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# RESPONSE OF TOMATO PLANTS TO POTASSIUM RATES AND CALCIUM SOURCES UNDER PLASTIC HOUSE CONDITIONS IN NORTH SINAI

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## ABSTRACT

Afield experiment was carried out under greenhouse conditions during the winter seasons of 2013-14 and 2014-15 at The Experimental Farm of the Faculty of Environmental Agricultural Sciences, Arish University, North Sinai Governorate, Egypt. The aim of this experiment was to study the effect of different K rates (40, 60 and 80 Kg $K_2O/540m^2$) and two sources of calcium; *viz*, Ca-chelate at 5g $l^{-1}$(0.5% Ca), Gurenkal at 5 ml $l^{-1}$ (0.5% Ca) as well as the control treatment (without Ca), with their interactions on growth, and yield of tomato (*Solanum lycopersicon* L.) hybrid V 59-48 under sandy soil conditions using drip irrigation system. A split plot design in three replicates was used. The results showed that treating tomato plants with calcium and potassium had significant and positive effects on almost studied traits of growth, and yield. The highest fresh and dry weight, as well as total yield of tomato plants were achieved when tomato plants fertilized with 80 kg $K_2O/540$ $m^2$ combined with Gurenkalat 5 ml $l^{-1}$(0.5% Ca) as foliar spray followed by 80 kg $K_2O/540$ $m^2$ combined with Ca- chelate at 5 g $l^{-1}$(0.5% Ca).

**Key words:** Tomato, greenhouse, potassium, calcium sources, fresh weight, marketable yield, and total yield.

## INTRODUCTION

Tomato (*Solanum lycopersicum* L.) previously named (*Lycopersicon esculentum* Mill.) is an important vegetable crop in several parts of the world, including the regions suffering from drought and soil salinity, such as the Mediterranean region **(Savic *et al*., 2009; Jensen *et al*., 2010).** Tomato is widely used as salad as well as for cooking purposes. It is well known for its nutritional importance as it is the rich source of nutrients *viz*., Na, K, Fe, vitamin A and C, and antioxidants especially lycopene and salicylate **(Afzal *et al*., 2013)**.

Potassium (K) is the most efficient cation for tomato plants and according to several authors, it plays a key role in the improvement of several quality traits in tomato fruits and in almost all vegetables **(Dorais *et al*., 2001; Chapagain and Wiesman, 2004; Cakmak, 2005).** Potassium is one of the essential mineral nutrients in plant nutrition and one of the three which are taken up by roots from the soil solution in its ionic form. It is involved in numerous physiological processes that control plant growth, yield and quality parameters such as sugars, titratible acidity (TA), soluble solids (SS), total soluble solids (TSS), taste, color, firmness and meliness **(Wuzhong, 2002; Lester *et al*., 2005)**. Potassium is a key nutrient for enhancing productivity of vegetable crops and its content in vegetables has significant positive relationship with quality attributes **(Bidariand and Hebsur, 2011)**.

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Calcium is one of the most important mineral nutrients in greenhouse tomato production. A low supply of calcium to fruit leads to increase tomato fruit cracking **(Simon, 1978)** and blossom-end rot **(Ho *et al.*, 1999)**. Calcium deficiency in tomato reduces leaf size, causes necrosis of young leaves and yield loss in extreme cases **(Adams and El-Gizawy, 1988; Holder and Cockshull, 1990)**. Calcium foliar spray increased the firmness of tomato fruit measured with and without the skin present **(Garcia *et al.*, 1995)**.

Involved in a wide range of processes in plants including flower induction (**Friedman *et al.*, 1989)**; reduced the incidence of BER **(Hao *et al.*, 2000)**. Calcium is an important nutrient that plays a key role in the structure of cell walls and cell membranes, fruit growth and development **(Kadir, 2004)**; and fruit yield **(Hao and Papadopoulos, 2004)**.

Calcium application increases growth; chlorophyll content, number of fruits per plant in tomato plants **(Rady, 2012)**. So, the objectives of this work was to study the effect of potassium levels as soil application and two calcium sources as foliar application and their interactions on tomato plants grown under plastic house in sandy soil at El-Arish region.

## MATERIALS AND METHODS

This study included a field study was carried out under greenhouse conditions during the winter growing seasons of 2013-14 and 2014-15 in The Experimental Farm of The Faculty of Environmental Agricultural Sciences, Arish University, North Sinai, Egypt to study the effect of three K rates (40,60,and 80 $K_2O$ kg/540m$^2$), added as soil application and two sources of calcium; *viz*, Ca-chelate at 5 g $l^{-1}$(0.5% Ca),Gurenkal at 5 ml $l^{-1}$(0.5% Ca) as well as the control treatment (without Ca), with their interactions added as foliar application on tomato growth, and yield of tomato hybrid V 59-48 under sandy soil conditions.

