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Response of Tomato Plant to Foliar Application of Calcium and Potassium Nitrate Integrated with Different Phosphorus Rates under Sandy Soil Conditions

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TOMATO is a strategic export vegetable crop in Egypt and the world. So, two field experiments were performed to study the effect of three phosphors rates (0, 14 and 28 kg P fed^{-1}); five foliar treatments (0, 0.3 and 0.6% of Ca and 0.5% and 1% of K) and their interactions on tomato growth and yield.The used experimental design was a split block design with three replicates. Plant height, leaf area, fresh and dry weight (g) of leaves, fruit yield (Mg fed^{-1}), fruit diameter, N, P, K and Ca content (%) in leaves and uptake in fruits and lycopene content (mg kg^{-1}) were determined. The obtained data reveal that all the used treatments significantly affected the previous parameters. Data also show that phosphorus treatment of 14 kg P fed^{-1} gave the best results of leaf area (cm^2), fresh weight of tomatoes leaves, potassium content (%) in leaves, fresh weight of four fruit, fruit diameter and tomatoes yield (Mg fed^{-1}). In addition, foliar application treatments at 0.3 Ca and 0.5% K recorded the highest results of plant height, leaf area (cm^2), fresh weight of tomato leaves, N, P contents in leaves, weight of four fruits, fruit diameter, tomato yields (Mg fed^{-1}), fruit lycopene content (mg kg^{-1}), N and P uptake by fruits. The highest tomato yields (Mg fed^{-1}) values were18 and 18.06 Mg fed^{-1} recorded with 14 kg P fed^{-1} and 0.3% calcium as a foliar application followed by 14 kg P fed^{-1} and 0.5 % potassium which recorded 17.36 and 17.32 Mg fed^{-1}, respectively in both seasons. Generally, it is concluded that the interaction between the treatment of 14 P fed^{-1} and 0.3% calcium or 0.5 % potassium as a foliar application enhanced tomato yield and nutrient uptake.

Keywords: Tomato , Nutrients uptake, Phosphorus , Lycopene, and Yield.

Introduction

Tomato (*Lycopersicon esculentum*) is a strategic export vegetable crop in Egypt and the world.Tomato is widely used in salad as well as for cooking purposes. In Egypt lately, tomatoe plant has been infected by early blight and late blight diseases in wide regions which affected directly tomatoes production. This may be caused by the metrological conditions or increasing nitrogen fertilizers leading to succulent plants which were rapid infected by fungi in addition, no attention to other nutrient especially phosphorus, potassium and calcium.Tomatoes grown in different periods over Egyptian governorates particularly Damietta Governorate where, it isx grown in December and at this time tomatoes showed phosphorus deficiency caused by climatic changes and reduced phosphorus availability especially in alkaline sandy soil. On the other hand, many researchers decided that calcium plays a vital role in the structure of cell walls and cell membranes, fruit growth, and development, as well as general fruit quality (Kadir, 2004). Calcium also can enhance plant resistance to bacterial and viral diseases (Usten et al., 2006). In contrast, Ca deficiencies cause a decline in the growth of merismatic tissues, reduce leaf size, yields, and causes necrosis of young leaves in extreme cases blossom-end rot (BER). In the case of BER, which can cause severe economic losses (Hao and Papadopoulos, 2003 and Taylor & Locascio, 2004) especially in alkaline soils suffering from calcium reduction and increasing sodium. On the otherside, potassium involves in many physiological processes, where it impacts the mechanism of stomatal opening and closing by affecting cell water potential and turgor (Rending

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& Taylor, 1989 and Very & Sentenac, 2003), photosynthesis, assimilate transport, enzyme activation, cell turgor maintenance, synthesis of protein and ion homeostasis (Marshner 1995 and Kanai et al., 2011), direct consequences on crop productivity and fruit quality. Additionally, it's also involved in the enrichment of lycopene contents of tomato fruit through synthesis of pigments or carotenoids (Bedari and Hebsur, 2011) and osmotic adjustment. Contrary, under potassium deficient conditions, tomato fruit will be small size, lacking red color especially in alkaline sandy soil. Sandy soils are considered a poor soil from nutrient and people also there is no care about phosphorus fertilization which led to phosphorus deficiency in plants especially at winter seasons. So, phosphorus is considered a key element in several physiological and biochemical processes as well as it achieves a high yield through addition to soil. In General, the balanced supply of nutrients is important to achieve the optimum yield and fruit quality (Akhtar et al., 2010). This study aimed to illustrate the effects of foliar application of calcium and potassium nitrate on tomatoes plant properties grown under different phosphorus rates in sandy soil.

Materials and Methods

Two field experiments were performed at a private farm, Damietta Governorate , Egypt, during 2013/2014 and 2014/2015 seasons to evaluate the influence of foliar application of potassium and calcium nitrate on tomatoe plant grown in sandy soil under different phosphorus levels. The texture of the used soil was sandy loam and the physical and chemical properties of the used soil are tabulated in Table 1.

TABLE 1. Some physical and chemical properties of the experimental soil

Clay	Silt	Sand	Texture	pH*	EC (dSm^{-1})*	Available nutrient ($mg\ kg^{-1}$) soil		
						N	K	P
11.16%	20.93%	67.91%	Sandy loam	7.86	3.57	25.20	165.00	4.55
Soluble cationmeq L^{-1}				Soluble anions meq L^{-1}				$CaCO_3$ %
Ca^{2+}	Mg^{2+}	K^+	Na^+	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	
9.2	10.2	1.3	15.00	0.00	17.75	10.75	7.85	1.53

* Soil paste was 40 % and field capacity was 21 %.

