>Plant Adaptation Unit, Genetic Resource Department, Desert Research Center, Cairo, Egypt.

<sup>4</sup>Department of Horticulture, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

\*Corresponding author. E-mail:  
dr.bahaa\_badry@agr.asu.edu.eg.

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## INTRODUCTION

It is known that calcium (Ca<sup>+2</sup>) plays essential physiological roles in stabilizing bio membranes, strengthening cell walls and plant tissues, and regulating various physiological processes during growth and development stages (Marschner, 1995; Reddy and Reddy, 2001). Moreover, Ca<sup>+2</sup> foliar application is necessary and its efficiency depends on treatment time, quality and rate of Ca fertilizers, spray number and weather conditions during and after the foliar application to overcome the inadequate Ca<sup>+2</sup> nutrition due to poor nutrient supply, immobilized or less mobile element, substrate pH, the antagonism by other nutrients and the ratio of Ca<sup>+2</sup> to other cations which limit growth, yield and crops quality (Wojcik, 2004; Fageria et al., 2009).

Eggplant (*Solanum melongena* L., Solanaceae) is an important traditional vegetable cash crop. It is considered

as a very good source of vitamins, dietary fibers, minerals, antioxidants, phenolic compounds, such as caffeic and chlorogenic acid, and flavonoids, such as nasunin or delphinidin-3-(coumaroylrutinoside)-5-glucoside (Dias, 2012).

The objective of the present study was to evaluate the impacts of foliar spray with different Ca<sup>+2</sup> sources on growth, yield and some bio-chemical changes of eggplant.

## MATERIALS AND METHODS

### Seedlings transplanting, fertilizers program and experimental conditions

Field experiments were carried out at the Experimental

**Table 1:** Calcium sources treatments.

Calcium source	Formula	Ca <sup>+2</sup> percentage	Ca <sup>+2</sup> concentration
Calcium superphosphate	Ca(H <sub>2</sub> PO <sub>4</sub> ) <sub>2</sub> .H <sub>2</sub> O	15.8 % Ca <sup>+2</sup>	3.96 mM
Calcium sulphate (gypsum)	CaSO <sub>4</sub> .2H <sub>2</sub> O	23.2 % Ca <sup>+2</sup>	5.81 mM
Calcium nitrate	Ca(NO <sub>3</sub> ) <sub>2</sub>	24.3 % Ca <sup>+2</sup>	6.1 mM
Calcium chloride	CaCl <sub>2</sub>	36.3 % Ca <sup>+2</sup>	9.09 mM
Control ( without Ca sources) sprayed with distilled water			

Station Farm, Faculty of Agriculture, Ain Shams University, Cairo, Egypt, (Soil pH 7.45, E.C = 1.20 ds/m, HCO<sub>3</sub><sup>-</sup> 0.40 meq /l, Na<sup>+</sup> 4.36 meq /l, Ca<sup>+2</sup> 4.20 meq /l, Mg<sup>+2</sup> 3.31 meq /l, K<sup>+</sup> 0.13 meq /l, Cl<sup>-</sup> 8.00 meq /l, SO<sub>4</sub><sup>-2</sup> 3.60 meq /l ) during the two successive summer seasons of on the 21 March 2017 and in 2018. Transplantation of Eggplant (long white) of 30-days-old consisting of 3-4 leaves was set up in the soil. The area of the experimental plot was 14 m and consisted of four rows, each row was 4 m length and 0.7 m width. The plant distance was 50 cm apart between transplants on one side. Soil application with calcium super-phosphate (15 % P<sub>2</sub>O<sub>5</sub>), ammonium nitrate (33% N) and potassium sulfate (48 %K<sub>2</sub>O) was done at 300, 300 and 150 kg per feddan, respectively. All fertilizers applications, the other cultural practices, disease and pest control programs were followed according to the recommendations of the Egyptian Ministry of Agriculture.

### Experimental design and calcium treatments

The design of the experiment was a randomized complete block with five treatments and four replicates. Different calcium sources were applied as foliar applications at 40 and 50 days from transplanting (Table 1).