Tomato seeds were sown in trays on 15$^{th}$ October and transplanted 45 days later in both seasons of study. The plot area was 15m$^2$ (10 m length and 1.5m wide), planting density was 2.22 plant/m$^2$. Drip irrigation system was used, each plot had two dripper lines. The distance between each two dripper lines was 40 cm, the distance between the plants in the same row was 50 cm, while the distance between double dripper lines centers was 150 cm. Potassium was added at three doses per week, while Ca was sprayed every two weeks.

The physical and chemical analyses of the experimental soil and irrigation water are presented in Tables 1 and 2.

This experiment included nine treatments which were the combination between three potassium rates (40,60 and 80 kg $K_2O$/540 m$^2$) and two calcium source; *i.e.*, Ca-chelate at 5g $l^{-1}$ (0.5% Ca), and Gurenkal at 5 ml $l^{-1}$ 0.5% Ca) in addition to control treatment. The experimental treatments were randomly arranged in a split-plot design with three replicates, where potassium rates were randomly distributed in the main plots and Ca sources were randomly arranged in the sub plots. The normal agricultural practices were carried out as commonly followed in El-Arish region.

### Data Recorded

#### Vegetative growth parameters

Three plants from each replicate were randomly taken after 70 and 90 days from transplanting and the following data were recorded.

#### Fresh weight/plant (g)

Fresh weight of root, stem and leaves/ plant were determined as well as total fresh weight/plant was calculated.

#### Dry weight/plant (g)

Different plant parts of tomato plant sample were oven dried at 70$^o$C until.

Constant weight and the dry weight of root, stem and leaves/plant were determined and total dry weight was calculated.

**Table (1): The physical and chemical properties of the experimental soil***

| Property | $1^{st}$ season (2013-14) | $2^{nd}$ season (2014-15) |
|---|---|---|
| **Physical properties** | | |
| **Texture** | **Sandy Clay Loam** | **Sandy Clay Loam** |
| **Chemical properties** | | |
| **pH** | 8.0 | 7.6 |
| **EC ($dSm^{-1}$)** | 0.7 | 1.3 |
| **Total N (%)** | 0.03 | 0.10 |
| **Total P (%)** | 0.26 | 0.30 |
| **Total K (%)** | 0.62 | 0.50 |

* Soil samples were taken from the 25 cm of the soil surface.

**Table (2): The physical and chemical analyses of irrigation water.**

| EC | Soluble ions ($meq.l^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cations | | | | | Anions | | | |
| Ppm | $Mg^{-1}$ | $Ca^{++}$ | $Mg^{++}$ | $Na^{+}$ | $K^{+}$ | $Cl^{-}$ | $HCO_3^{-}$ | $CO_3^{-}$ | $SO_4^{--}$ |
| 3513 | 44.99 | 16.56 | 17.60 | 35.87 | 0.27 | 42.26 | 6.13 | - | 21.91 |

**Yield and its components**

Fruits of all pickings tell the end of the experiment were counted and weighed and the following data were calculated:

a- Total marketable yield number and weight/plant.

b- Total unmarketable yield number and weight/plant.

### Statistical Analysis

The obtained data were subjected to statistical analysis of variance according to **Snedecor and Cochran (1980)**, and means separation was done according to **Duncan's Multiple Range Test (1955)**.

## RESULTS AND DISCUSSION

### Fresh Weight

#### Effect of potassium rates

Results in Table 3 show that, in the first season, application of potassium had no significant effect on fresh weight of leaves, fresh weight of stem, and fresh weight of roots, except fresh weight of leaves at 70 DAT and total fresh weight at 70 and 90 DAT, where application of potassium at a rate of 80 kg $K_2O/540m^2$ had a significant effect and recorded the highest value of total fresh weight/plant in both seasons. In the second season, there were significant effects for potassium soil application on all studied traits, except fresh weight of roots at 90 DAT which did not reach 5% level of probability. Application of 80 kg $K_2O$ /540 $m^2$ recorded the maximum values for all studied traits of plant fresh weight; *viz*., leaves, stem, roots, and total fresh weight of plant without significant difference with application of 60 kg $K_2O$/540 $m^2$ at 70 DAT on fresh weight of roots. These results are in agreement with those reported by **Saida *et al*. (2014) and Ul-Hassan *et al*. (2016)** who found that potassium nutrition significantly enhanced growth and biomass production of tomato plants. It could be concluded that soil application of 80 kg $K_2O$/540$m^2$ was the superior treatment for increasing fresh weight of tomato plant in the second season.