The different used treatments

Phosphorus fertilizers were used at three rates 0, 14 and 28 kg P fed^{-1} as single super phosphate (7% P) while, foliar application were the control (water only), 0.3 % and (0.6%) calcium as a calcium nitrate, 0.5 % and 1% potassium in potassium nitrate. The experimental design consisted of three replications per treatment in a split block design. Soil preparation was adopted as recommended by the Ministry of Agriculture and Land Reclamation, Egypt and lined then seedlings were spaced 0.5 m between plants in a single row corresponding to approximately 40000 plant fed^{-1}. Tomatoes seedlings (*Lycopersicon esculentum)* Mill cv. Alisa Hybrid F1,were transplanted to the permanent soil on 27 December in each seasons. Plot area was 30 m^2. Phosphorus treatments were added two weeks after seedling planting while the foliar applications were added at branching stage beginning about 45 day after seedling planting. Foliar applications treatments were added four times, 15 days between every spray.

Data collection

After a week from the last foliar spray a vegetative sample (five tomatoes leaves) were collected from each treatment, then fresh and dry weight and leaf area determined. At harvest, fruits of each treatment were collected to determine fruit yield and plant height. Four fruits were weighted as a means of the forth collection. Plant height was determined as average of ten plants. Tomatoes yield was calculated as a summation of yield of each plot in every collection* feddan area / (plot area). The N, P, K and calcium contents in fruit and vegetative samples were analyzed.

Soil analyses

Particle size distribution was determined using the international pipette method as described by Haluschak (2006). The soil electrical conductivity and soil pH values were determined in soil paste as described by Carter and Gregorich (2007). Field capacity and saturated percentage were determined as described by Black (1965).Available nitrogen in soil was extracted by using 2.0 N KCl according to van Reeuwijk (2002) and determined using half automatic kjldhal apparatus while available phosphorus in the soil was extracted by using 0.5 N $NaHCO_3$–pH, 8.5 according to van Reeuwijk (2002). Available potassium in soil was extracted using 1.0 N (CH_3) $COONH_3$ according to Hesse (1971) and determined by using the Flame photometer Janways model PFP7 .

Plant analysis

Fruit and vegetative samples were oven dried (70°C) until constant weight. The oven dry plant samples were ground and wet digested by a sulfuric - percloric acid mixture as described by Cottenie et al. (1982). Nitrogen, phosphorus and potassium contents of vegetative and fruit samples were measured in the digesting extract according to the methods of AOAC International (2012). Calcium content was determined in vegetative sample and fruit by ashing as described by Chapman and pratt (1978) extract method.

Nutrient uptake in kg fed^{-1} equals Nutrient % in leaves or fruits *dry matter of leaves or fruits in kg fed^{-1}/100 (Sharma, et al., 2012).

Lycopene concentration (mg kg^{-1} fresh weight) in fruit was extracted as follows: samples were first chopped and homogenized in a laboratory homogenizer. Approximately 0.3 to 0.6 g samples were weighed and 5 ml of 0.05% (w/v) BHT in acetone, 5 ml of ethanol and 10 ml of hexane were added. The recipient was introduced in ice and stirred on a magnetic stirring plate for 15 min. After shaking, 3 ml of deionized water were added to each vial and the samples were shaken for 5 min on ice. Samples were then left at room temperature for 5 min to allow the separation of both phase sand quantified spectrophotometrically at 472 nm. Apparatus UV-Vis. Spectral analysis has been done using a Janways spectrophotometer (Ravelo-Pérez et al., 2008).

Lycopene content (mg/kg) = absorption reading at $_{503}$* 31.2/g tissue

Statistical analysis

All data were statistically analyzed according to the technique of analysis; variance (ANOVA), the least significant difference (LSD) method and correlation coefficient analysis were used to compare the difference between the means of treatment values to methods described by Gomez and Gomez (1984). Analysis of variance was done for each parameter at $P<0.05$ using CoSTATE PC programming.

Results and Discussion

Vegetative growth parameters

Data presented in Table 2 illustrate that tomato plant height significantly increased with increasing phosphorus rates and the treatment of 28 kg P fed^{-1} gave the highest plant height values (85.33 and 86.40 cm) in both seasons without significant differences with the recommended rate. These results are consistent with that of Sun et al. (2004). Foliar application treatments also significantly increased tomato plant height where, it increased by 14.45, 8.89, 12.40 and 7.14% in the first season and 10.84, 7.52, 12.43 and 6.25% in the second season with the treatments 0.3%, 0.6% calcium (Ca), 0.5 % and 1% potassium (K), respectively. These results may be because of calcium activating enzymes for cell mitosis, division and elongation (Jones,1999).The interaction between phosphorus treatments and foliar application treatments also significantly increased tomatoes plant height compared with the control. The treatment of 28 kg P fed^{-1} combined with 0.5 % K followed by the treatment of 14 kg P fed^{-1} integrated with 0.3 % Ca recorded the highest tomato plant height in both seasons.

On the other hand, phosphorus treatments significantly increased tomato leaf area (cm^2) and the recommended rate (14 kg P fed^{-1}) gave the highest leaf area values (38.93 and 39.12cm^2). These results are in line with Sun et al. (2004) who found that leaf area cm^2 increased linearly with the increase in the phosphorus rates. On the other side, foliar application treatments also significantly increased leaf area except with the treatment of 1% K and 0.6 Ca, it decreased significantly compared with the control.

