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Impact of Calcium Foliar Application on Quality Improvement of Grafted Tomato Seedlings

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Abstract: Two investigations were conducted during the winter and summer seasons of 2014 and 2015, at the Eastern Experimental Station of the Faculty of Agriculture, Cairo University under net-house conditions, to study the influence of foliar application with calcium under two different conditions of temperature on quality improvement of tomato seedlings cv. Castlerock (scion) that grafted on wild tomato *Solanum pennellii*'LA716'(rootstock). Rootstock tomato seeds were sown 15 days before the scion seeds in two different dates as follow: on 14th January or 25th June 2014 and on 15th January or 28th June 2015 in seedling-trays. Scion and rootstock seedlings were sprayed by calcium (global chelated calcium 12%) 3 times 1, 2 or 3 weeks after emergence at rate of 1g Ca per one litter of water as compared with the control. A randomized complete blocks design with 3 replicates was adopted. The results indicated that shoot and root fresh weights and shoot and root dry weights were significantly higher in the summer grafting date than the winter grafting date in both seasons, except shoot fresh weight and shoot dry weight in the first season that did not show any significant differences between the winter and summer grafting dates. Moreover, grafting date in both seasons did not appear any significant differences in SPAD readings of leaves as well as in photosynthesis in the first season, whereas photosynthesis in the second season was significantly higher in the summer grafting date than the winter grafting date.On the other hand, foliar application by Ca gave significant increment in root fresh weight, shoot dry weight, SPAD readings, photosynthesis and stomatal conductance than non-treated one. Generally, foliar calcium application increased percentage of grafting success between cultivated tomato and wild species and also increased seedling quality.

Key words: Tomato, Calcium · Grafting · Photosynthesis · Chlorophyll · Stomatal Conductance.

INTRODUCTION

Grafting of the herbaceous seedlings is a unique horticultural technique practiced for many years, to solve the problems associated with the intensive cultivation given limited arable land for vegetable production [1]. At present, grafted plants are used for fruit production of most watermelon, tomato, eggplant, cucumber, melon and pepper. Grafting of these crops is performed for both open field and protected cultivation in Japan and Korea, as well as in China, Spain, Italy, Greece and Turkey [2-4]. In Egypt, grafting became an essential mean to solve many problems such as salinity, soil excessive moisture, high and low temperatures [5-14]. One key component for successful high quality and high yielding vegetable production is to begin with high quality transplants. Seedling quality is one of the primary concerns among farmers. High quality transplants can be produced through grafting and more farmers are purchasing grafted seedlings from professional nurseries [15]. Sometimes, the grafting process becomes very difficult and may be failed when the used rootstock is a wild species especially in tomato that has slow growth and thin stem [16]. One of the wild species of greatest interest is *Solanum pennellii* which has tolerance to water deficit and has high resistance to isolates of three strains of *Fusarium oxysporum f. sp. Lycopersici* [17, 18].

Even though the main nutrients are very important for most plants, calcium is even more important for some plants, such as tomatoes.In the form of calcium pectate, calcium holds the cell walls of plants together. It also activates specific plant enzymes, which send signals to the plant cells that coordinate certain growth activities. Also, calcium plays a role in increasing stem thickness

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and in excess cell healing and cell regeneration [19]. Also, calcium is required for cell elongation in both shoots and roots and for enzymes activities [20]. So, the objective of this work was to study the influence of foliar calcium application on improvement quality of grafted seedlings tomato and percentage success of grafting.

MATERIALS AND METHODS

Two investigations were conducted during the winter and summer seasons of 2014 and 2015, at the Eastern Experimental Station of the Faculty of Agriculture, Cairo University, under net-house conditions, to experiment the influence of foliar application with calcium under two different conditions of temperature on quality improvement of tomato seedlings cv. Castlerock (scion) that grafted on wild tomato *Solanum pennellii* 'LA716' (rootstock). Rootstock tomato seeds were sown15 days before the scion seeds in two different dates as follow: on 14thJanuary or 25th June 2014 and on 15th January or 28th June 2015 in seedling-trays. Scion and rootstock seedlings were sprayed by calcium (global chelated calcium 12%) 3 times 1, 2 or 3 weeks after emergence at rate of 1g Ca per one litter of water as compared with the control (spraying with water only). All rootstocks were transplanted before grafting in black plastic bags, 20 cm^2 diameter, filled by peat moss and vermiculite (1:1v). Seedlings were grafted by hand, applying the cleft grafting method when the scion had 2 true leaves and the rootstock 3 true leaves. Then the grafted plants were kept for 7-10 days under 90-95% RH and 45% shading conditions at temperature between 30 to 32 °C for healing. A randomized complete block design with 3 replicates was adopted; the number of grafted tomato of each replicate was 40 plants. After healing period, success percentage of all grafted plants of each treatment was calculated. Also, a sample of five successful grafted plants of each treatment was randomly sampled to estimate leaf temperature, leaf relative humidity,SPAD readings (measured by SPAD 502 chlorophyll meter), photosynthesis, stomatal conductance and transpiration with using Prometer (Portable Photosynthesis System, model LI 6200, JICA Project, Japan). In the same samples, shoot or root fresh weight and shoot or root dry weight as well as Ca concentration, in leaves in mg/g dry weight, using absorption flame photometer according to the method described by Brown and Lilliland [21], were estimated. All data were analyzed according to split plot design during the grafting date to illustrate the interaction between calcium spraying and grafting date. Data were treated by analysis of variance with using MSTAT-C v. 2.1 and means were compared by the least significant difference test (LSD) at 5% level of probability [22].