### Effect of calcium sources

Results in Table 3 indicate that there were no significant differences among calcium foliar application treatments on fresh weight of tomato plant in the first season, and fresh weight of leaves as well as fresh weight of roots at 90 DAT in the second one. However, spraying tomato plant with Gurenkal (5 ml $l^{-1}$) recorded the highest significant values of fresh weight of leaves, stem, roots as well as total fresh weight of plant at 70 and 90 DAT, followed by spraying with Ca-chelate (5 g $l^{-1}$) in the second season. Check treatment (without Ca) recorded the lowest values of plant fresh weight in both seasons. These results are in harmony with the findings of **Lopez and Satti (1996)** and **Lolaei (2012)** who found that increasing $Ca^{2+}$ concentration in leaves linearly increased total vegetative biomass. It was reported that increasing calcium rates caused positive gradual increase in tomato growth **(Rady, 2012)**.

It could be said that spraying tomato plants with Gurenkal (5 ml $l^{-1}$) as calcium source, followed by spraying with Ca-chelate (5g$l^{-1}$) were the superior treatments for enhancing plant fresh weight.

### Effect of interaction between potassium and calcium

It is clear from the results in Table 4 that there were significant interaction effects between calcium and potassium on all studied tomato plant fresh weight traits in both seasons, except fresh weight of leaves at 70 DAT, fresh weight of roots at 70 and 90 DAT, total fresh weight at 90 DAT in the first season. However, application of 80 kg $K_2O$/540 $m^2$ + Gurenkal had the maximum value of fresh weight; *viz*., leaves, stem, and total fresh weight of plant after 70 or 90 DAT, with no significant differences with 80 kg $K_2O$/540$m^2$+Ca-chelateor without Ca in the first season, while in the second season application of 80 kg $K_2O$/540 $m^2$ + Gurenkal recorded the highest values of the pervious studied parameters.

It could be concluded that the best interaction treatments for increasing fresh weight of different parts of tomato plants was 80kg $K_2O$/540 $m^2$ + spraying with Gurenkal (5ml $l^{-1}$), followed by application of 80kg $K_2O$ /540$m^2$ + Ca- chelate (5 g $l^{-1}$).

## Dry Weight

### Effect of potassium rates

Results in Table 5 illustrate significant effects for $K_2O$ on dry weight of tomato plants, except dry weight of stem in the first season and dry weight of root in the second one. The same results reveal that application of $K_2O$ at a rate of 80kg $K_2O$/540$m^2$ was the superior treatment which increased dry weight of stem, root and total dry weight of plant in both seasons.

The increment in total dry weight of plant, especially in the second season may be attributed to the increments in dry weight of leaves, stem and roots. These results are in agreement with those reported by **Wuzhong (2002), El-Nemr *et al.* (2012), Amjad *et al*. (2014) and Ul-Hassan *et al*. (2016)** who found a positive response to potassium concentration on dry weight of tomato plant.

**Table (3): Effect of potassium rates and calcium source on fresh weight of tomato plants (g) during 2013/2014 and 2014/2015 seasons.**

| Parameter | Fresh weight (g)/plant | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaves | | Stem | | Roots | | Total | | Leaves | | Stem | | Roots | | Total | |
| | Days after transplanting | | | | | | | | | | | | | | | |
| Treatment | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 |
| **Effect of potassium rates** | | | | | | | | | | | | | | | | |
| $K_2O$( kg) /540m$^2$ ) | First season (2013/2014) | | | | | | | | Second season (2014/2015) | | | | | | | |
| **40** | 299.0b | 374.5a | 194.2 a | 210.7 a | 88.61 a | 93.36 a | 581.81b | 678.56 c | 293.7 c | 341.4 c | 142.7 c | 177.2 c | 96.2 b | 116.3a | 532.6a | 620.1c |
| **60** | 304.1b | 386.7a | 186.7 a | 224.3 a | 89.17 a | 92.43 a | 579.97 b | 703.43 b | 356.7 b | 382.0 b | 163.7 b | 207.9 b | 112.8ab | 118.9a | 633.2a | 708.7b |
| **80** | 335.1a | 392.0a | 202.4 a | 251.9 a | 90.50 a | 92.65 a | 628.00 a | 736.55 a | 422.7 a | 425.6 a | 194.4 a | 234.7 a | 120.0a | 129.8a | 740.4a | 790.1 a |
| **Effect of calcium source** | | | | | | | | | | | | | | | | |
| **Without Ca** | 314.6a | 385.2a | 189.3 a | 225.7 a | 88.59 a | 91.00 a | 592.5 a | 701.9 a | 323.6 b | 377.7 a | 152.7 b | 198.4 b | 94.3 b | 124.5a | 570.6a | 690.4b |
| **Ca-chelate*** | 332.2a | 381.5a | 199.3 a | 226.5 a | 89.77 a | 93.83 a | 621.2 a | 701.8 a | 370.1 a | 371.8 a | 171.4 a | 202.9 b | 115.6a | 119.8a | 661.9 a | 694.5b |
| **Gurenkal*** | 311.5a | 386.5a | 194.7 a | 234.8 a | 89.93 a | 93.6 a | 596.1 a | 714.9 a | 379.4 a | 399.4 a | 176.6 a | 218.4 a | 118.9a | 120.7a | 637.7 a | 734.0a |