The obtained results may be due to the role of Ca in cell division, mitosis and carbohydrate metabolism (Davis et al., 2003) and also potassium role in shoot elongation, enzyme activity, protein synthesis, photosynthetic transport, and chlorophyll content (Kanai et al., 2011). The foliar application of 0.5% potassium recorded the highest leaf area. Leaf area (cm^2) significantly increased by the interaction between treatments except with the treatment of 14 kg P fed^{-1} and 1 % K compared with the control.The best leaf area values were 44 and 44.38 cm^2 found at the interaction between 14 kg P fed^{-1} and 0.6 % calcium as a foliar treatment.

TABLE 2. Effect of foliar application of potassium and calcium nitrate and soil phosphorus treatments on plant height (cm), leaf area (cm²), fresh weight (g) and dry weight (g) of tomato leaf samples during the 1st and 2nd seasons.

Treat. Char.		Plant height(cm)		Leaf area(cm²)		Fresh weight(g)		Dry weight (g)	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Phosphorus levels									
0 kg P		79.66b	78.95c	31.26c	32.03c	64.21c	65.78c	13.49c	13.80a
14 kg P		82.93ab	84.00b	38.932a	39.12a	80.54a	80.92a	15.17a	14.96a
28 kg P		85.33a	86.40a	33.75b	34.16b	70.61b	71.45b	13.93b	13.91a
LSD at 5 %		3.76	1.86	0.43	0.94	0.92	1.96	0.16	Ns
Foliar treatment									
Control		76.11c	77.38b	34.93b	35.61b	66.09d	67.41d	13.34c	13.42b
0.3 %Ca		87.11a	85.77a	35.05b	35.47b	74.37b	75.27b	14.36ab	14.34ab
0.6 % Ca		82.88b	83.20a	34.35c	34.61c	71.62c	72.16c	14.25b	14.29ab
0.5 % K		85.55a	87.00a	36.68a	37.20a	75.72a	76.78a	14.69a	14.72a
1 % K		81.55b	82.22a	32.23d	32.61d	71.13c	71.97c	14.33ab	14.34ab
LSD at 5 %		2.13	3.67	0.56	0.43	1.19	0.94	0.32	0.39
Interaction									
0 kg P	**Control**	70.00e	70.16f	28.40k	29.39i	54.34k	56.23i	11.87h	12.48f
	0.3 %Ca	86.33ab	80.33de	28.09k	28.90i	60.91j	62.67h	12.64g	13.49de
	0.6 % Ca	78.66d	79.26e	31.36ij	32.17g	64.00i	65.66g	13.64ef	13.60de
	0.5 % K	81.66cd	82.66cde	36.14de	36.58d	73.75de	74.65de	14.74bc	14.75b
	1 % K	81.66cd	82.33cde	32.33hi	33.11f	68.05h	69.70f	14.58bcd	14.69b
14 kg P	**Control**	80.00d	80.66cde	36.34d	36.59d	75.76cd	76.42c	14.87b	14.48b
	0.3 %Ca	90.00a	90.33ab	42.81b	42.77b	90.10a	90.03a	16.35a	15.45a
	0.6 % Ca	81.66cd	83.33cde	44.00a	44.38a	76.48c	77.01c	14.59bcd	14.76b
	0.5 % K	85.00bc	86.33abcd	40.52c	40.51c	85.28b	85.26b	15.84a	15.42a
	1 % K	78.00d	79.33e	30.98j	31.32h	75.10cd	75.90cd	14.20cd	14.20bc
28 kg P	**Control**	78.33d	81.33cde	32.40gh	33.05f	68.18gh	69.56f	13.30f	13.32e
	0.3 %Ca	85.00bc	86.66abcd	34.26f	34.73e	72.10ef	73.10e	14.10de	14.21bc
	0.6 % Ca	88.33ab	87.00abc	35.34e	35.06e	74.39d	73.80e	14.64bcd	14.53b
	0.5 % K	90.00a	92.00a	33.39f	34.51e	68.15h	70.44f	13.50f	13.65cde
	1 % K	85.00bc	85.00bcde	33.37fg	33.41f	70.23fg	70.33	14.21cd	14.12bcd
LSD at 5 %		3.68	6.35	0.97	0.76	2.05	1.63	0.55	0.67

Leaves fresh weight (g)

From the obtained data in Table 2, fresh weight of tomato leaves significantly increased with phosphorus levels and the treatment of 14 kg P fed^{-1} gave the highest fresh weight values (80.54 and 80.92 g) in both seasons. These results may be regarded to phosphorus role in photosynthesis, the process by which plants harvest energy from the sun to produce carbohydrate molecules, *i.e.* sugars. These results are consistent with Groot et al. (2002). Otherwise, the foliar application treatments increased significantly tomato fresh weight. It was observed that the lower concentration of foliar materials enhanced plant fresh weight than the higher concentration. These results may be due to the increase of leaf area (cm²) by foliar treatments highly correlated with fresh weight (r= 0.82 and r=0.82, $P < 0.05$ level) in both seasons. The best fresh weight values were recorded at the treatment of 0.5 % potassium as a foliar spray in both seasons. These results are consistent with Bidari and Hebsur (2011). A similar trend was found by the interaction between phosphorus treatments and foliar treatments on fresh weight which increased significantly by this interaction compared with thecontrol and the best values of tomatoes fresh weight were 90.1 and 90.03 g found at the treatment of 14 kg P fed^{-1} and 0.3 % Ca as calcium nitrate form. These results may be due to the phosphorus role in root growth and photosynthesis and calcium role in the maintenance of cell membrane integrity, membrane permeability and growth (Morard et al., 1996).

Dry weight of leaves took the same trend in both seasons where, phosphorus, foliar application treatments and its interaction significantly increased dry weight whereas phosphorus rate effects in the second season were not significant. The treatment of 14 kg P fed^{-1} combined with 0.3% Ca gave the best dry weight values (16.35 and 15.45 g) of the vegetative sample in both seasons.