### Vegetative growth characteristics

In both growing summer seasons, four plants were taken at 60 days after transplanting, and the following vegetative growth characters as plant height (cm), number of branches/plant, number of leaves/plant, leaves fresh weight (g), leaves dry weight (g), leaf area (cm<sup>2</sup>) were recorded to the full expanded fourth leaf from the plant top according to Koller (1972):

Leaf area (cm<sup>2</sup>) = disk area × no. of disks × leaf fresh weight ÷ disk fresh weight.

### Fruits yield and its components

The fruits were harvested thirteen times when having attained full size but still shining purple for fresh use. Fruits

harvest started on the 20/5/ 2017 and continued until 15/ 7/ 2017 and 2018 seasons. Fruit length, diameter, fresh weight, number of fruits per plant, total fruits yield per plant and per feddan were also recorded.

### Bio-chemical changes

#### *Photosynthetic pigments extraction and determination*

Eggplant leaves samples were taken from the youngest fully developed leaves from three plants o 60 days physiological age per treatment and were cut into pieces to obtain a representative sample (0.1 g). They were extracted with 10 ml N, N-dimethylformamide (DMF) and incubated in the dark at room temperature (25°C) for 24h to determine the photosynthetic pigments. The absorption of the extracted pigments was done using a spectrophotometer (Mapada UV 1200) at 480, 647 and 664 nm. Chlorophyll a, b, total chlorophylls and total carotenoids were calculated using formulae described by Wellburn (1994).

#### *Total soluble sugars, total carbohydrates and total free amino acids determination*

One gram of eggplant leaves was collected at 60 days after transplanting to determine the total sugars and total free amino acids, separately by 80% hot ethanol using the modified method of Irigoyen et al. (1992) and Katoch (2011), respectively. Total free amino acids were determined using a spectrophotometer at 570 nm according to the method described by Swamy (2008). Also, total sugars in the ethanol-soluble fractions were determined by the method of Sadasivam and Manickam (2010). One ml of supernatant was reacted with 4 ml freshly prepared anthrone (100 mg anthrone + 50 ml 95% H<sub>2</sub>SO<sub>4</sub>) at 100°C for 10 min. After cooling on ice, the total sugars concentration was determined at 620 nm by a spectrophotometer using glucose as standard to determine the total carbohydrates using the same anthrone method, after leaves sample were hydrolyzed in HCl acid.

#### *Proline determination*

Proline concentration in the fresh leaves samples of

**Table 2:** Influence of different calcium sources as foliar spray on the vegetative growth characteristics of eggplant at 60 days after transplanting during 2017 and 2018 seasons.

Treatments	Plant height (cm)			Branches number per plant			Leaves number per plant		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	64.00d	67.33d	65.67	4.67b	5.33a	5.00	72.33c	76.66d	74.5
Calcium superphosphate	96.00a	99.00a	97.50	6.33a	6.67a	6.50	111.00a	126.00a	118.5
Calcium sulphate	79.00bc	84.00bc	81.50	5.67ab	6.33 a	6.00	97.33ab	116.66ab	107
Calcium nitrate	75.33c	79.00c	77.17	5.67ab	6.33a	6.00	85.00bc	99.33bc	92.17
Calcium chloride	85.00b	91.66ab	88.33	5.67ab	6.00 a	5.83	81.00bc	94.00cd	87.5

  

Treatments	Leaf area (cm <sup>2</sup> )			Leaf fresh weight (g)			Leaf dry weight (g)		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	158.65d	163.21d	160.93	2.39c	2.47d	2.43	0.48d	0.51d	0.50
Calcium superphosphate	360.30a	365.76a	363.03	3.5a	3.57a	3.53	0.74a	0.77a	0.76
Calcium sulphate	196.35c	202.12c	199.24	2.72b	2.80b	2.76	0.54c	0.58c	0.56
Calcium nitrate	201.08c	212.15c	206.62	2.55c	2.64c	2.60	0.52cd	0.55cd	0.53
Calcium chloride	329.54b	335.27b	332.40	3.49a	3.56a	3.52	0.65b	0.68b	0.66

Means followed by different letters are significantly different at  $P \leq 0.05$  level; Tukey's HSD test.

eggplant was determined using the acid ninhydrin method described by Bates et al. (1973).