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

*Ca-chelate and Gurenkal were used at a rate of 5g $l^{-1}$ and 5ml $l^{-1}$, respectively.

**Table (4): Effect of interaction between potassium rates and calcium source on fresh weight of tomato plants during 2013/2014 and 2014/2015 seasons.**

| Treatment | Parameter | F.W of leaves(g) | | F.W of stem(g) | | F.W of roots(g) | | Total fresh weigh /plant(g) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Days after transplanting | | | | | | | |
| | | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 |
| **$K_2O$ (kg) /540m$^2$X Ca sources** | | **Effect of potassium rates X calcium sources** | | | | | | | |
| | | **First Season (2013/2014)** | | | | | | | |
| **40** | **+ Without Ca** | 308.9cd | 372.8a | 184.1bc | 213.8c | 85.46a | 91.01a | 578.4cd | 677.6a |
| **40** | **+ Ca-chelate*** | 314.6cd | 374.7a | 201.3a | 202.9c | 89.05a | 95.10a | 604.9bc | 672.7a |
| **40** | **+ Gurenkal*** | 273.6e | 376.2a | 197.2ab | 215.5c | 91.33a | 93.99a | 562.1d | 685.7a |
| **60** | **+ Without Ca** | 286.6de | 380.6a | 181.3c | 210.7c | 89.40a | 88.88a | 557.3d | 680.2a |
| **60** | **+ Ca-chelate*** | 324.6bc | 383.0a | 192.3abc | 205.9c | 88.08a | 95.12a | 604.9bc | 684.0a |
| **60** | **+ Gurenkal*** | 301.2cde | 396.5a | 186.5bc | 256.3ab | 90.04a | 93.28a | 577.7cd | 746.1a |
| **80** | **+ Without Ca** | 348.4ab | 402.4a | 202.5a | 252.5ab | 90.90a | 93.12a | 641.8ab | 748.0a |
| **80** | **+ Ca-chelate*** | 357.2a | 386.7a | 204.2a | 270.7a | 92.20a | 91.28a | 653.6a | 696.2a |
| **80** | **+ Gurenkal*** | 359.7a | 386.8a | 200.4a | 232.5bc | 88.41a | 93.54a | 596.1a | 712.8a |
| **$K_2O$( kg) /540m$^2$X Ca sources** | | **Second Season (2014/2015)** | | | | | | | |
| **40** | **+ Without Ca** | 268.8d | 335.0d | 142.8de | 164.2f | 83.00e | 140.1a | 494.7e | 594.9e |
| **40** | **+ Ca-chelate*** | 314.0c | 343.5d | 148.3d | 177.9ef | 105.8cd | 106.8bc | 568.2d | 628.2de |
| **40** | **+ Gurenkal*** | 298.3cd | 345.7d | 137.0ef | 189.5de | 99.67d | 101.9c | 535.0de | 637.1cd |
| **60** | **+ Without Ca** | 280.8cd | 362.2cd | 128.8f | 195.4cde | 101.0d | 114.5abc | 510.7e | 672.0c |
| **60** | **+ Ca-chelate*** | 376.5b | 382.5bc | 170.8c | 211.7bcd | 114.5bc | 119.4abc | 661.8c | 713.6b |
| **60** | **+ Gurenkal*** | 412.7a | 401.3b | 191.3ab | 216.5bc | 123.0ab | 122.7abc | 727.0ab | 740.5b |
| **80** | **+ Without Ca** | 421.0a | 435.9a | 186.5b | 235.6ab | 99.00d | 118.8abc | 706.5b | 804.2a |
| **80** | **+ Ca-chelate*** | 419.8a | 389.5bc | 195.2ab | 219.2bc | 126.7ab | 133.1ab | 755.8a | 741.8b |
| **80** | **+ Gurenkal*** | 427.2a | 451.3a | 201.7a | 249.4a | 134.1a | 137.6a | 759.0a | 824.4a |

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.
*Ca-chelate and Gurenkal were used at a rate of 5g $l^{-1}$and 5ml $l^{-1}$, respectively.