Nitrogen, P, K and Ca contents in tomato leaves

As shown in Table 3 nitrogen content in tomato leaves significantly decreased with increasing phosphorus rates upto 28 kg P fed^{-1}, while the foliar application treatments significantly increased nitrogen content (%) in leaves in both seasons. The calcium foliar application treatment recorded the best nitrogen content in tomato leaves in both seasons and the highest nitrogen content values were 4.55 and 5.01 found at the treatment of 0.3% calcium. Data also illustrate that the lower concentration of foliar application materials gave the best results than the higher concentrations. On the other hand, the interaction between phosphorus treatments and foliar treatments significantly increased nitrogen content in tomatoes leaves compared with the control treatment whereas the interaction between 28 kg P fed^{-1} and 1 % k as foliar application decreased nitrogen content. The integration between 0.6 % calcium and phosphorus treatments (14 and 28 kg P fed^{-1}) recorded the highest nitrogen content values (4.83 and 5.31%) in the two successive seasons, respectively.

Data in Table 3 show that phosphorus content (%) in tomato leaves significantly decreased with increasing phosphorus rates. These results may be due to dilution effect where, the concentration decreased when the growth increased.While the foliar application treatments significantly increased phosphorus content at the lower concentration of foliar application materials and it decreased at the higher concentrations. The obtained data may be due to, at nutrient balance, the little nutrient concentration encourages phosphorus uptake in contrast with higher concentrations.

TABLE 3. Effect of foliar application of potassium and calcium nitrate and soil phosphorus treatments on N, P, K and Ca content (%) of tomato leaves during the 1st and 2nd seasons

Treat.		N % in tomato leaves		P % in tomato leaves		K % in tomato leaves		Ca % in tomato leaves	
Char.		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Phosphorus levels									
0 kg P		4.35a	4.79a	0.207a	0.228a	3.50b	3.67b	0.339b	0.410c
14 kg P		4.35a	4.78a	0.203a	0.224a	3.73a	3.99a	0.392a	0.450b
28 kg P		4.20b	4.63b	0.161b	0.176b	3.61a	3.85a	0.392a	0.470a
LSD at 5 %		0.072	0.079	0.016	0.018	0.14	0.20	0.007	0.009
Foliar treatment									
Control		4.04e	4.44e	0.186b	0.205b	3.36c	3.69c	0.314d	0.377d
0.3 %Ca		4.56a	5.01a	0.216a	0.237a	3.63ab	4.00a	0.315d	0.378d
0.6 % Ca		4.40b	4.83b	0.178a	0.196b	3.48b	3.82b	0.504a	0.600a
0.5 % K		4.32c	4.74c	0.223a	0.245a	3.66ab	4.00a	0.373b	0.440b
1 % K		4.23d	4.65d	0.188b	0.193b	3.79a	4.04a	0.364c	0.437c
LSD at 5 %		0.06	0.067	0.012	0.013	0.15	0.10	0.008	0.010
Interaction									
0 kg P	Control	3.80i	4.18i	0.233ab	0.256ab	3.25f	3.54e	0.292j	0.243i
	0.3 %Ca	4.85a	5.33a	0.252a	0.277a	3.69b	4.06b	0.372f	0.293h
	0.6 % Ca	4.50b	4.95b	0.216bcd	0.238bcd	3.4cde	3.73de	0.536c	0.413e
	0.5 % K	4.24ef	4.67ef	0.220bc	0.242bc	3.62bc	3.94bc	0.520cd	0.433d
	1 % K	4.38cd	4.82cd	0.116f	0.127g	3.56bcd	3.88bcd	0.376f	0.313g
14 kg P	Control	4.13g	4.54g	0.205cde	0.226cde	3.51bcd	3.86cd	0.328g	0.273hi
	0.3 %Ca	4.34de	4.77de	0.199de	0.219cdef	3.60bc	3.99bc	0.552b	0.493b
	0.6 % Ca	4.83a	5.31a	0.186e	0.205f	3.63bc	3.96bc	0.620a	0.533a
	0.5 % K	4.13g	4.54g	0.216bcd	0.238bcd	3.96a	4.35a	0.312h	0.260i
	1 % K	4.34de	4.77de	0.211cd	0.232bcde	3.93a	4.27f	0.308i	0.400ef
28 kg P	Control	4.18fg	4.59fg	0.121f	0.134g	3.34cdef	3.67de	0.312h	0.279hi
	0.3 %Ca	4.48bc	4.92bc	0.197de	0.216def	3.60bc	3.96bc	0.512cde	0.430d
	0.6 % Ca	4.85a	4.24i	0.133f	0.147g	3.42cde	3.77de	0.560b	0.470c
	0.5 % K	4.57b	5.03b	0.232ab	0.255ab	3.81a	3.89bcd	0.512cde	0.426d
	1 % K	3.97h	4.36h	0.122f	0.131g	3.90a	3.99bc	0.456e	0.380f
LSD at 5 %		**0.11**	**0.12**	**0.021**	**0.022**	**0.26**	**0.17**	**0.015**	**0.018**

The highest phosphorus contents were 0.223 and 0.245% recorded at the foliar application of 0.5% potassium in both seasons. On the other side, the phosphorus content (%) was significantly affected by the interaction between different treatments. It was observed that with increasing phosphorus rate integrated with foliar calcium treatments, phosphorus content decreased compared with the control treatment. These results may be regarded to antagonism between phosphorus and calcium which declare from the negative correlation (r =-0.5, $P < 0.05$ level).