#### **Total soluble protein assay and crude protein**

The method of Bradford (1976) was used to determine the concentration of total soluble protein in eggplant leaves at 595 nm by a spectrophotometer (Mapada UV 1200):

Crude protein = total nitrogen  $\times$  6.25 (A.O.A.C. 2005).

#### **Superoxide dismutase (SOD) assays**

SOD (EC: 1.15.1.1) activity was determined by nitrobluetetrazolium (NBT) photochemical assay at 560 nm following the method described by Beauchamp and Fridovich (1971).

#### **Macro- and micronutrients determination**

Micro- Kjeldahl method as described by FAO (1980) was used to determine the concentration of total nitrogen in eggplant samples (leaves and fruits). Available phosphorus (P) concentration was estimated calorimetrically using ammonium molybdate and ascorbic acid method described by Chapman and Pratt (1982). Available concentrations of K, Mg, Ca, Fe, Mn, Zn and Cu in eggplant tissues were estimated calorimetrically using Pu 9100 Atomic Absorption Spectrometer (Westerman, 1990).

#### **Statistical analysis**

All data of the two tested seasons (2017 and 2018) were arranged and statistically analyzed using SAS (2006).

Tukey's HSD test was used to test for significant differences between individual treatments.

## **RESULTS**

### **Vegetative growth characteristics**

Data presented in Table 2 showed the vegetative growth characteristics of eggplant that responded positively to foliar spraying with all different calcium sources included calcium superphosphate, calcium sulphate, calcium nitrate and calcium chloride at 3.96, 5.81, 6.1 and 9.09 mM  $\text{Ca}^{+2}$ , respectively as compared with the check treatment in both seasons. Foliar applications of different calcium sources significantly stimulated the plant height and leaf area as compared with the control plants in the two seasons (2017 and 2018). Leaf growth expressed number of leaves per plant, leaf area, leaf fresh and dry weights of eggplant were stimulated by spraying different calcium sources as compared with check plants in the two tested seasons. Leaf area and leaf dry weight recorded 363.03, 332.40 cm<sup>2</sup>, 0.76 and 0.66 g under spraying calcium superphosphate and calcium chloride treatments, respectively as compared with 160.93 cm<sup>2</sup> and 0.50 g for the check plants.

The present results showed the superiority of foliar spray with 3.96 mM calcium superphosphate treatment which achieved the highest values for all vegetative growth parameters as compared with the check plants and the other  $\text{Ca}^{+2}$  sources in the two tested seasons (Table 2). Data presented in Table 2 show that plant height, number of leaves per plant, leaf area, leaf fresh and dry weights were significantly affected with calcium sulphate ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) foliar application at 5.81 mM, respectively as compared with the check plants in the two tested seasons and the number of branches per plant in the first season.

Spraying calcium nitrate at 6.1 mM gave a significant

**Table 3:** Influence of different calcium sources as foliar spray on yield components of eggplant during 2017 and 2018 seasons.

Treatments	Fruit length (cm)			Fruit diameter (cm)			Fruits number per plant		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	14.33b	15.00c	14.67	2.67b	2.83b	2.75	81.37d	82.33d	81.85
Calcium superphosphate	18.00a	19.00a	18.50	3.83a	3.67ab	3.75	100.88a	101.67a	101.28
Calcium sulphate	17.00a	17.33ab	17.17	3.33ab	3.50ab	3.42	97.03b	96.97b	97.00
Calcium nitrate	16.00ab	16.67bc	16.33	3.33ab	3.75a	3.54	97.73b	98.75b	98.24
Calcium chloride	16.33ab	17.00ab	16.67	3.25ab	3.67ab	3.46	84.40c	85.12c	84.76

  

Treatments	Fruit weight (g)			Fruits yield per plant (kg)			Fruits yield per fed (ton)		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	13.22c	13.14c	13.2	1.76d	1.82c	1.79	17.57d	18.17c	17.87
Calcium superphosphate	30.194a	35.6a	32.9	3.46a	3.62a	3.54	34.57a	36.17a	35.37
Calcium sulphate	32.462a	34.34a	33.4	3.15b	3.33a	3.24	31.47b	33.33a	32.40
Calcium nitrate	21.31b	29.67b	25.5	2.83c	2.93b	2.88	28.33c	29.33b	28.83
Calcium chloride	32.583a	32.66ab	32.6	2.75c	2.78b	2.77	27.50c	27.83b	27.67

