# Effect of Different Calcium Sources on some Soil Chemical Properties and Garlic (*Allium sativum* L.) Productivity Under Saline Soil Conditions

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## ABSTRACT

**Two field experiments were carried out at El- Road village, Sahl El-Hossinia, El-Sharkia Governorate, Egypt, during two winter growing seasons: 2017/18 and 2018/2019 to study the effect of different calcium sources (calcium sulphate, calcium phosphate and calcium nitrate) at different rates (0, 100, 200 and 300 kg/fed) on some soil properties and garlic plants productivity under saline soil conditions. The experiment was laid out in a split plot design with three replicates. The results showed that applications of different calcium sources at high rates decreased soil salinity and increased available macro and micronutrients contents in soil. The plant height (cm), No. of leaves/plant, No. of cloves / bulb and bulb diameter (cm) were increased with increasing calcium sources rates due to more reduction in soil salinity. While the application of the three calcium sources significantly increased fresh and dry weight of garlic bulb /plant (g) of the two growing seasons, the weight of garlic clover /plant (g) and bulb yield (ton/fed) significantly increased with increasing application rates of each calcium source in the second season. The interaction between calcium sources and rates showed significant increases in N, P and K concentration of bulb plants and significant decreases in $Na^+$ concentration at both seasons. Calcium sulphate application reduced proline content, while chlorophyll contents were increased. Calcium nitrate application increased the protein contents (%) of garlic plants. These results cleared that calcium sulphate, calcium phosphate and calcium nitrate can be used at a rate of 300 kg/fed to improve soil properties and to increase yield and yield components of garlic plant grown under saline soil condition.**


**Keywords: calcium sulphate, calcium phosphate, calcium nitrate, garlic productivity, saline soil properties.**

## INTRODUCTION

Salt affected soils represent about 30 % of the total cultivated area in Egypt and 37% of the total cultivated soils in Nile Delta, The North Delta contains the highest area of saline and saline-sodic soils (46%), (FAO, 2005). Sodic soils reclamation involves substituting sodium in the soil with calcium ions, through applying large quantities of gypsum ($CaSO_4.2H_2O$). The released sodium ions are then leached deep beyond the root zone using excess water and moved out of the field through drainage (Manuel and Ricardo, 2017).

Calcium is an essential plant nutrient. It plays many important roles in plant such as, participation in the metabolic process of another nutrient uptake, promotion of proper plant cell elongation, strengthen cell wall, and participation in an enzymatic and hormonal process. High levels of $Ca^{2+}$ can alter both growth and $Na^+$ exclusion of plant roots exposed to NaCl stress (Mahajan et al., 2008).

Use of calcium salphate improve soil physical and chemical properties, mainly in terms of reduction in sodium concentration and reduced salt concentration, that may enhance soil permeability, hence increase leaching of the salts (Muya and Macharia, 2003).

Calcium phosphate is necessary to stimulate early root formation and growth, hasten crop maturity, stimulate flowering and seed production, give winter hardiness to fall plantings and seeding, and promote vigorous start (cell division) to plants. Phosphorus has a role in fat, carbon, hydrogen, and oxygen metabolism, in respiration, and in photosynthesis (Sandhya, 2014). $Ca(NO_3)_2$ can significantly improve the variables affected by high salinity (e.g. plant growth, fruit yield, and membrane permeability) and can also correct both Ca and N deficiencies (Cengiz and David, 2006).

Garlic (*Allium sativum* L.) is one of the most important bulb vegetable crops and is next to onion (*Allium cepa*) in importance (Hamma et al., 2013). Egypt is ranked as the fourth leading country around the world for garlic production (244.626 ton) after China, India and North Korea (FAO, 2011). It has been reported that the total world harvested area was 1,547,381 ha with an annual production of 24,939,965 tones of bulbs in 2014 while the harvested area in Egypt was 10,997 ha with production of 263,167 tons (FAO, 2014). Growing garlic in the newly reclaimed soils is faced by various problems, such as low availability of nutrients and poor organic matter content as well as poor hydro physical, chemical and biological soil properties (Shafeek et al., 2015). Francois (1994) found that the effect of soil salinity at 7.4 $dSm^{-1}$ reduced the garlic yield by 50% as well as the yield components, bulb weight and diameter, and number of plants per unit area, as well as percent of solids, which is a major component of bulb quality. Abo El-Fadel and Mohamed (2013) reported that the increased salt concentrations can lead

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to a reduction in evapotranspiration, disturbances in mineral nutrition of plants, plant hormone imbalance, and formation of free radicals that damage cell membranes of garlic plants. Fusun et al., (2010) reported that garlic shoot and root fresh weight, shoot and root dry weight, root and shoot length and leaf number were significantly enhanced by the Ca $(NO_3)_2$ treatment. Javad (2014) indicated that the concentration of calcium ion is very important in increasing the plant resistance for soil salinity. Calcium is one of the elements which has protective effects on plants roots and causes the plant to survive under the high saline conditions.

This work aimed to investigate the effect of three calcium sources (Ca SO4, $(CaNO_3)_2$, $(CaSO_4.2H_2O)$) at different application rates on some soil properties and yield and yield components of garlic (*Allium sativum* L.*)* grown in a salt affected soil.

## MATERIALS AND METHODS

Two field experiments were conducted in clay saline soil at Sahl El-Hussinia Agric. Res. Station, Center in El-Sharkia Governorate, Egypt; during the tow growing seasons, 2017/2018 and 2018/2019, to study the effect of different calcium sources at different rates on clay saline soil fertility and garlic (*Allium sativum* L.*)* productivity. The experimental site is located at El-Road village, Shal El-Hussinia (31º 8' 12.461" N and 31º 52' 15.496" E). The field experiments were arranged in a split plot design with three replicates where the sources were placed at the main plots and rates were replaced at the sub main plots.