Potassium content (%) in tomato leaves shows that phosphorus treatment significantly increased potassium content up to 28 kg P fed^{-1} and the treatment of 14 kg P fed^{-1} gave the highest potassium content values (3.73 and 3.99%). The same trend was found with foliar treatments where, potassium content increased significantly with the foliar application treatments and the increment was higher at the high concentration of 0.6 Ca and 1 % K compared to the low concentration of foliar application treatments. The results are in line with Kazemi (2014) who found that potassium application alone significant increased leaf-NPK contents and chlorophyll content. Also, these results may be due to the increased plant leaf area as affected by foliar treatment which correlated with potassium content by (r= 0.37 and 0.34, $P < 0.05$ level) in both seasons, respectively. Potassium content also significantly increased by the interaction between phosphorus treatment and foliar application treatments compared with the control.The treatment of 14 kg P fed^{-1} and 0.5% potassium recorded the highest potassium content (%) in both seasons. These results may be caused by the response of plants grown in poor sandy soil to phosphorus fertilizer and foliar application with calcium and potassium.

Data in Table 3 illustrate that calcium content in tomatoe leaves significantly increased with increasing phosphorus rate in both seasons and the treatment of 28 kg P fed^{-1} gave the highest calcium content in both seasons. These results may be because phosphorus fertilizers contained a higher amount from calcium as a secondary nutrient with those fertilizers. A similar trend was found with the foliar application treatments where, it increased with different foliar application treatments and the increment was higher in calcium treatments than potassium treatments. The treatment of 0.6 % calcium as a foliar application gave the highest calcium content values (0.5 and 0.6%) in both seasons, respectively. On the other hand, calcium content (%) was significantly affected by the interaction between the different treatments. The highest calcium content values were 0.62 and 0.53% found at the treatment of 14 kg P fed^{-1} combined with 0.6 % calcium as foliar spray. These results may be regarded to the effects of foliar nutrition which stimulates the intake of mineral nutrient by roots (Adamec, 2002).

Tomato yield and fruit nutrients uptake

Concerning tomato yield (Mg fed^{-1}), weight of four fruit, fruit length and fruit diameter data in Table 4 illustrate that all used treatments significantly affected the aforementioned parameters. Where the fresh weight of four fruit increased with increasing phosphorus rate and the highest values were found with 14 kg P fed^{-1} in both seasons. Similar direction was found also with foliar application treatments but the increment in weight of four fruits was higher in the low concentration than the higher concentration. These results may be due to the role of calcium and potassium on photosynthesis, enzyme activation, leaf area (cm^2) cell turgor maintenance and ion homeostasis (Marshner, 1995). The obtained results agree with Anac et al. (1994) and Afzal et al. (2015). The highest weights of four fruits values were 450 and 455.6 g recorded with the interaction between 14 kg P fed^{-1} and foliar application with calcium nitrate at 0.3 %. Fruit diameter increased with the recommended phosphorus dose than the other treatments in both seasons.While it increased with foliar application of 0.3 % Ca, 0.6 %, 0.5 K and 1 % K by 7.50, 4.05, 12.77 and 8.72 % in the first season and by 8.5, 6.23, 13.09 and 10.60% in the second season, respectively compared to the control. Data also show that the lower concentration of foliar application materials achieve a high increase than the higher concentration. The treatment of 0.5 % K as potassium nitrate recorded the highest fruit width values (5.6 and 5.44 cm) in both seasons while the interaction between 14 kg P fed^{-1} and 0.5 % K recoded the best fruit diameter values (6 and 6.1cm) in both seasons, respectively.

Tomatoe yield (Mg fed^{-1})

From the obtained data shown in Table 4, Tomato yield (Mg fed^{-1}) significantly increased with increasing phosphorus rate up to 14 kg P fed^{-1} then decreased compared with the control treatment. These results are consistent with those of Dhinakaran and Savithri (1997) and Idowu et al. (2013) who stated that phosphorus levels significantly increased growth, yield and yield components of snake tomato at 15 kg ha^{-1} up to 30 kg P ha^{-1}. This result is almost similar to Pandey et al. (1996). They reported that fruit yield was increased with the increasing rates of phosphorus. On the other hand, foliar application treatment also significantly increased tomato yield (Mg fed^{-1}), where it increased by 13.50, 1.49, 19.85 and 12.23% in the first season and 17.32, 5.08, 23.55 and 15.93% in the second season with the treatments of 0.3 %, 0.6 % calcium, 0.5 % and 1 % potassium, respectively. The increment was higher with the low concentration of foliar application materials than the high concentration. These results are consistent with that of Shafeek et al. (2013). However the interaction between phosphorus treatment and foliar treatments significantly affected tomato yield (Mg fed^{-1}) where, in the lower phosphorus rate (0 P) foliar application treatment led to increased tomatoe yield (Mg fed^{-1}) compared to the control (0P and 0 foliar) while, at the rate of 14 kg P fed^{-1}, the yield increased also except with the treatment of 0.6 % calcium which decreased tomatoe yield. These results may be regarded to the high calcium content in soil from single super phosphates which contain a big amount of calcium and antagonism between phosphorus and calcium. The results agree with Peyvast, et al. (2009) who revealed different effects of calcium nitrate and potassium phosphate as foliar nutrition and the interaction of these fertilizers on the yield and quality of tomato. The highest tomato yield values (18 and 18.06 Mg fed^{-1}) were recorded with the treatment of 14 kg P fed^{-1} combined with 0.3% calcium as a foliar application followed by 14 kg P fed^{-1} and 0.5 % potassium as a foliar application which recorded 17.36 and 17.32 Mg fed^{-1}, respectively in both seasons. This increased fruit yield with K supply might be due to phloem loading, unloading efficient translocation of assimilates towards sink tissues (Zhao et al., 2001). These results agree with that of Ilyas et al. (2014).