Means followed by different letters are significantly different at  $P \leq 0.05$  level; Tukey's HSD test.

increase in plant height, leaf area in both seasons, branches number per plant and leaf fresh weight in the second season, while number of leaves per plant and leaf fresh and dry weights in the first season were non-significant as compared with the control plants. Calcium chloride ( $\text{CaCl}_2$ ) foliar application at 9.09 mM improved the vegetative growth characteristics of eggplant as compared with the control in both seasons and was more effective on the plant height, number of leaves per plant, leaf area, leaf fresh and dry weights than calcium nitrate and calcium sulphate in the two tested seasons (Table 2).

## Yield

Foliar spray with calcium superphosphate treatment at 3.96 mM produced a significant increase in fruits length, number per plant, average weight, yield per plant and yield per feddan in both seasons and fruit diameter in the first season as compared with the check plants. The highest values of yield and yield components were recorded for calcium superphosphate as compared with the control and other calcium sources in both seasons. It produced a 97.76 and 97.92 % increase in fruits yield per plant and fruits yield per feddan, respectively as compared with check plants in both seasons (Table 3). Increase in eggplant yield was involved in significant increases in the vegetative growth, total carbohydrates, proline accumulation and SOD activity by 3.96 mM  $\text{Ca}^{+2}$  (Tables 2 and 5).

Data presented in Table 3 showed that fruits length, number per plant, average fruit weight, fruits yield per plant and fruits yield per feddan in both seasons were significantly increased by 5.81 mM calcium sulphate spraying as compared with the check plants. It produced a 81.00 and 81.13% increase in fruits yield per plant and fruits yield per feddan, respectively as compared with control, but its effect was non-significant for fruit diameter

in both seasons. Calcium sulphate foliar application recorded the highest values for the average fruits weight in both seasons as compared with the check plants and other calcium sources.

Data presented in Table 3 showed that using calcium nitrate at 6.1 mM as foliar application gave a significantly increase eggplant yield components, such as fruits number per plant, average fruit weight, fruits yield per plant and fruits yield per feddan, and produced a 60.89 and 61.33% increase in fruits yield per plant and fruits yield per feddan, respectively as compared with check plants in both seasons. Fruit length in both seasons and fruit diameter in the first season were insignificant when compared with the control plants.

Fruits number per plant, average fruit weight, fruits yield per plant and fruits yield per feddan of eggplant in both seasons were significantly increased under 9.09 mM calcium chloride foliar spray and produced a 54.75 and 54.84% increase in fruits yield per plant and per feddan, respectively as compared with check plants in the two tested seasons (2017 and 2018). Whereas fruit diameter in both seasons and fruit length in the first season was non-significant as compared with the control plants.

The positive impacts of different calcium foliar applications stimulate the vegetative growth and yield of eggplant presented in Tables 2 and 3 such that  $\text{Ca}^{+2}$  achieved increases in photosynthetic pigments (Table 4).

## Biochemical changes

### Photosynthetic pigments

Data presented in Table 4 showed that all foliar supplies with different calcium sources increased the photosynthetic pigments in eggplant leaves as compared with the control plants in the two tested seasons. Chlorophyll a

**Table 4:** Influence of different calcium sources as foliar spray on the leaf photosynthetic pigments concentration of eggplant at 60 days after transplanting during 2017 and 2018 seasons.