Some soil physical and chemical properties of studied soil before planting were determined according to the methods described by Cottenie *et al.* (1982) and Page *et al.* (1982) and presented in Table 1.

**Treatments:**

The treatments were laid in plots with area of 12 $m^2$ and the applications were during land preparation and 15 days before planting as follows:

1- Calcium sulphate $(CaSO_4.2H_2O)$at rates of (0 , 100 , 200 and 300 kg/fed)
2- Calcium phosphate $Ca(H_2PO_4)_2$ at a rates of (0, 100, 200 and 300 kg/fed) and
3- Calcium nitrate $(CaNO_3)_2$ at a rates of (0, 100, 200 and 300 kg /fed). All treatments were applied before 15 days form planting during tillage soil.

The mineral fertilizers, at the recommended rates, for garlic plants were used. Urea (46 % N) was added at a rate of 100 kg/fed three times after 31, 45 and 65 days from sowing. Potassium sulphate (48 % $K_2O$) was added at rates of 50 $K_2O$ /fed two equal doses after 31 and 45 days from planting.

a local garlic variety called White Skin color garlic supplied from Horticulture Research Institute, Agriculture Research Center (ARC) Giza, Egypt. Sowing was carried out at 15 October 2016/2017 and 2017/ 2018. Two to three cloves were sown in a hole with 5 cm depth and 25 cm after on the two sides of each ridge. After 25 days from planting, the plants of each hole were thinned to one seedling. At harvest after 160 days and after curing period (20 days) the plant height (cm), No. of leaves/ plant, No. of clovers /bulb , total yield ton/fed, weight of fresh and dry bulbs (g), bulb diameter (cm) and weight of clover (g) were determined.

**Table 1. Soil physical and chemical characteristics of the studied soil (mean values of the two growing seasons)**

| Physical properties | | Chemical properties | | | |
|---|---|---|---|---|---|
| Particle size distribution | | O.M (%) | 0.58 | pH (1:2:5) | 8.03 |
| Crosse sand (%) | 4.08 | $CaCO_3$ (%) | 13.66 | EC (dS/m) | 10.66 |
| Fin sand (%) | 25.97 | | Cations (meq/l) | | |
| Silt (%) | 31.61 | $Ca^{++}$ | 8.29 | $Na^+$ | 69.20 |
| Clay (%) | 38.34 | $Mg^{++}$ | 18.35 | $K^+$ | 10.8 |
| Texture | Clay loam | | Anions (meq/l) | | |
| F.C. | 31.25 | $HCO^-_3$ | 10.66 | $SO^{--}_4$ | 33.05 |
| W.P. | 14.96 | $Cl^-$ | 62.89 | | |
| A.W. | 16.29 | | Available macronutrients (mg/kg) | | |
| B.D ($g/cm^3$) | 1.42 | N | 38.94 | K | 186 |
| T.P (%)46.92 | | P | 4.58 | | |
| | | | Available micronutrients (mg/kg) | | |
| | | Fe | 3.10 | Mn | 2.46 |
| | | Zn | 0.57 | Cu | 1.26 |

A 0.5 g of each oven dried cloves sample was digested using $H_2SO_4$, $HClO_4$ mixture according to the method described by Chapman and Pratt (1961). Then plant content of N, P, K, Fe, Mn, Zn and Cu was determined in the plant digest using the methods described by Cottenie *et al*. (1982) and Page *et al*., (1982). Proline content was estimated according to the methods described by Bates *et al.,* (1973). Photosynthetic total chlorophyll was estimated in fresh leaves as described by Witham et al., (1971). Protein percentage of cloves was calculated by multiplying the nitrogen percentage by the factor 6.25, (Hymowitz et al., 1972).

Data were analyzed by MSTATC computer software program (Bricker, 1991) using ANOVA with the least significant difference (LSD) at $P \leq 0.05$.

## RESULTS AND DISCUSSION

**Effects of different calcium sources and application rates on soil properties after harvesting.**

**Soil pH.**

Data presented in Table (2) showed that soil pH was decreased with increasing rates of calcium sources. The application of calcium sources minimized soil pH from to 8.01 to 7.83 for soil treated with calcium sulphate, 8.02 to 7.85 for soil treated with calcium phosphate and 8.02 to 7.94 for soil treated with calcium nitrate. Rasouli et al., (2013) indicated that the decrease of soil pH reflect the effect of calcium ions that react with bicarbonate to precipitate as calcite then the protons ($H^+$) would be released in soil solution which neutralize the hydroxide ions ($OH^-$ ) consequently, decrease the soil pH. The slight decreases in soil pH may be due to that anions of sulfate were released from calcium sulfate in soil solution. Nitrate and phosphate also reflect its acidic effect on soil solution consequently decrease soil pH. On the other hand replacing the cation $Ca^{++}$ to exchange $Na^+$ on soil particles likewise might lead to a decrease in soil alkalinity.

**Soil salinity:**

The pertinent data in Table (2) elucidated that the application of different calcium sources markedly diminished EC of the soil by more than double-fold according to ($CaSO_4.2H_2O$) as the highest rate of addition. The same trend on EC was observed with the other two sources of Ca, Ca ($H_2PO_4$) followed by $Ca(NO_3)$. The beneficial effect of added Ca sources on decreasing EC in the soil may be attributed to leaching the $Na^+$ from the soil profile resulted from substitution of $Ca^{++}$. The interaction between calcium sources and rates on saline soil were significantly decreased with increasing rates.