**Table (5): Effect of potassium rates and calcium source on dry weight of tomato plants during 2013/2014 and 2014/2015 seasons.**

| Parameter / Treatment | Dry weight (g)/plant | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaves | | Stem | | Roots | | Total | | Leaves | | Stem | | Roots | | Total | |
| | Days after transplanting | | | | | | | | | | | | | | | |
| | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 |
| | Effect of potassium rates | | | | | | | | | | | | | | | |
| | First season (2013/2014) | | | | | | | | Second season (2014/2015) | | | | | | | |
| $K_2O$( kg) /540m$^2$ | | | | | | | | | | | | | | | | |
| **40** | 41.43c | 45.43b | 28.15a | 29.26a | 23.91a | 25.56b | 93.49a | 100.25b | 44.16b | 45.89b | 25.29c | 33.09c | 22.62b | 27.18a | 92.07c | 106.10b |
| **60** | 43.84b | 46.60b | 26.37a | 28.37a | 23.22a | 26.79a | 93.43a | 101.78b | 48.69a | 49.19b | 28.96b | 40.76b | 27.07a | 26.94a | 104.71 b | 116.89b |
| **80** | 50.39a | 53.62a | 25.45a | 29.34a | 23.57a | 26.82a | 99.41a | 109.78a | 50.73a | 62.96a | 32.52a | 43.30a | 29.61a | 32.06a | 112.87 a | 138.31a |
| | Ca sources | | | | | | | | Effect of calcium source | | | | | | | |
| **without Ca** | 43.38b | 46.60a | 26.62a | 28.62a | 22.82a | 25.91a | 92.82a | 101.10a | 45.86b | 48.56b | 27.92b | 37.58b | 23.52b | 27.43a | 97.30 c | 113.57b |
| **Ca-chelate*** | 45.78ab | 49.33a | 26.21a | 28.21a | 24.92a | 26.54a | 96.91a | 104.08a | 47.26b | 54.12ab | 27.91b | 38.63ab | 27.14a | 29.20a | 102.31 b | 121.96a |
| **Gurenkal*** | 46.51a | 49.73a | 27.15a | 30.15a | 22.95a | 26.73a | 96.61a | 106.60a | 50.47a | 55.36a | 30.93 a | 40.93a | 28.63a | 29.54a | 110.03 a | 125.83a |

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

*Ca-chelate and Gurenkal were used at a rate of 5g $l^{-1}$ and 5ml $l^{-1}$, respectively.

**Effect of calcium sources**

Results in Table 5 show insignificant effects due to application of calcium on all dry weight traits in the first season expressed in dry weight of roots, stem, leaves and consequently total dry weight of plant at both studied sampling dates, except dry weight of leaves after 70 DAT, while in the second season application of Gurenkal gave the maximum values of the studied parameters, followed by Ca- chelate.

The increments in total dry weight at 70 and 90 DAT may be owe to the increase in dry weight of different plant parts (roots, stem, leaves). These results are in a good line with those reported by **Hao and Papadopoulos (2004), and Kazemi(2013).**

**Effect of interaction between potassium and calcium**

It is clear from the results in Table 6 that the interaction among potassium and calcium treatments had significant effects on all studied parameters, except dry weight of stem at 70 and 90 DAT and dry weight of roots at 70 DAT in the first season. The interaction between application of 80 kg $K_2O/540m^2$ and all sources of Ca (Gurenkal; Ca-chelate; without Ca) increased dry weight of leaves at 70 and 90 DAT and dry weight of roots at 90 DAT that led to increase in total dry weight of plant at 70 and 90 DAT in the first season.

In the second season, the interaction between application of 80 kg $K_2O$ /$540m^2$ + Gurenkal was the best interaction treatment which led to increase the dry weight of leaves at 70 and 90 DAT and dry weight of stem at 70 DAT as well as dry weight of roots at 90 DAT. The increase in these parameters led to increase in total dry weight of tomato plant.

## Yield and Its Components

**Marketable and unmarketable yield**

**Effect of potassium rates**

Results in Table 7 reveal that application of potassium had significant effects on total marketable yield/plant, total yield/540 $m^2$in both seasons, and fruit weight of unmarketable yield in the first season, but it did not reflect any significant effects on number of unmarketable fruits in both seasons. Application of 80 kg $K_2O$/540 $m^2$ was the best treatment for increasing the previous studied yield parameters.