Treatments	Chlorophyll a (mg / g f.w.)			Chlorophyll b (mg / g f.w.)			Total chlorophylls (mg / g f.w.)			Carotenoids (mg / g f.w.)		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	1.31cd	1.34bc	1.32	0.50d	0.52d	0.51	1.80c	1.85c	1.825	0.28d	0.29c	0.29
Calcium superphosphate	1.25d	1.28c	1.27	0.56c	0.58c	0.57	1.81c	1.86c	1.835	0.33c	0.34b	0.33
Calcium sulphate	1.55a	1.62a	1.59	0.69b	0.70b	0.69	2.24a	2.32a	2.280	0.36ab	0.37a	0.37
Calcium nitrate	1.48ab	1.51a	1.49	0.72a	0.74a	0.73	2.20a	2.24a	2.220	0.38a	0.39a	0.38
Calcium chloride	1.41bc	1.49ab	1.45	0.51d	0.53d	0.52	1.92b	2.01b	1.920	0.35b	0.33b	0.34

Means followed by different letters are significantly different at  $P \leq 0.05$  level; Tukey's HSD test.

**Table 5:** Influence of different calcium sources as foliar spray on some biochemical changes of eggplant leaves at 60 days after transplanting during 2017 and 2018 seasons.

Treatments	Total soluble sugars (mg / g f.w.)			Total carbohydrates (mg / g f.w.)			Proline(mg / g f.w.)		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	10.13c	10.66c	<b>10.40</b>	20.13b	20.47b	<b>20.30</b>	3.32d	3.28d	<b>3.30</b>
Calcium superphosphate	6.80d	6.93d	<b>6.87</b>	24.31a	24.61a	<b>24.46</b>	4.61c	5.19c	<b>4.90</b>
Calcium sulphate	11.16b	11.78b	<b>11.47</b>	12.84e	13.05e	<b>12.95</b>	7.58b	7.77b	<b>7.68</b>
Calcium nitrate	12.11a	12.39a	<b>12.25</b>	15.99c	16.11c	<b>16.05</b>	7.95a	8.24a	<b>8.09</b>
Calcium chloride	5.72e	5.90e	<b>5.81</b>	14.28d	14.56d	<b>14.42</b>	2.65e	2.95d	<b>2.80</b>

  

Treatments	Total free amino acids (mg / g f.w.)			Total soluble proteins ( $\mu$ g / g f.w.)			SOD activity (IU/ mg protein)		
	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean	Seas 1	Seas 2	Mean
Control	0.388a	0.399a	<b>0.393</b>	133.81a	154.41a	<b>144.11</b>	107.74e	102.75e	<b>105.24</b>
Calcium superphosphate	0.387a	0.332c	<b>0.360</b>	93.44c	105.82d	<b>99.63</b>	137.08b	117.97b	<b>127.52</b>
Calcium sulphate	0.381a	0.393a	<b>0.387</b>	115.85b	123.64b	<b>119.74</b>	124.38c	112.93c	<b>118.65</b>
Calcium nitrate	0.379a	0.364b	<b>0.371</b>	115.01b	112.36c	<b>113.69</b>	119.75d	123.87a	<b>121.81</b>
Calcium chloride	0.316b	0.286d	<b>0.301</b>	93.57c	101.29e	<b>97.43</b>	146.61a	107.47d	<b>127.04</b>

concentration was increased significantly with calcium nitrate and calcium sulphate treatments as compared with the control and calcium superphosphate in the two tested seasons. In this regard, spraying calcium nitrate, calcium superphosphate and calcium sulphate gave a significant increase in the concentration of chlorophyll b as compared with the control and calcium chloride in both seasons. However, spraying with calcium chloride gave non-significant

increase in chlorophyll a and b of eggplant leaves as compared with the control plants in the two tested seasons.

Data presented in Table 4 showed that, all different calcium sources achieved a significant increase in the concentration of total carotenoids in eggplant leaves as compared with the control plants in the two tested seasons. The highest concentrations of chlorophyll a, total chlorophylls and carotenoids pigments were observed in plants

sprayed with calcium sulphate treatment, whereas calcium nitrate gave the highest concentration of chlorophyll b and carotenoids. Photosynthetic pigments in eggplant leaves strongly indicate that most assimilates produced by photosynthesis are directed to enhance growth and yield.