**Table 2. Soil pH, EC and available macronutrients content mg/kg in soil after harvesting in the two growing season**

| Treatments | Rate kg/fed | pH (1:2.5) | | EC ($dSm^{-1}$) | | Macronutrients ($mg\ kg^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | N | | P | | K | |
| | | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 | S1 | S2 |
| Calcium Sulphate | 0 | 8.01 | 7.98 | 8.52 | 7.85 | 39.85 | 41.82 | 4.79 | 4.88 | 193.00 | 198.00 |
| | 100 | 7.95 | 7.94 | 6.95 | 5.30 | 42.13 | 44.52 | 4.85 | 5.09 | 196.00 | 203.00 |
| | 200 | 7.92 | 7.88 | 5.30 | 4.22 | 44.86 | 47.31 | 5.12 | 5.32 | 198.00 | 208.00 |
| | 300 | 7.89 | 7.83 | 3.62 | 3.20 | 46.52 | 49.52 | 5.26 | 5.75 | 205.00 | 213.00 |
| Mean | | -- | ---- | 6.10 | 5.14 | 43.34 | 45.79 | 5.01 | 5.26 | 198.00 | 205.50 |
| Calcium phosphate | 0 | 8.02 | 8.00 | 8.85 | 8.17 | 38.60 | 40.96 | 4.70 | 4.93 | 190.00 | 194.00 |
| | 100 | 7.98 | 7.97 | 7.14 | 6.36 | 41.37 | 43.12 | 4.93 | 5.07 | 194.00 | 198.00 |
| | 200 | 7.96 | 7.93 | 6.20 | 5.52 | 43.68 | 44.85 | 5.17 | 5.30 | 199.00 | 204.00 |
| | 300 | 7.93 | 7.85 | 5.35 | 4.39 | 44.10 | 46.37 | 5.29 | 5.73 | 203.00 | 209.00 |
| Mean | | -- | --- | 6.89 | 6.11 | 41.94 | 43.83 | 5.02 | 5.26 | 196.50 | 201.25 |
| Calcium nitrate | 0 | 8.02 | 8.01 | 8.75 | 8.22 | 38.12 | 40.13 | 4.65 | 4.82 | 189.00 | 193.00 |
| | 100 | 8.01 | 7.98 | 7.85 | 6.59 | 40.85 | 43.87 | 4.79 | 4.98 | 190.00 | 195.00 |
| | 200 | 7.97 | 7.96 | 6.41 | 5.98 | 41.32 | 45.12 | 4.89 | 5.20 | 197.00 | 201.00 |
| | 300 | 7.95 | 7.94 | 6.24 | 5.14 | 42.77 | 46.95 | 5.12 | 5.34 | 200.00 | 206.00 |
| Mean | | | | 7.31 | 6.48 | 40.77 | 44.02 | 4.86 | 5.09 | 194.00 | 198.75 |
| LSD. 0.05 treatments | | ---- | ---- | ns | ns | ns | ns | ns | 0.08 | ns | ns |
| LSD. 0.05 Rates | | ---- | ---- | ns | ns | ns | ns | ns | 0.06 | ns | 1.18 |
| Interaction | | ---- | ----- | *** | *** | *** | *** | *** | *** | *** | *** |

On the other hand, the relative decreases of mean EC values in the soil was 37.91 and 45.99 % for soil treated with different calcium sulphat rates in first and second seasons respectively, compared to control . Also, the relative decreases of mean EC values were 29.60 and 33.66 % for soil treated with calcium phosphate at different rates in first and second seasons compared to the control. As well as, corresponding relative decreases of mean values soil EC ($dSm^{-1}$) were 21.94 and 28.22 % for soil treated with calcium nitrate at different rates compared to the control in first and second seasons. These results are in agreement with Abd El-Azeem and Ramadan (2018) who found that the application of calcium sulphate to saline soil led to decrease soil salinity. Ardakani and Zhirnia (2006) reported that the application of calcium sulphate led to removal of excess salts into drainage. Giovanina et al (2012) revealed that the application of calcium sulphate to saline soil was the decreasing percentage of soil salinity with irrigation water for a long time. Abou Yuossef (2001) indicated that the applied phosphogypsum decreased soil pH, EC, ESP and bulk density with increasing phosphogypsum rate. However, hydraulic conductivity, total porosity, mean weight diameter of soil aggregates, geometric mean diameter and water stable aggregates are also, increased (Ahmad et al., 2001 and Abd El- Fattah, 2014).

**Available macronutrients in soil.**

Data presented in Table (2) showed that N, P and K availability (mg $kg^{-1}$) in the studied soil as affected by calcium sources at different rates. Generally, it is clear from these data that the application of different calcium sources at different rates had no significant effect on the amount of available N, P and K in treated soil. The interaction between calcium sources and its different rates included a significant increase of N, P and K content in soil. The relative increases of mean values were 11.67 and 12.67 % for N, 6.05 and 10.45 % for P and 3.46 and 5.05 % for available K contents in soil first and second seasons respectively as soil treated with calcium sulphate compared to the soil treated without calcium sulphate. Concerning that the relative increases of mean values were 11.53 and 9.33 % for N; 9.15 and 8.92 % for P and 4.56 and 4.98 % for K contents in soil treated with calcium phosphate at different rates in first and second seasons compared to the soil received no calcium phosphate. Also, the relative increases of mean values were 9.26 and 12.91 % for N; 6.02 and 7.26 % for P and 3.53 and 3.97 % for K contents in soil treated with calcium nitrate in first second seasons respectively, compared to the soil without calcium nitrate.

In general, the positive effects of the used calcium sources at different rates on available N, P and K could be arranged in the following order:

Calcium sulphate> calcium phosphate > calcium nitrate > without Ca for N and P in both seasons; Calcium phosphate > calcium sulphate > calcium nitrate > without Ca for P in first season and Calcium phosphate > calcium nitrate > calcium sulphate > without Ca for K in first season. As well as, the relative increases in soil available N and K contents in soil after garlic harvest in second season could be arranged in the folloing order: Calcium nitrate > calcium sulphate > calcium phosphate > without. These results are in agreement with El-Kouny (2009) who indicated that application of calcium sulphate increased availability N, P and K in soil as compared with the control. Abd El-Azeem and Ramadan (2018) revealed that application of calcium sulphate treatment the maximum accumulation of available N, P and K, especially at the high rate.