The increment in total yield may be owe to the increment in total yield of plant expressed in fruits number and the other yield components. The increase in plant yield may be due to the increases in photosynthetic pigments due to application of $K_2O$ which led to increase in photo assimilation expressed in fresh and dry weight of different parts of tomato plants and consequently increase in yield per plant and per a single greenhouse ($540m^2$).

It could be concluded that both total yield per greenhouse and unmarketable fruit weight had the highest values with application of80 kg $K_2O$/540 $m^2$ as soil application.

**Effect of calcium sources**

Results in Table (7) illustrate the effect of Ca sources on total marketable yield and unmarketable yield /a single greenhouse ($540m^2$). The same results show that application of Ca in different sources had no significant effect on the previous parameters in the second season and on fruit weight of unmarketable yield in the first season. Application of Ca as Gurenkal at concentration of 5ml $l^{-1}$ as foliar spray increased the components of total yield/plant (numbers and weight of fruits) which led to an increase in total yield/a greenhouse in the first season.

Table (6): Effect of interaction between potassium rates and calcium sources on dry weight of tomato plants during 2013/2014 and 2014/2015 seasons.

| Treatment \ Parameter | | D.W of leaves(g) | | D.W of stem(g) | | D.W of roots(g) | | Total Dry weigh(g) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Days after transplanting | | | | | | | |
| | | 70 | 90 | 70 | 90 | 70 | 90 | 70 | 90 |
| | | Effect of potassium rates X calcium sources | | | | | | | |
| $K_2O$( kg) /540m$^2$X Ca sources | | First season (2013/2014) | | | | | | | |
| 40 | + without Ca | 41.75c | 45.08cd | 27.99a | 29.32a | 23.11a | 26.45ab | 92.85bc | 100.9def |
| 40 | + Ca-chelate* | 41.26c | 45.93cd | 27.37a | 28.37a | 25.42a | 24.21c | 94.05bc | 98.51ef |
| 40 | + Gurenkal* | 41.29c | 45.29cd | 29.09a | 30.09a | 23.20a | 26.00abc | 93.58bc | 101.4c-f |
| 60 | + without Ca | 40.76c | 43.09d | 25.46a | 26.12a | 23.14a | 25.23bc | 89.36c | 94.45f |
| 60 | + Ca-chelate* | 45.12b | 48.45bc | 25.91a | 27.91a | 25.00a | 27.63a | 96.03ab | 104.0b-e |
| 60 | + Gurenkal* | 45.63b | 48.30bc | 27.75a | 31.08a | 21.52a | 27.52a | 94.90abc | 106.9a-d |
| 80 | + without Ca | 47.63b | 51.63ab | 26.41a | 30.41a | 22.22a | 26.04abc | 96.26ab | 108.1abc |
| 80 | + Ca-chelate* | 50.96a | 53.62a | 25.34a | 28.34a | 24.34a | 27.77a | 100.6a | 109.7ab |
| 80 | + Gurenkal* | 52.60a | 55.60a | 24.61a | 29.28a | 24.14a | 26.66ab | 101.3a | 111.5a |
| $K_2O$( kg) /540m$^2$X Ca sources | | Second season (2014/2015) | | | | | | | |
| 40 | + without Ca | 43.04f | 46.20cd | 25.70d | 30.07f | 19.73f | 30.10bc | 88.47f | 106.4d |
| 40 | + Ca-chelate* | 43.80ef | 47.20cd | 25.30d | 32.93ef | 24.27e | 26.03c | 93.37e | 106.2d |
| 40 | + Gurenkal* | 45.63de | 44.27d | 24.87d | 36.27d | 23.87e | 25.40c | 94.37e | 105.9d |
| 60 | + without Ca | 45.23ef | 48.00cd | 25.23d | 35.47de | 22.43e | 26.30c | 92.90e | 109.8d |
| 60 | + Ca-chelate* | 50.10bc | 51.50c | 31.70bc | 43.17b | 26.27d | 28.40bc | 108.1cd | 123.1c |
| 60 | + Gurenkal* | 50.73b | 48.07cd | 29.93c | 43.63b | 32.50a | 26.13c | 113.2b | 117.8c |
| 80 | + without Ca | 49.30bc | 51.47c | 32.83b | 47.20a | 28.40c | 25.90c | 110.5bc | 124.6c |
| 80 | + Ca-chelate* | 47.87cd | 63.67b | 26.73d | 39.80c | 30.90ab | 33.17ab | 105.5d | 136.6b |
| 80 | + Gurenkal* | 55.03a | 73.73a | 38.00a | 42.90b | 29.53bc | 37.10a | 122.6a | 153.7a |

Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.

*Ca-chelate and Gurenkal were used at a rate of 5g $l^{-1}$ and 5ml $l^{-1}$, respectively.