#### **Total carbohydrates and total sugars**

Data on total sugars presented in Table 5 indicated

that exogenously applied calcium nitrate and calcium sulphate recorded the higher significant values of the concentration of the total soluble sugars in eggplant leaves, whereas minimum concentration of total sugars produced using calcium chloride was observed followed by calcium superphosphate in both seasons. The highest significant concentration of total carbohydrates was recorded in plants sprayed with calcium superphosphate, followed by control plants in both seasons. The individual foliar spray with calcium nitrate, calcium sulphate and calcium chloride treatments gave a significant decrease in the concentration of total carbohydrates when compared with the control in both seasons. The lowest significant concentration of total carbohydrates in eggplant leaves was for plants treated with calcium sulphate in both seasons.

### **Proline**

Data presented in Table 5 showed that foliar applications with calcium nitrate, calcium superphosphate and calcium sulphate gave a significant increase in proline concentration in eggplant leaves as compared with the check plants and calcium chloride treatment in the two tested seasons. Spraying calcium nitrate recorded the highest significant values of proline concentration in both seasons, whereas the lowest concentration of proline was for plants sprayed with calcium chloride in both seasons.

### **Total soluble proteins and total free amino acids**

Data presented in Table 5 showed that all foliar supplies with different  $\text{Ca}^{+2}$  sources reduced the total soluble proteins significantly and the total free amino acids concentrations in eggplant leaves as compared with the check plants gave maximum significant values for the concentration of total soluble proteins and recorded the highest concentration of total free amino acids. On the contrary, using calcium chloride foliar spray recorded the lowest concentrations of total soluble proteins and total free amino acids in the two tested seasons (2017 and 2018).

### **Superoxide dismutase activity (SOD)**

Foliar spray with calcium nitrate, calcium superphosphate, calcium sulphate and calcium chloride increased superoxide dismutase activity in leaves at 60 days after transplanting as compared with the control plants in both seasons (Table 5). Increasing SOD activity in eggplant sprayed with  $\text{Ca}^{+2}$  sources reduced the harmful effects under high temperature of summer seasons.

### **Macro- and micronutrients**

Table 6 shows that calcium superphosphate foliar spray

produced a significant increase in the concentration of N, P, K, Mg, Ca, Fe, Mn, Cu, Zn in eggplant fruits and Cu leaf concentration as compared with the check plants.

In this regard, calcium superphosphate foliar spray recorded the highest significant concentration of N, P, Mg, Ca, Fe, Mn, Cu and Zn in eggplant as compared with the check plants and other calcium sources (Table 6).

Spraying eggplant with calcium sulphate gave a significant increase in Ca, Mn, Cu and Zn concentration and insignificant increase for Mg concentration in the leaf. Same treatment achieved a significant increase in concentration of N, K, Fe and Cu of the eggplant fruits.

The data presented in Table 6 showed that foliar spray with calcium nitrate led to a significant increase in the concentration of Ca in eggplant leaves and the concentrations of N, P, K, Fe, Mn and Cu in fruits as compared with the check plants.

The concentration of N, K, Mg, Ca, Mn, and Cu in eggplant leaves and N, P, Fe and Cu in fruits were significantly increased, under calcium chloride foliar application as compared with the check plants (Table 6).

Synergism effect of  $\text{Ca}^{+2}$  treatments on improving leaf and fruit concentrations of macro- and micro-nutrients Table 6 are in harmony with the increased photosynthetic pigments in leaves (Table 4) and are strongly implicated in the enhancement of vegetative growth characteristics and fruits yield (Tables 2 and 3).

## **DISCUSSION**

Impacts of  $\text{Ca}^{+2}$  foliar applications depend on the rate and the chemical form solubility and its physiological activity such as calcium nitrate and calcium chloride, or calcium sulphate and calcium phosphate as non-exchangeable forms (Wojcik, 2004).

The positive effects of calcium superphosphate foliar spray at 3.96 mM  $\text{Ca}^{+2}$  on eggplant growth and productivity observed in Tables (2 and 3) comes in accordance with the results of El-Tohamy et al. (2006) who observed that sprayed pepper plants with the high level of superphosphate (2%) recorded the highest values of growth parameters and yield components including plant height, number of branches, fresh weight of plants, number of fruits, fruit fresh weight and total yield per plant as compared with calcium chloride treatments at 1 and 2% and control. Also, Sawan et al. (2008) indicated that cotton growth and yield attributes significantly increased by calcium superphosphate foliar applications at 576, 1152 and 1728 g ha.