**Available micronutrients in soil.**

Table (3) showed that significant pronounced increases in soil available micronutrients i.e. Fe, Mn and Zn were occurred as affected by addition of the different calcium sources with different rates. It's clear, therefore that the amount of the available Fe, Mn and Zn in soil tend to increase with increasing the application rates of calcium sources as determined after harvesting garlic plants. These increases may be attributed to improvement of the availability of nutrients in soil as a result of reduction of soil pH. The highest effect of calcium sources on the availability of micronutrients was detected due to application of calcium sulphate on the soil.

It ought to be mentioned that a promotion in the determined Fe, Mn and Zn were detected with increasing the rates of Ca sources in both seasons. On the other hand, the interaction between calcium sources and its different application rates led to a significant enhancement of available Mn in both seasons, while Fe showed significant increases in the second season and for Fe and Zn in first one. The relative increases of mean values were 12.06 and 14.24 % for Fe; 13.73 and 15.44 % for Mn and 16.95 and 17.74 % for Zn contents in soil treated with calcium sulphate at different rates in first and second seasons compared to the control. Also, the relative increases of mean values for Fe were 4.18 and 4.71 %; 20.65 and 13.78 % for Mn and 13.79 and 14.75 % for Zn respectively, in soil treated with calcium phosphate at different rates in the first and second seasons compared to soil received no Ca sources. As well as, the relative increases of mean values for Fe, Mn and Zn contents in soil treated with calcium nitrate were

**Table 3. Available Micronutrients contents in soil after harvesting as affected by application of different Ca sources in the two growing seasons S1 and S2**

| Treatments | Rate kg/fed | Micronutrients (mg kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fe | | Mn | | Zn | |
| | | S1 | S2 | S1 | S2 | S1 | S2 |
| Calcium sulphate | 0 | 3.40 | 3.44 | 2.55 | 2.59 | 0.59 | 0.62 |
| | 100 | 3.68 | 3.81 | 2.86 | 2.93 | 0.65 | 0.68 |
| | 200 | 3.87 | 3.96 | 2.88 | 2.98 | 0.69 | 0.72 |
| | 300 | 3.89 | 4.03 | 2.95 | 3.05 | 0.73 | 0.78 |
| Mean | | 3.71 | 3.81 | 2.81 | 2.89 | 0.67 | 0.70 |
| Calcium phosphate | 0 | 3.35 | 3.40 | 2.47 | 2.54 | 0.58 | 0.61 |
| | 100 | 3.39 | 3.49 | 2.53 | 2.84 | 0.63 | 0.66 |
| | 200 | 3.48 | 3.52 | 2.66 | 2.88 | 0.65 | 0.70 |
| | 300 | 3.59 | 3.66 | 3.75 | 2.95 | 0.70 | 0.74 |
| Mean | | 3.45 | 3.52 | 2.85 | 2.80 | 0.64 | 0.68 |
| Calcium nitrate | 0 | 3.33 | 3.36 | 2.45 | 2.53 | 0.59 | 0.60 |
| | 100 | 3.38 | 3.42 | 2.51 | 2.81 | 0.62 | 0.64 |
| | 200 | 3.46 | 3.55 | 2.63 | 2.88 | 0.63 | 0.68 |
| | 300 | 3.55 | 3.61 | 2.74 | 2.93 | 0.69 | 0.73 |
| Mean | | 3.43 | 3.49 | 2.58 | 2.79 | 0.63 | 0.66 |
| LSD. 0.05 treatments | | 1.16 | 0.04 | 0.03 | 0.02 | 0.01 | 0.014 |
| LSD. 0.05 Rates | | 0.12 | 0.02 | 0.02 | 0.01 | 0.009 | 0.013 |
| Interaction | | ns | *** | *** | ** | ** | ns |

3.90 and 5.06 % for Fe; 7.35 and 13.44 % for Mn and 10.17 and 13.33 % for Zn in first and second seasons respectively compared to the soil without addition. The relative increases of available Fe, Mn and Zn contents in soil as affected by different Ca sources can be arranged in the following order:

Calcium sulphate > calcium phosphate > calcium nitrate > control in first and second seasons, in both seasons except Fe content in soil treated with Calcium sulphate > calcium nitrate > calcium sulphate > control in second season.

The relative increases in soil the amount of available Fe, Mn and Zn as results of using the calcium sources may be due to decrease in soil pH and salinity. Theses results are in consequence with Abd El-Azeem and Ramadan (2018) who indicated that the application of calcium Sulphate led to increase of soil available Fe, Mn and Zn contents.

**Garlic plants growth**

Direct effects of the used different calcium sources and rates on garlic productivity grown under saline soil are shown in Table (4) which showed that the Plant height (cm), No. of leaves/plant, No. of cloves / bulb and Bulb diameter (cm) were increased with increasing calcium sources rates due to more reduction in soil salinity. Results appeared that the influence of application of different calcium sources on No. leaves/plant and No. clover /bulb were significant in second season, while, the plant height (cm) and bulb diameter (cm) showed no significant response in both the seasons. Also, No. leaves/plant and No. clover /bulb were significantly increased with increasing rate of Ca sources in both seasons, while the Plant height (cm) and Bulb diameter (cm) were significantly affected in first seasons. The interaction between the different sources and rates on plant parameters were significant.

Application of 300 kg ($CaSO_4.2H_2O$) /fed produced the maximum values for plant height (cm), No. of leaves /plant, No. of clover /bulb and Bulb diameter (cm). Theses result may be due to that ($CaSO_4.2H_2O$) has an important role in alleviation the adverse effect of salinity on the growth of garlic plants, also the important role of $SO_4^{--}$ in formation $H_2SO_4$, which, led to reduction of soil pH, consequently enhancing the availability of nutrients in soil and its uptake by plants. These results are in agreement with those reported by Ghoname et al. (2007) who indicated that calcium application to soil significantly increased plant length, leaves number, leaves fresh and dry weight. Magray et al. (2017) reported that the application of sulphur produced significant increases for number of clover/ bulb and diameter bulb.