TABLE 4. Effect of foliar application of potassium and calcium nitrate and soil phosphorus treatments on fresh weight of four fruit, fruit diameter, fruit length (cm) and tomato yield (Mg fed^{-1}) during the 1st and 2nd seasons

Treat. / Char.		Fresh weight of four fruit (g)		Fruit diameter (cm)		Fruit length (cm)		Yield (Mg fed^{-1})	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Phosphorus levels									
0 kg P		339.31c	340.07c	5.10b	5.10b	5.46b	5.46b	13.57c	13.60c
14 kg P		400.44a	394.25a	5.54a	5.54a	5.77a	5.78a	16.01a	15.77a
28 kg P		360.11b	360.79b	5.20b	5.22b	5.56b	5.54b	14.40b	14.43b
LSD at 5 %		1.51	15.7	0.23	0.24	0.18	0.14	0.06	0.63
Foliar treatment									
Control		335.06e	324.95e	4.93c	4.81d	5.4b	5.36d	13.40d	12.99d
0.3 %Ca		380.26b	381.03b	5.30b	5.22b	5.64a	5.63b	15.21b	15.24b
0.6 % Ca		340.15d	341.25d	5.17b	5.11c	5.73a	5.73a	13.60c	13.65c
0.5 % K		401.62a	401.27a	5.62a	5.44a	5.65a	5.66b	16.06a	16.05a
1 % K		376.02c	376.68c	5.43ab	5.32ab	5.56ab	5.56c	15.04b	15.06b
LSD at 5 %		2.45	15.10	0.22	0.20	0.19	0.068	0.10	0.60
Interaction									
0 kg P	Control	280.70h	282.40e	4.61e	4.61f	5.05e	5.05h	11.22h	11.29e
	0.3 %Ca	337.60g	338.50d	5.17d	5.21de	5.33cd	5.38f	13.50g	13.54d
	0.6 % Ca	337.80g	339.40d	5.23cd	5.22de	5.92a	5.97b	13.51g	13.58d
	0.5 % K	368.40d	367.50c	5.58bc	5.53c	5.84ab	5.86c	14.73d	14.69c
	1 % K	371.90d	372.60c	5.25cd	5.24de	5.35cd	5.35f	14.87d	14.90c
14 kg P	Control	369.60d	335.80d	5.00d	5.05ef	5.56bc	5.54d	14.78d	13.43d
	0.3 %Ca	450.00a	451.60a	5.83ab	5.86b	5.87a	5.83c	18.00a	18.06a
	0.6 % Ca	346.00f	347.30cd	5.15d	5.17def	5.58bc	5.52d	13.84f	13.90d
	0.5 % K	433.90b	432.90a	6.11a	6.10a	5.95a	6.10a	17.36b	17.32a
	1 % K	402.60c	403.40b	5.81ab	5.83b	5.92a	5.95b	16.10c	16.14b
28 kg P	Control	354.80e	356.60cd	5.20cd	5.20de	5.55bc	5.45e	14.19e	14.26cd
	0.3 %Ca	353.20e	352.90cd	5.12d	5.25de	5.81ab	5.87c	14.12e	14.12cd
	0.6 % Ca	336.50g	336.98d	5.23cd	5.26de	5.88a	5.82c	13.46g	13.48d
	0.5 % K	402.50c	403.50b	5.34cd	5.37de	5.23cd	5.27g	16.10c	16.13b
	1 % K	353.50e	354.00cd	5.25cd	5.28de	5.59bc	5.53d	14.54d	14.66cd
LSD at 5 %		4.25	26.18	0.38	0.18	0.32	0.20	0.17	1.04

Note: Mg is a weight unit and equal 1000 kg or one ton.

Nitrogen, P, K and Ca contents on tomatoes fruits

Data in Table 5 show that nitrogen uptake by tomatoe fruits significantly increased with increasing phosphorus rate and also increased with different foliar application treatments in both seasons. The foliar treatment of 0.5% potassium gave the highest nitrogen uptake by fruits in both seasons. The results agree with Shafeek et al. (2013). On the other hand, the interaction between different treatments significantly influenced nitrogen uptake and the highest nitrogen uptake values (35.83 and 39.50kg N fed^{-1}) were obtained by the interaction between 28 kg P fed^{-1} and 0.5% potassium as a foliar spray. From the obtained data it was observed that at the low phosphorus rate nitrogen uptake increased with different foliar application treatment in both seasons while it decreased with increasing phosphorus rate up to 28 kg P fed^{-1} except with the treatments of 28 kg P fed^{-1} and 0.5 % or 1 % potassium. Data presented in Table 5 declare that phosphorus uptake by tomato fruits increased with increasing phosphorus rate and the increased with 28 kg P fed^{-1} and the increment was less than with the treatment of 14 kg P fed^{-1}.These results agree with Dhinakaran and Savithri (1997) who reported that phosphorus treatment applied at 100 kg P_2O_5 ha^{-1} significantly increased the yield of tomatoes. Phosphorus content and phosphorus uptake of tomato fruit increased with the increased application of phosphorus . Also, foliar application treatments significantly increased phosphorus uptake by tomato fruits compared with the control treatment except with the treatment of 0.6 % calcium.While, the interaction between different treatments significantly increased phosphorus uptake by fruits whereaswith the treatments of 0.3 and 0.6 % calcium with 0 and 14 % kg P fed^{-1} it decreased.The highest phosphorus uptake values by tomato fruits were found with the treatment of 14 kg P fed^{-1} combined with 0.5 % potassium as a foliar application.