In this regard, Tuna et al. (2007) found that tomato fruits yield was significantly improved under calcium sulphate applications. Also, Khayyat et al. (2009) observed that using calcium sulphate and calcium chloride at 5 and 10 mM caused a significant increase in shoot dry weight of strawberry grown under 35 mM NaCl salinity condition as compared with the control salt stressed plants. Also, Manaa

**Table 6:** Influence of different calcium sources as foliar spray on macro- and micronutrients concentrations of eggplant leaves and fruits at 60 days after transplanting (main of two seasons).

Treatments	N (%)		P (%)		K (%)		Mg (%)		Ca(%)	
	leaf	fruit	leaf	fruit	leaf	fruit	leaf	fruit	leaf	fruit
Control	3.68a	1.44e	0.55a	0.353d	3.7b	3.766d	0.643b	0.420bc	1.62d	0.120b
Calcium superphosphate	1.84c	2.72a	0.50a	0.630a	3.24b	5.623b	0.393d	0.883a	0.200e	2.150a
Calcium sulphate	3.16b	1.67d	0.57a	0.380cd	3.40b	4.083c	0.650b	0.407c	1.86c	0.087b
Calcium nitrate	3.13b	1.80c	0.25b	0.423bc	3.85c	6.323a	0.487c	0.460b	3.22a	0.133b
Calcium chloride	3.81a	1.92b	0.53a	0.460b	4.52a	3.683d	0.703a	0.460b	2.15b	0.143b

  

Treatments	Fe (mg / kg d.w.)		Mn (mg / kg d.w.)		Cu (mg / kg d.w.)		Zn (mg / kg d.w.)		Total crude protein	
	leaf	fruit	leaf	fruit	leaf	fruit	leaf	fruit	leaf	fruit
Control	389.65a	un	33.77c	15.400c	12.09d	6.106e	4.29c	un	23.00a	8.97e
Calcium superphosphate	51.39e	284.72a	15.44e	37.723a	16.32a	14.083a	5.00c	13.35	11.52c	17.02a
Calcium sulphate	377.80b	17.26c	37.90a	14.723d	13.72c	8.586d	9.48b	un	19.77b	10.43d
Calcium nitrate	338.46d	15.856d	31.97d	16.723b	11.65e	12.070b	47.92a	un	19.56b	11.25c
Calcium chloride	361.95c	27.55b	37.15b	14.423e	15.02b	9.483c	un	un	23.83a	12.02b

un= undetected.

Means followed by different letters are significantly different at  $P \leq 0.05$  level; Tukey's HSD test.

et al. (2014) showed that the exogenous supply of 5 mM calcium sulphate under non-saline conditions through the rooting medium significantly increased the plant and leaf dry weights production of tomato genotypes.

The obtained results presented in Tables 2 and 3 are in line with the previous results of calcium nitrate treatment confirmed by El-Hadidi et al. (2017) who showed that calcium nitrate foliar supplies achieved a significant increase in potato plant fresh and dry weights, number of leaves, leaf area, tubers yield per plant, average weight of tuber and fresh tuber yield. Likewise, Abd-El-Hamied and Abd El-Hady (2018) found that the plant height, leaf fresh weight, fruits weight and yields of tomato were significantly increased by calcium nitrate foliar applications at 0.3 and 0.6%. Similar result has been found on cucumber fruits number per plant, average fruit weight and total fruits yield per plant to increase using calcium nitrate foliar application at 15 mM (Shafeek et al., 2013).

Calcium chloride foliar spray had a positive effect on vegetative growth parameters and yield components (Tables 2 and 3). This is in agreement with the results of El-Tohamy et al. (2006) on sweet pepper, Rab and Haq (2012) on tomato and Salim et al. (2019) on hot pepper. They observed that spraying calcium chloride enhanced the vegetative growth characteristics and fruits yield as compared with the control plants. Also, spraying lettuce with 20 mM  $\text{CaCl}_2$  significantly increased plant length, number of leaves/head, fresh and dry weights of head and average leaf area (Youssef et al., 2017).