**Table 4. Effect of calcium sources at different rates on morphology bulb plants of garlic**

| Treatments | Rate kg/fed | Plant height (cm) | | No. of leaves/plant | | No. of cloves / bulb | | Bulb diameter (cm) | |
|---|---|---|---|---|---|---|---|---|---|
| | Seasons | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Calcium sulphate | 0 | 67.34 | 69.85 | 6.15 | 6.22 | 18.37 | 19.63 | 5.12 | 5.55 |
| | 100 | 85.39 | 89.34 | 7.39 | 8.39 | 22.84 | 24.52 | 5.80 | 6.45 |
| | 200 | 91.78 | 95.81 | 8.22 | 9.55 | 29.34 | 32.41 | 6.14 | 7.95 |
| | 300 | 94.37 | 98.72 | 9.00 | 10.40 | 32.17 | 36.75 | 7.52 | 8.67 |
| Mean | | 84.72 | 88.43 | 7.69 | 8.64 | 25.68 | 28.33 | 6.15 | 7.16 |
| Calcium phosphate | 0 | 65.79 | 67.32 | 6.11 | 6.17 | 16.85 | 17.64 | 5.10 | 5.23 |
| | 100 | 75.34 | 79.52 | 7.10 | 8.15 | 19.87 | 21.50 | 5.66 | 5.88 |
| | 200 | 83.49 | 89.87 | 7.89 | 8.88 | 23.47 | 25.00 | 5.95 | 6.45 |
| | 300 | 88.10 | 93.75 | 8.30 | 9.70 | 25.63 | 27.65 | 6.22 | 7.52 |
| Mean | | 78.18 | 82.62 | 7.35 | 8.23 | 21.46 | 22.95 | 5.73 | 6.27 |
| Calcium nitrate | 0 | 66.79 | 69.38 | 6.14 | 6.19 | 17.94 | 18.00 | 5.13 | 5.41 |
| | 100 | 79.34 | 83.74 | 7.35 | 8.65 | 20.63 | 23.47 | 5.75 | 5.99 |
| | 200 | 84.65 | 90.44 | 8.00 | 9.25 | 26.47 | 28.10 | 6.10 | 7.88 |
| | 300 | 89.72 | 93.55 | 8.75 | 9.89 | 29.75 | 29.88 | 6.98 | 7.97 |
| Mean | | 80.13 | 84.28 | 7.56 | 8.50 | 23.70 | 24.86 | 5.99 | 6.81 |
| LSD. 0.05 treatments | | ns | ns | ns | 0.06 | ns | 1.30 | ns | ns |
| LSD. 0.05 Rates | | 1.67 | ns | 0.34 | 0.19 | 1.26 | 1.91 | 0.34 | ns |
| Interaction | | *** | *** | *** | *** | *** | *** | *** | *** |

**Yield and yield component.**

Table (5) showed that the values of fresh and dry weight of garlic clover (g/plant) and bulb yield (ton/fed) of the two growing seasons increased with increasing the different rates of calcium sources. The highest mean values of fresh and dry weight bulb, weight of clover (g/plant) and bulb yield (ton/fed) with soil treated with calcium sulphate at rate 300 kg /fed compared to other treatments. The effect of different calcium sources on fresh, dry and weight clover (g/plant) showed no significant effect in both seasons, while the yield of bulb (ton/fed) significantly increased in the two growing seasons.

**Table 5. Effect of calcium sources at different rates on yield component bulb of garlic plants**

| Treatments | Rate kg/fed | Weight of fresh bulb (g) | | Weight of dry bulb (g) | | Weight of Clover (g) | | Bulb yield (ton/fed) | |
|---|---|---|---|---|---|---|---|---|---|
| | Seasons | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Calcium sulphate | 0 | 64.39 | 65.00 | 30.62 | 32.47 | 1.12 | 1.15 | 6.35 | 6.40 |
| | 100 | 75.34 | 79.52 | 36.21 | 38.52 | 2.85 | 3.14 | 7.10 | 7.88 |
| | 200 | 82.10 | 86.34 | 39.85 | 41.95 | 3.55 | 3.88 | 7.59 | 7.93 |
| | 300 | 83.62 | 89.25 | 42.38 | 44.63 | 3.85 | 3.96 | 8.00 | 9.25 |
| Mean | | 76.36 | 80.03 | 37.27 | 39.39 | 2.84 | 3.03 | 7.26 | 7.87 |
| Calcium phosphate | 0 | 62.47 | 63.89 | 29.55 | 30.88 | 1.09 | 1.12 | 5.98 | 6.13 |
| | 100 | 69.58 | 73.41 | 34.66 | 36.75 | 1.85 | 1.92 | 6.75 | 7.22 |
| | 200 | 74.62 | 78.63 | 38.75 | 39.11 | 1.96 | 2.10 | 7.26 | 7.66 |
| | 300 | 80.34 | 85.00 | 41.82 | 43.85 | 2.08 | 2.89 | 7.45 | 7.95 |
| Mean | | 71.75 | 75.23 | 36.20 | 37.65 | 1.75 | 2.01 | 6.86 | 7.24 |
| Calcium nitrate | 0 | 63.95 | 64.84 | 30.00 | 31.55 | 1.11 | 1.14 | 6.17 | 6.22 |
| | 100 | 72.45 | 76.32 | 34.89 | 36.99 | 2.96 | 3.11 | 6.95 | 7.65 |
| | 200 | 79.63 | 84.33 | 38.98 | 40.23 | 3.10 | 3.65 | 7.32 | 7.84 |
| | 300 | 82.10 | 86.75 | 40.33 | 44.20 | 3.67 | 3.95 | 7.80 | 8.10 |
| Mean | | 74.53 | 78.06 | 36.05 | 38.24 | 2.71 | 2.96 | 7.06 | 7.45 |
| LSD. 0.05 treatments | | ns | ns | ns | ns | ns | ns | ns | 0.22 |
| LSD. 0.05 Rates | | 1.37 | 1.73 | 0.74 | ns | ns | 0.30 | ns | 0.38 |
| Interaction | | *** | ** | *** | ** | *** | ** | *** | ** |

Also, the different application rates of calcium sources significantly augmented weight of fresh bulb /plant (g) and dry weight of bulb /plant (g) in both season, on other hand the weight of clover /plant (g) and bulb yield (ton/fed) were significant promoted with increasing rates of calcium sources in second season. As well as, the positive interaction effect between different calcium sources and different rates on fresh, dry, weight clover (g/plant) and bulb yield (ton/fed) were significant in both seasons.