Potassium uptake by tomato fruits

TABLE 5. Effect of foliar application of potassium and calcium nitrate and soil phosphorus treatment on N, P, K, Ca uptake by tomatoes fruits (kg fed^{-1}) and lycopene content(mgkg^{-1}) during the 1st and 2nd seasons.

Treat.	Char.	N		P		K		Ca		Lycopene (mgkg^{-1})	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Phosphorus levels											
0 kg P		20.56c	22.75c	2.43c	2.07c	28.40c	27.57b	2.92c	3.52c	84.26a	92.69a
14 kg P		24.92b	26.91b	3.68a	3.06a	35.19a	33.35a	3.25b	4.06b	60.51c	66.56c
28 kg P		26.69a	29.41a	3.06b	2.59b	33.69b	32.58c	3.70a	4.36a	72.89b	80.18b
LSD at 5 %		0.28	1.22	0.16	0.15	1.004	2.10	0.21	0.14	0.94	1.04
Foliar treatment											
Control		21.81e	23.91c	2.74d	2.23d	28.12d	26.21c	2.78d	3.16d	61.61e	67.77e
0.3 %Ca		22.5d	24.04c	2.98c	2.52c	30.26c	29.46b	2.71d	3.30d	84.55a	93.00a
0.6 % Ca		23.20c	25.61b	2.08e	1.76e	28.52d	27.55c	4.02b	4.86b	80.24b	88.26b
0.5 % K		28.68a	31.67a	3.99a	3.39a	37.09b	35.85a	3.59a	4.57a	67.41d	74.15d
1 % K		24.09b	26.55b	3.48b	2.96b	38.14a	36.77a	3.33c	4.00c	68.96c	75.86c
LSD at 5 %		0.49	1.37	0.14	0.19	0.96	1.66	0.17	0.16	1.16	1.27
Interaction											
	Control	15.16k	16.78g	2.17g	1.85fg	22.56k	21.85h	1.71i	2.12i	67.44g	74.18g
	0.3 %Ca	17.97j	19.82f	1.96ghi	1.66gh	24.56j	24.10gh	3.01e	3.71f	95.29a	104.81a
0 kg P	0.6 % Ca	23.48gh	25.95cd	1.88hi	1.59gh	28.64hi	27.69ef	4.53a	5.63a	91.86b	101.0b
	0.5 % K	25.8cd	28.72b	3.46e	2.96cd	35.05d	34.16c	4.12b	5.24b	77.25e	84.97e
	1 % K	20.39i	22.47e	2.67f	2.27e	31.19f	30.06de	2.88ef	3.58fg	89.49c	98.44c
	Control	27.29b	27.29bcd	4.00c	3.07cd	32.49ef	28.42ef	2.80ef	2.87h	49.71i	54.68i
	0.3 %Ca	24.14fg	26.65bcd	3.28e	2.79d	35.23d	34.03c	2.68fg	3.38g	76.49e	84.14e
14 kg P	0.6 % Ca	22.79h	25.17d	1.78i	1.51h	29.38gh	28.39ef	3.67cd	4.36cde	73.14f	80.45f
	0.5 % K	24.42ef	26.80bcd	6.05a	5.11a	34.14de	32.78cd	2.04h	2.71h	52.88h	58.17h
	1 % K	25.99c	28.66b	3.31e	2.81cd	44.73a	43.14a	3.41d	4.29de	50.33i	55.37i
	Control	25.04de	27.67bc	2.05gh	1.75gh	29.32h	28.36ef	3.84bc	4.49cd	67.67g	74.44g
	0.3 %Ca	23.33gh	25.64cd	3.7d	3.12c	30.99fg	30.26de	3.46g	2.81h	81.87d	90.06d
28 kg P	0.6 % Ca	23.34gh	25.70cd	2.57f	2.18ef	27.56i	26.56fg	3.88bc	4.59c	75.74e	83.31e
	0.5 % K	35.83a	39.50a	2.48f	2.10ed	42.1b	40.62a	4.63a	5.75a	72.12f	79.34f
	1 % K	25.91c	28.53b	4.47b	3.79b	38.49c	37.09b	3.7cd	4.15e	77.08e	73.78g
LSD at 5 %		0.84	2.37	0.23	0.33	1.66	2.87	0.30	0.27	2.01	2.22

Potassium uptake by tomato fruits significantly increased with increasing phosphorus rate and increased also with the foliar application treatments compared with unfertilized plants. The foliar application treatments of 0.3 and 0.6% calcium and 0.5 and 1 % potassium increased potassium uptake by 7.61, 1.42, 31.89 and 35.85% in the first season and by 12.39, 5.11, 36.77 and 40.28 % in the second season, respectively compared with the control treatment. These results may be attributed to the increment in the yield by the used treatments. The same trend was found with the interaction between phosphorus and foliar treatments where, potassium uptake by tomatoe fruits increased with foliar application treatment under different phosphorus treatments compared with the control treatment except with the treatments of 0.6 % calcium with 14 and 28 kg P fed^{-1}. The highest potassium uptake values were found with the treatment of 14 kg P fed^{-1} and 1% potassium in both seasons. These results agree with Shafeek et al. (2013) who found that N, P K and Ca uptake content recorded by foliar application of higher concentration of potassium nitrate emphasizes the role of K in plant metabolism and its involvement in many associated processes (Marschner,1995).