Our results are in agreement with those of other researcher where many efforts owed the increment in yield and its components due to foliar application of calcium to the vital role of calcium as one of the essential macroelements necessary for plant growth. It is used for maintenance of the plant cell structure and increasing resistance to environmental stresses (salinity, drought, chilling, heat, ... *etc*.) **(Mestre *et al*., 2012).**

It is also appear to play an essential role in the inhibition of abscission and delays leaf senescence, plays a compratively role in enzyme activation **(Mengel and Kirkby, 1978)**; and stimulatethe accumulation of phytoalexin, which implicated in the defense mechanisms of plants against fungal attacks (**Zook *et al*., 1987; Aghofack- Nguemeziet *al.,* 2014**) and consequantly led to an increase in chloroohyll content, laef area / plant, photo-assimilation and plant growth. The increment in plant growth reflected positively on increasing number of flowers/cluster, number of fruits/cluster, number of fruits/plant, fruits weight and this in turn increase yield/ha. **(Aghofack-Nguemezi and Tatchago, 2010; Mestre *et al*., 2012; Elbeik, 2014; Ilyas *et al*., 2014)**. On the other hand, **Rab and Haq (2012)** found that there were no significant differences between control and foliar application of $CaCl_2$ on tomato fruit weight, and yield/fed.

It could be concluded that application of Ca as Gurenkal increased fruits number and weight of marketable yield/plant and increased total yield per a single greenhouse ($540m^2$).

**Effect of interaction between potassium and calcium**

Results in Table 8 indicate that there were significant effects for the interaction between Ca and K on all studied traits in both seasons, except unmarketable fruits weight/plant in the first season. The same results show that the interaction between application of 80 kg $K_2O$/540 $m^2$ + Gurenkal (as a source of Ca) was the best interaction treatment for increasing total yield/plant and reducing unmarketable yield/plant leading to an increment in yield/greenhouse in both seasons. The increment in total marketable yield/plant may be owe to decreasing unmarketable yield and the effect of K and Ca on photosynthetic pigments which increased the photo-assimilation process and increase in fresh and dry weight of different parts of tomato plant (Tables 4 and 5).

It could be concluded that the best interaction treatment for increasing total marketable yield/plant and per greenhouse as well as decreasing unmarketable yield of tomato plants was application of 80 kg $K_2O$/540 $m^2$ +Gurenkal as a source of Ca foliar application.

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**Table (7): Effect of potassium rates and calcium sources on total yield of tomato plants during 2013/2014 and 2014/2015 seasons.**

| Parameter / Treatment | Total marketable yield /plant | | Unmarketable yield/ plant | | Total yield | Total marketable yield /plant | | Unmarketable yield/ plant | | Total yield |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number of fruits | weight of fruits (g) | Number of fruits | weight of fruits (g) | ton/ 540m$^2$ | Number of fruits | weight of fruits (g) | Number of fruits | weight of fruits (g) | ton/ 540m$^2$ |
| | | | | | Effect of potassium rates | | | | | |
| | First season ( 2013/2014 ) | | | | | Second season ( 2014/2015 ) | | | | |
| $K_2O$( kg) /540m$^2$ | | | | | | | | | | |
| **40** | 80.19b | 5040b | 6.05a | 193.8b | 6.046b | 79.78b | 5035c | 2.927a | 123.7a | 6.042c |
| **60** | 80.59b | 5094b | 6.76a | 264.1a | 6.112b | 92.04ab | 5846b | 3.703a | 163.8a | 7.015b |
| **80** | 92.22a | 6220a | 7.00a | 267.1a | 7.467a | 95.81a | 6218a | 2.591a | 99.50a | 7.461a |
| | Ca sources | | | | | Effect of calcium sources | | | | |
| **Without Ca** | 79.06b | 5083b | 7.69a | 288.3a | 6.097b | 89.82a | 5537a | 3.444a | 114.9a | 6.644a |
| **Ca-chelate*** | 80.56b | 5478ab | 6.12b | 222.1a | 6.574ab | 89.48a | 5756a | 3.371a | 156.9a | 6.907a |
| **Gurenkal*** | 93.34a | 5795a | 6.01b | 214.5a | 6.953a | 88.33a | 5806a | 2.406a | 115.2a | 6.967a |

**Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.**

***Ca-chelate and Gurenkal were used at a rate of 5g $l^{-1}$ and 5ml $l^{-1}$, respectively.**

**Table (8): Effect of interaction between potassium rates and calcium sources on total yield of tomato plants during 2013/2014 and 2014/2015 seasons.**

| Parameter | | Total marketable yield /plant | | Unmarketable yield /plant | | Total yield ton/ 540m$^2$ | Total marketable yield /plant | | Unmarketable yield /plant | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | | Number of fruits | weight of fruits (g) | Number of fruits | weight of fruits (g) | | Number of fruits | weight of fruits (g) | Number of fruits | weight of fruits (g) | Total yield ton/ 540m$^2$ |
| | | Effect of potassium rates X Calcium sources | | | | | | | | | |
| $K_2O$( kg) /540m$^2$X Ca sources | | First season ( 2013/2014 ) | | | | | Second season ( 2014/2015 ) | | | | |
| 40 | + without Ca | 78.62d | 4915ef | 7.38ab | 223.2a | 5.8928ef | 76.22 c | 4918e | 3.557abc | 126.3b | 5.901e |
| 40 | + Ca-chelate* | 73.33d | 5155e | 5.65de | 207.5a | 6.1872de | 86.11bc | 5274de | 2.447c | 132.1b | 6.329de |
| 40 | + Gurenkal* | 88.45bc | 5049e | 5.12e | 150.6a | 6.0592e | 77.00c | 4913e | 2.777bc | 112.7b | 5.896e |
| 60 | + without Ca | 76.81d | 4584f | 8.18a | 342.1a | 5.4992f | 91.11ab | 5650cd | 4.110ab | 109.0b | 6.780cd |
| 60 | + Ca-chelate* | 76.58d | 5104e | 5.76de | 214.5a | 6.1232e | 90.00ab | 5819bc | 4.780a | 236.3a | 6.983bc |
| 60 | + Gurenkal* | 88.40bc | 5596d | 6.33cd | 235.7a | 6.7152cd | 95.00ab | 6069abc | 2.220c | 145.9b | 7.283abc |
| 80 | + without Ca | 81.71cd | 5748c | 7.50ab | 299.7a | 6.9008bc | 102.1a | 6043abc | 2.667bc | 109.3b | 7.251abc |
| 80 | + Ca-chelate* | 91.76b | 6176b | 6.93bc | 244.4a | 7.4128b | 92.33ab | 6174ab | 2.887bc | 102.2b | 7.409ab |
| 80 | + Gurenkal* | 103.18a | 6737a | 6.58bcd | 257.3a | 8.0848a | 93.00ab | 6436 a | 2.220 c | 86.94b | 7.723a |

**Values having the same alphabetical letter(s) did not significantly differ at 0.05 level of significance according to Duncan's multiple range test.**

***Ca-chelate and Gurenkal were used at a rate of 5g $l^{-1}$ and 5ml $l^{-1}$, respectively.**

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## الملخص العربي

# استجابة نباتات الطماطم لمعدلات البوتاسيوم ومصادر الكالسيوم تحت ظروف الصوب البلاستيكية في شمال سيناء

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أجريت تجربة حقلية تحت الصوب البلاستيكية في الموسم الشتوي لعامي ٢٠١٤، و٢٠١٥م في المزرعة البحثية لكلية العلوم الزراعية البيئية، جامعة العريش. كان الهدف هو دراسة تأثير التسميد بمعدلات مختلفة من البوتاسيوم المضافة للتربة (٤٠، ٦٠، و٨٠كجم/٥٤٠م٢) ومصادر للتسميد رشاً بالكالسيوم هي: كنترول (بدون كالسيوم)، والكالسيوم المخلبي بمعدل ٥جم/لتر (٥% كالسيوم)، وجيرنكال بمعدل ٥مل/لتر (٥% كالسيوم) على نمو، ومحصول الطماطم، هجين" في ٥٩-٤٨" تحت ظروف التربة الرملية باستخدام نظام الري بالتنقيط، استخدم نظام القطع المنشقة مرة واحدة في ثلاث مكررات، وأوضحت النتائج أن معاملة نبات الطماطم بكل من البوتاسيوم والكالسيوم كان لها تأثير معنوي إيجابي على معظم صفات النمو الخضري والمحصول تحقق أعلى وزن طازج للنبات وأعلى محصول للطماطم عند تسميد النباتات بمعدل ٨٠كجم/٥٤٠م$^{2}$ + الرش بالجيرنكال بمعدل ٥مل/لتر (٥% كالسيوم)، وتلاه التسميد بمعدل ٨٠كجم/م٥٤٠م$^{2}$ + الرش الكالسيوم المخلبي بمعدل ٥مل/لتر (٥% كالسيوم ).

**الكلمات الاسترشادية:** الطماطم، الصوب البلاستيكية، مصادر البوتاسيوم والكالسيوم، الوزن الطازج، المحصول الكلى.

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