The relative increases of mean values were 24.79 and 30.83% for fresh weight of bulb (g/plant); 28.94 and 28.43 % for dry bulb (g /plant); 205.36 % and 218.26 % for clover weight (g/plant) and 19.06 and 30.47 for yield bulb (ton/fed) in the first and the second growing seasons, respectively as affected by application of calcium sulphate compared to the treatments without calcium sulphate. Also, the relative increases of mean values were 19.82 and 23.67 % for fresh weight of bulb g/plant ; 29.98 and 29.21 % for dry bulb g /plant ; 79.82 % and 105.36 % for clover weight (g/plant) and 19.57 and 24.14 for yield bulb ton/fed respectively in first and second seasons as affected by application of calcium phosphate compared to the control.

As well as, the relative increases of mean vales were 22.06 and 27.19 % for fresh weight of bulb g/plant; 26.90 and 28.27 % for dry bulb g /plant; 191.89 and 213.16 % for clover weight (g/plant) and 19.29 and 26.37 for yield bulb ton/fed respectively in first and second seasons as affected with applied calcium nitrate compared to the soil without calcium nitrate.

These results may be due to calcium action as the main cofactors in plants for many metabolism reactions (e.g., energy reactions in metabolism, enzymatic reaction and synthesis of protein and nucleic acid. These results are in coincidence with Mesbah (2016) who indicated that the application of ($CaSO_4.2H_2O$) led to alleviate the high salt concentrations in the soil solution and enhance yield traits plant. The beneficial influence of Ca sources on plant yield followed the orders:

i. Calcium sulphate > calcium nitrate >calcium phosphate> control in both seasons for fresh and clover weight (g /plant).
ii. Calcium phosphate > calcium sulphate > calcium nitrate > control in both seasons for dry bulb /plant.
iii. Calcium phosphate > calcium intrate > calcium sulphate> control in first season for yield.
iv. Calcium sulphate > calcium nitrate > calcium phosphate > without in second season yield.

Ca application positively affected onion growth parameters, i. e., plant length, number of leaves, and neck and bulb diameter as well as fresh and dry weight of onion plant. Calcium nitrate was very beneficial in reducing flaking and increasing exportable portion of the yield (Ghoname et al. 2007). Zaman et al. (2011) found that the increase in the rate of sulphur up to 45 kg/ha led to increase bulb yield. Ghoname et al. (2007) reported that application of calcium nitrate gave the highest total yield and bulb weight in both seasons. Addition of supplementary calcium nitrate at 1 g $kg^{-1}$ to salt stressed plants resulted in increased total dry weight and chlorophyll concentrations compared to high salt treatments. Sandhya (2014) reported that the tri- calcium phosphate application has increase effect on increasing root length of mustard plant as compared to control. . Tri-calcium phosphate has shown in good result in shoot and root biomass of mustard plant compared to control. Shah et al. (2007) suggested that the application of calcium phosphate and calcium sulfate to soils tended to ameliorate the detrimental effects of salinity stress on dry matter yield. On the other hand, a decrease in dry matter yield was obtained with calcium nitrate.

**Macronutrients content in bulb plants**

Table (6) showed that the macronutrients concentrations (%) in bulbs were clearly decreased with raising soil salinity in both seasons. The content of N, P and K augmented in second season, while the $Na^+$ content was diminished. These results may be due to the improved of soil properties and increase the available N, P and K. The effect of different calcium sources on P and $Na^+$ concentration in bulb were not significant in both seasons, however the K concentration was significant in both seasons and N concentration was significant in the first one. The different additions rates of calcium sources significantly increased N and P concentration in both seasons, while the K concentration was significant in second one. However, $Na^+$ concentration significantly reduced with raising rates of calcium sources in both seasons. As well as, the interaction between calcium sources and different rates showed a significant enhancing effect of N, P and K concentration in bulb plants, notwithstanding a significant decrease in $Na^+$ concentration in both seasons was noticed.

The relative increases of mean values of N, P and K concentrations in bulb plants were 23.74 and 21.46 % for N ; 40.91 and 34.62 % for P and 7.62 and 7.89 % for K in first and second seasons respectively while the mean value of $Na^+$ decrease were 12.90 and 12.50 % as affected by calcium sulphate compared to soil without