Concerning calcium uptake by tomato fruits (kg fed^{-1}), the present data illustrate that calcium uptake by tomato fruits is significantly affected by phosphorus treatments, foliar application treatments and their interaction. It increased by increasing phosphorus rate and foliar treatments. These results may be due to increasing yield with increasing phosphorus rates. In addition, it was observed that at the lower phosphorus rate (0 kg fed^{-1}), foliar treatments increased calcium uptake by tomato fruits (kg fed^{-1}) compared with the other phosphorus treatments.The highest values calcium uptake by tomatoe fruits (kg fed^{-1}) were found at the treatment of 28 kg P fed^{-1} joined with 0.5% potassium as a foliar application in both seasons.

Fruit lycopene content (mg kg^{-1})

Data in Table 5 show that the different treatments significantly affected fruit lycopene content where it decreased with increasing phosphorus rates compared with the control. These results may be due to the low volume of tomatoe plant in this treatment and the effect of climate factor (solar radiation and temperature). These results agree with Oke et al. (2005) who observed that climatic factors had more effect than P fertilization on the lycopene content of tomatoes. While, lycopene content was increased with foliar application treatments especially calcium treatments. This result may be associated with the little content of calcium in the studied soil. These results are in contrast with that of Paiva et al. (1998) and in agreement with that of Kazemi, (2014) who found that potassium nitrate increased fruit lycopene content. The highest fruit lycopene content (mg kg^{-1}) values (84.55 and 93 mg kg^{-1}) were recorded with the treatment of 0.3% calcium in both seasons.The same trend was found with the interaction between phosphorus treatment and foliar application treatments. The obtained data also illustrate that at 0 P kg fed^{-1} combined with calcium treatments, lycopene content was higher than potassium treatment compared with the control treatment. Also, lycopene content decreased with the integration between 14 kg P fed^{-1} and foliar treatments than the control. These results may due to the effect of phosphorus increment rate, soil calcium content and nutrient balance which affected photosynthesis, pigments and also the negative correlation with phosphorus content (r= -0.54 and -0.52, $P < 0.05$ level) in both seasons, respectively. The treatment of 0 phosphorus rate and 0.3% calcium recorded the highest fruit Lycopene content (mg kg^{-1}) values (95.29 and 104.81 mg kg^{-1}) followed by 0 phosphorus rate and 0.6% calcium in both seasons, respectively. These results may be due to reduced yield in these treatments compared with the other treatments.

Conclusion

Finally, phosphorus treatments, foliar treatments and their interaction significantly influenced tomato growth, yield and nutrient uptake. Lycopene content significantly increased with foliar application treatments especially calcium treatments. Generally, we concluded that the interaction between the treatment of 14 kg P fed^{-1} and 0.3% calcium or 0.5 % potassium as a foliar application enhanced and increased tomato growth, yield and nutrient uptake.

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استجابة نبات الطماطم للرش بنترات البوتاسيوم والكالسيوم متحدا مع معدلات مختلفة من الفوسفور تحت ظروف الاراضي الرملية

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تعتبر الطماطم من محاصيل الخضر التصديرية الاستراتيجية في مصر والعالم. لذا أقيمت تجربتين حقليتين لدراسة تأثير معدلات الفوسفور (صفر و ١٤ و ٢٨ كجم فوسفور/فدان) وخمسة معاملات رش (صفر – ٠,٣ ٪ و ٠,٦ ٪ كالسيوم – ٠,٥ ٪ و ١ ٪ بوتاسيوم) والتفاعل بينهم علي نمو محصول الطماطم. التصميم التجريبي المستخدم هو تصميم القطع المنشقة مرة واحدة في ثلاثة مكررات. تم تقدير كلا من طول النبات – مساحة الورقة – الوزن الطازج والجاف للأوراق ومحصول الثمار (طن/ فدان) و قطر الثمرة ومحتوي الاوراق من النيتروجين والفوسفور والبوتاسيوم والكالسيوم والممتص منهم في الثمار وكذلك محتوي الثمار من الليكوبين . قد أوضحت النتائج المتحصل عليها أن جميع المعاملات المستخدمة أثرت معنويا علي الصفات المدروسة. تبين النتائج ايضا أن معاملة ١٤ كجم فوسفور /فدان أعطت افضل النتائج لكلا من مساحة الورقة و الوزن الطازج والجاف للأوراق و محتوي الاوراق من البوتاسيوم و الوزن الطازج لأربعة ثمار و قطر الثمرة و ومحصول الثمار (ميجا/ فدان). بالإضافة الي ذلك سجلت معاملات الرش ب ٠,٣ ٪ و٠,٥ ٪ بوتاسيوم اعلي نتائج لطول النبات – مساحة الورقة – الوزن الطازج للأوراق محتوي الأوراق من النيتروجين والفوسفور والوزن الطازج لأربعة ثمار ومحصول الثمار (ميجا/ فدان) و قطر الثمرة ومحتوي الثمار من الليكوبين و الفوسفور والنيتروجين الممتص بواسطة الثمار. سجلت التفاعل بين ١٤ كجم فوسفور /فدان و٠,٣ ٪ كالسيوم أعلي قيم لمحصول الطماطم ١٨,٠٦ و ١٨ ميجا /فدان متبوعا بمعاملة ١٤ كجم فوسفور /فدان و ٠,٥ ٪ بوتاسيوم رشا والتي سجلت ١٧,٣٦ و ١٧,٣٢ ميجا/ فدان في كلا الموسمين. بصفة عامـــة يمكن استنتاج ان التفاعل بين معاملة ١٤ كجم فوسفور /فدان مع ٠,٣ ٪ كالسيوم أو ٠,٥ ٪ بوتاسيوم رشا أدت الي زيـــادة وتحسين محصول الطماطم والعناصر الممتصة.