These results involve the physiological functions of  $\text{Ca}^{+2}$  in regulating various physiological processes during growth and development stages, as cell walls and plasma membrane formation and functions stabilize bio membranes, plant cell division and elongation, synergism other nutrients uptake, activation of various enzymatic systems, biomass production, pollen growth and

senescence (Johnson and Uriu 1989; Reddy and Reddy, 2001; Marisa et al., 2015).

Different calcium sources foliar applications have a positive impact on photosynthetic pigments, that is, chlorophyll a, b, total chlorophylls and carotenoids (Table 4). This is in agreement with the results of spraying calcium nitrate of El-Hadidi et al. (2017) who found a significant increase in chlorophyll a, b and total chlorophylls of potato leaves under non-saline conditions. Also, total chlorophyll was significantly increased under calcium superphosphate foliar spray on sweet pepper (El-Tohamy et al., 2006) and in cotton leaves (Sawan et al., 2008). Also, calcium sulfate has been considered a better form to achieve a significant increase in chlorophyll concentration and protecting the photosynthetic pigments in strawberry plants under salt stress (Khayyat et al., 2009) and on tomato (Manaa et al., 2014). Also, a significant increase in chlorophyll pigments concentration produced on lettuce by spraying calcium chloride at 20 mM was observed by Youssef et al. (2017).

Manaa et al. (2014) observed that leaf sugars and proline concentrations of tomato genotypes increased significantly under the exogenous application of  $\text{CaSO}_4$  at 5 mM. Also, Nasrollahzadeh-asl et al. (2015) found a high significant increase in the percentage of sugars fruit (3.57) in greenhouse cucumber plants sprayed with calcium nitrate as compared with (2.88) in non-sprayed plants. However, proline concentration in sweet pepper fruits decreased by foliar Ca application at 4.3  $\text{g l}^{-1}$  (Piñero et al., 2018). The concentration of free amino acids, that is, arginine, alanine, aspartic acid, cysteine, glutamic acid, isoleucine, leucine, phenylalanine, methionine, proline, glycine, and tyrosine were decreased and the total protein in fruits of sweet pepper was not affected by foliar Ca application (Piñero et al., 2018).

Nutrients uptake was affected with  $\text{Ca}^{+2}$  applications as observed by Dong et al. (2005). They found that the

concentrations of P, K, Mg, Fe, Mn, Zn and Cu were significantly affected in tomato by calcium nitrate application. In addition, Tuna et al. (2007) found that the concentration of N, K and Ca in tomato leaves increased by calcium sulphate supply. Also, N and K uptake by cotton plants enhanced significantly under spraying calcium superphosphate applications (Sawan et al., 2008). The concentration of Fe in strawberry shoots was significantly decreased using calcium sulphate at 5 and 10 mM (Khayyat et al., 2009).

Likewise, macronutrients uptake, that is, N, P, K, Ca and Mg were significantly increased in leaves and tubers of potato sprayed with calcium nitrate (El-Hadidi et al., 2017). Also, Youssef et al. (2017) indicated that calcium chloride at 20 mM foliar application significantly increased N, P, K, Mg, Ca, Fe, Zn, Mn and Cu concentrations in lettuce leaves. In this regard, Marisa et al. (2015) indicated that, Ca<sup>2+</sup> sources had positive effects on roots development and leaf mineral concentration.

## Conclusion

Based on the results of the present study, it can be concluded that foliar applications with different calcium sources, that is, calcium superphosphate (3.96 mM Ca<sup>2+</sup>), calcium sulphate (5.81 mM Ca<sup>2+</sup>), calcium nitrate (6.1 mM Ca<sup>2+</sup>) and calcium chloride (9.09 mM Ca<sup>2+</sup>) stimulated the vegetative growth characteristics and increased the endogenous photosynthetic pigments forms as chlorophyll a, b, total chlorophylls, total carotenoids, leaves and fruits mineral composition and fruits yield as compared with the check plants. Therefore, it can be suggested that foliar applications of the different Ca<sup>2+</sup> sources especially, calcium superphosphate (3.96 mM Ca<sup>2+</sup>), can be used as applicable method, which gave the highest values of growth characteristics and yield components under these experiment conditions in this study.

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