**Table 6. Macronutrients and sodium concentrations in bulbs in the two-growing season S1 and S2**

| Treatments | Rate kg/fed | N (%) | | P (%) | | K (%) | | Na (%) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Calcium sulphate | 0 | 1.98 | 2.05 | 0.22 | 0.26 | 3.14 | 3.17 | 0.93 | 0.88 |
| | 100 | 2.41 | 2.47 | 0.28 | 0.32 | 3.34 | 3.38 | 0.86 | 0.82 |
| | 200 | 2.44 | 2.49 | 0.31 | 0.35 | 3.36 | 3.42 | 0.80 | 0.78 |
| | 300 | 2.49 | 2.52 | 0.35 | 0.38 | 3.45 | 3.47 | 0.78 | 0.72 |
| Mean | | 2.33 | 2.38 | 0.29 | 0.33 | 3.32 | 3.36 | 0.84 | 0.80 |
| Calcium phosphate | 0 | 1.87 | 1.99 | 0.20 | 0.23 | 3.12 | 3.15 | 0.92 | 0.89 |
| | 100 | 2.31 | 2.39 | 0.35 | 0.38 | 3.27 | 3.31 | 0.88 | 0.85 |
| | 200 | 2.36 | 2.44 | 0.39 | 0.41 | 3.38 | 3.42 | 0.83 | 0.81 |
| | 300 | 2.39 | 2.48 | 0.42 | 0.45 | 3.42 | 3.47 | 0.79 | 0.77 |
| Mean | | 2.23 | 2.33 | 0.34 | 0.37 | 3.30 | 3.34 | 0.86 | 0.83 |
| Calcium nitrate | 0 | 1.92 | 2.03 | 0.21 | 0.24 | 3.13 | 3.16 | 0.92 | 0.88 |
| | 100 | 2.49 | 2.53 | 0.27 | 0.30 | 3.28 | 3.33 | 0.89 | 0.86 |
| | 200 | 2.55 | 2.59 | 0.28 | 0.33 | 3.30 | 3.38 | 0.81 | 0.79 |
| | 300 | 2.66 | 2.69 | 0.30 | 0.36 | 3.93 | 3.44 | 0.77 | 0.72 |
| Mean | | 2.41 | 2.46 | 0.27 | 0.31 | 3.41 | 3.33 | 0.85 | 0.81 |
| LSD. 0.05 treatments | | 0.014 | ns | ns | ns | 0.140 | 0.010 | ns | ns |
| LSD. 0.05 Rates | | 0.023 | 0.030 | 0.018 | 0.021 | ns | 0.013 | 0.014 | 0.014 |
| Interaction | | *** | *** | *** | *** | *** | *** | *** | *** |

calcium sulphat. Also the relative increases of mean values were 25.67 and 22.61 for N; 95.00 and 78.26 % for P and 7.69 and 7.94 for K concentration in bulb plants respectively , while the mean values of $Na^+$ decrease were 9.78 and 8.99 % for soil treated with calcium phosphate in first and second seasons compared to soil without calcium phosphate. The corresponding relative increases of mean values N, P and K concentrations were 33.85 and 28.08 % for N ; 33.33 and 37.50 % for P and 11.82 and 6.96 % for K , while the decrease of mean value $Na^+$ concentration in bulb plants was 10.87 and 10.23 in first and second seasons respectively as affected with calcium nitrate compared without calcium nitrate.

It is evident from the distribution pattern of N, P, K and $Na^+$ concentrations in bulb for the two growing seasons that the effect of the applied Ca sources can be arranged according to nutrients contents in the following orders:

i. Calcium nitrate > Calcium phosphate > Calcium sulphate > without Ca for N and K
ii. Calcium phosphate > calcium sulphate > Calcium nitrate > without Ca for K. The decreases of mean values of $Na^+$ concentration followed
iii. Calcium sulphate > Calcium phosphate > Calcium nitrate > without Ca.

These results may be due to that the application of calcium sulphat different rates reflecting an increase in $Ca^{+2}$ content in soil consequently led to decrease $Na^+$ in soil and concentration in bulb plants. These results are in agreement with those found by Ali et al. (2003) who reported that application of calcium sulphate led to significant decrease in $Na^+$ contents and increase Ca, S and K concentrations. Levent et al. (2011) found that the application of calcium sulphate to plants gave an increasing in the concentrations of N, P and K in plant and reducing $Na^+$ concentration. Dabuxilatu and Ikeda (2005) revealed that supplemental $Ca^{+2}$ can decrease sodium content in plant tissues. Shahriaripour et al. (2011) suggested that the application of phosphorus reduced $Na^+$ concentration with increased of phosphorus rates. The decrease of $Na^+$ concentration in plants growth in saline soil may be due to substitution of calcium by $Na^+$ in cell membrane. Shah et al (2007) indicated that the application of calcium phosphate and calcium sulfate increased N, P, K, and Ca and decreased Na and Mg concentrations when compared to control plants.

**Garlic quality.**

Table (7) revealed that the effect of different calcium sources on garlic quality (protein, Chlorophyll and proline) of garlic plants under saline soil conditions was not significant, while the different rates of different calcium sources were significant with proline in both seasons and chlorophyll in second season. The interaction between calcium sources and their different rates showed significant effect on increasing protein and chlorophyll with raising Ca rates, as well as proline was significantly decreased with increasing rates in both growing seasons.

The relative increases of mean values were 23.75 and 20.86 % for protein and 41.26 and 45.82 % for chlorophyll, while the relative decreases of mean values were 39.52 and 44.54 % for proline content in garlic plants in the first and second seasons as affected with calcium sulphate compared to soil without calcium sulphate. Also, the relative increases of mean values were 25.83 and 22.43 % for protein and 29.06 and 31.72 % for chlorophyll, while the relative decreases of mean values were 25.86 and 27.81 % for proline contents in garlic plants in first and second seasons as affected with calcium phosphate compared to soil without Ca sources. On the other hand, the relative increases of mean values were 33.67 and 28.21 for protein and 28.18 and 35.86 % for chlorophyll, while the relative decreases of mean values proline was 38.13 and 39.62 % content in garlic plants in first and second season as affected with calcium nitrate compared to without one. **It's clear therefore that the relative mean values followed the ascending order:**

i. Calcium nitrate > Calcium phosphate > calcium sulphate > control for protein;

ii. Calcium sulphate > Calcium phosphate > calcium nitrate > without Ca one for chlorophyll and

iii. Calcium sulphate > calcium nitrate > calcium phosphate > control for proline.

Calcium nitrate application led to increase of protein than other treatments, while the chlorophyll and proline were affected with calcium sulphate application. The proline increased with increasing soil salinity and is reduced with application rate of calcium sources. Calcium sulphate application decreased proline content, while increase the chlorophyll content in garlic plants. These results are in consequence with Peatel et al. (2011) who indicated that proline content significantly increased in leaves, stems, tap roots and lateral root tissues under saline conditions. Mehaseb et al (2018) found that the calcium sulphate application increased protein and chlorophyll contents in plants under saline soil conditions. Peatel et al. (2011) indicated that the application of calcium phosphate increased proline concentration in leaf pistachio seedlings was increased with increasing saline soils. The proline plays an important role in osmotic adjustment in saline condition. Ripour et al. (2011) found that the application of calcium phosphate increased proline concentration in leaf of pistachio seedlings with increasing salinity of tested soils. The proline plays an important role in osmotic adjustment in saline condition. The garlic quality as affected with calcium sources may be due to that calcium increases photosynthetic pigments content and photosynthesis rate.

**Table 7. Effect of different calcium sources on garlic quality**

| Treatments | Rate (kg/fed) | Protein (%) | | Proline (mg/g)f.w. | | Total Chlorophyll (mg/g) f.w | |
|---|---|---|---|---|---|---|---|
| | Seasons | S1 | S2 | S1 | S2 | S1 | S2 |
| Calcium sulphate | 0 | 12.38 | 12.81 | 30.14 | 27.95 | 19.34 | 19.88 |
| | 100 | 15.06 | 15.44 | 24.36 | 21.35 | 22.47 | 23.67 |
| | 200 | 15.25 | 15.65 | 16.48 | 14.52 | 27.34 | 29.14 |
| | 300 | 15.65 | 15.75 | 13.85 | 10.63 | 32.14 | 34.15 |
| Mean | | 14.56 | 14.88 | 21.21 | 18.61 | 25.32 | 26.71 |
| Calcium phosphate | 0 | 11.69 | 12.44 | 32.14 | 28.41 | 18.55 | 18.95 |
| | 100 | 14.44 | 14.94 | 28.74 | 26.37 | 20.69 | 21.40 |
| | 200 | 14.75 | 15.25 | 23.00 | 19.34 | 24.31 | 25.63 |
| | 300 | 14.94 | 15.50 | 19.76 | 15.82 | 26.82 | 27.85 |
| Mean | | 13.94 | 14.56 | 25.91 | 22.94 | 22.59 | 23.46 |
| Calcium nitrate | 0 | 12.00 | 12.69 | 31.52 | 27.99 | 19.20 | 19.55 |
| | 100 | 15.56 | 15.81 | 25.64 | 21.88 | 21.69 | 22.49 |
| | 200 | 15.94 | 16.19 | 17.63 | 16.44 | 25.84 | 27.35 |
| | 300 | 16.63 | 16.81 | 15.22 | 12.37 | 26.31 | 29.85 |
| Mean | | 15.06 | 15.38 | 22.50 | 19.67 | 23.26 | 24.81 |
| LSD. 0.05 treatments | | ns | ns | ns | ns | ns | ns |
| LSD. 0.05 Rates | | ns | ns | 2.40 | 2.39 | ns | 1.17 |
| Interaction | | * | ** | *** | *** | *** | *** |

## CONCLUSION

The application of calcium sources at high rate can be used to improve soil properties and increase the available nutrients. The application of calcium sources: calcium sulphate, calcium phosphate, and calcium nitrate led to enhanced yield and yield components of bulb garlic plants under saline soil conditions. On the other hand, the used calcium sources led to decrease $Na^+$ concentration in bulb garlic plants especially calcium sulphate application.

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## الملخص العربي

# تاثير استخدام مصادر الكالسيوم على بعض صفات التربة الكميائية وانتاجية الثوم تحت ظروف الأراضى الملحية

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اجريت تجربتان حقليتان فى قرية الرواد بسهل الحسينية، محافظة الشرقية – مصر فى الموسمين ٢٠١٦/٢٠١٧ و٢٠١٨ /٢٠١٧ لدراسة تاثير اضافة مصادر الكالسيوم (كبريتات كالسيوم، فوسفات الكالسيوم ونترات الكالسيوم ) بمعدلات (صفر، ١٠٠، ٢٠٠ و٣٠٠ كجم /فدان) على بعض صفات التربة وانتاجية محصول الثوم تحت ظروف الأراضى الملحية وكان تصميم التجربة قطاعات منشقة مرة واحدة و٦ مكررات.

تشير النتائج المتحصل عليها ان اضافة المصادر المختلفة الكالسيوم قد أدت الى تحسين التربة الملحية وزيادة تيسر العناصر الكبرى والصغرى فى التربة .وقد أدت زيادة معدلات اضافة مصادر الكالسيوم الى زيادة فى طول النبات، عدد الاوراق لكل نبات، عدد الاغلفة لرأس الثوم، وزيادة قطر راس الثوم وقد يرجع هذا لانخفاض نسبة الملوحة. وكان لزيادة معدلات الاضافة من مصادر الكالسيوم تاثيرا معنويا على الوزن الرطب والجاف لرأس الثوم (جم/نبات) خلال موسمي الزراعة، بينما كانت وزن الاغلفة /نبات ووزن الثوم/فدان كانت زيادة معنوية بزيادة معدلات الكالسيوم فى الموسم الثانى. وجد ان التفاعل بين مصادر الكالسيوم ومعدلاته كان لها تاثير معنوى على زيادة النتروجين والفوسفور والبوتاسيوم وكان لها تاثير معنوى على انخفاض تركيز الصوديوم خلال الموسمين. زيادة معدلات كبريتات الكالسيوم ادت الى زيادة الكلوروفيل وتناقص نسبة البرولين فى النبات بينما نترات الكالسيوم ادت الى زيادة نسبة البروتين (%) فى النبات.

وتوصى النتائج نستطيع بإستخدام كبريتات الكالسيوم وفوسفات الكالسيوم ونترات الكالسيوم بمعدلات ٣٠٠ كجم للفدان لتحسين صفات التربة وزيادة المحصول ومكوناتة تحت ظروف الأراضى الملحية.