RESULTS AND DISCUSSION

As shown in Table 1, shoot and root fresh weights and shoot and root dry weights were significantly higher in the summer grafting date than in the winter grafting date in both seasons, except for shoot fresh weight and shoot dry weight in the first season that did not show any significant differences between both grafting dates. These results may be attributed to the genetic characters of tomato, because tomato related to the warm season crops. So, it was logic to give higher growth in the summer season than the winter season.On the other hand, foliar applications with Ca gave significant excess in root fresh weight and shoot dry weight in both seasons than non-treated one, whereas foliar Ca application of tomato seedlings did not achieve any significant differences than non-treated one in shoot fresh weight and root dry weight in both seasons. These results are supported by Burstrom [20] who confirmed that root development commonly associated with calcium. The interaction between grafting date and Ca treatment showed that no significant effects on shoot or root weights were recorded in the summer grafting date with Ca foliar application than non-treated tomato, except for shoot dry weight in both seasons and root fresh weight in the second season which increased significantly in the case of Ca application than non-treated one. Moreover, there were no significant differences in shoot and root fresh weights as well as shoot and root dry weights in both seasons with Ca application of winter grafting date, except for root fresh weight in the second season that was significantly higher with Ca treatment than non-treated one. These results may be due to calcium role in activating specific plant enzymes, which send signals to the plant cells that coordinate certain growth activities despite low temperature in the winter. Moreover, increasing calcium concentration in leaves of grafted plants in the winter confirms the role of calcium in improving the quality of grafted seedlings [19].

With respect to success percentage of grafted tomato, data in Table 2 showed that success percentage of grafted plants was significantly higher in the winter grafting date than the summer grafting date only in the second season, while in the first season no significant differences appeared between the winter and summer grafting dates. This decrease in success percentage of

Table 1: Effect of grafting season and calcium spraying on seedling growth of tomato during 2014 and 2015 seasons.

Treatment		Season of 2014				Season of 2015			
Grafting season	Ca	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight g)	Shoot fresh weight (g)	Root fresh weight (g)	Shoot dry weight (g)	Root dry weight (g)
Summer grafting	With Ca	25.03	4.36	3.11	0.75	28.00	4.73	4.04	0.78
	Without a	23.72	3.86	2.65	0.70	26.13	4.05	3.58	0.74
Mean		24.38	4.11	2.88	0.72	27.06	4.39	3.81	0.76
Winter grafting	With Ca	22.23	3.65	2.47	0.67	23.96	3.62	3.11	0.67
	Without Ca	21.20	3.08	2.20	0.61	24.01	3.07	2.93	0.66
Mean		21.72	3.36	2.33	0.64	23.98	3.35	3.02	0.66
Ca application									
With Ca		23.63	4.01	2.79	0.71	25.98	4.17	3.57	0.73
Without Ca		22.46	3.47	2.42	0.66	25.07	3.56	3.25	0.70
LSD at 0.05									
Grafting season		NS	0.28	NS	0.08	2.70	0.08	0.27	0.08
Ca		NS	0.43	0.32	NS	NS	0.26	0.23	NS
Grafting season X Ca		3.55	0.61	0.45	0.07	2.39	0.36	0.33	0.10

Table 2: Effect of grafting season and calcium sprayingon success% of grafting, leaf temperature (LT), leaf relative humidity (LRH) and SPAD readings in tomato during 2014 and 2015 seasons.

Treatment		Season of 2014				Season of 2015			
Grafting season	Ca	Success (%)	LT (C°)	LRH (%)	SPAD readings	Success (%)	LT (C°)	LRH (%)	SPAD readings
Summer grafting	With Ca	99.00	37.67	25.33	51.30	98.33	37.53	26.93	52.10
	Without Ca	95.00	37.90	22.60	47.53	95.67	38.43	22.67	47.43
Mean		97.00	37.78	23.97	49.42	97.00	37.98	24.80	49.77
Winter grafting	With Ca	100.00	24.83	23.20	55.13	100.00	24.27	23.73	56.20
	Without Ca	98.00	24.47	22.27	50.23	98.33	24.40	22.13	54.33
Mean		99.00	24.65	22.73	52.68	99.17	24.33	22.93	55.27
Ca application									
With Ca		99.50	31.25	24.27	53.22	99.17	30.90	25.33	54.15
Without Ca		96.50	31.18	22.43	48.88	97.00	31.42	22.40	50.88
LSD at 0.05%									
Grafting season		NS	0.80	1.17	NS	0.72	0.97	2.61	NS
Ca		1.13	NS	0.38	4.31	0.65	0.47	1.73	NS
Grafting season X Ca		1.60	0.88	0.54	6.10	0.93	0.67	2.44	NS

grafted plants in the summer may be attributed to high temperature in this period that may cause great injuries of healing process. In this respect, Kumar and Sanket [11] mentioned that healing is most critical to provide favorable conditions to promote callus formation of grafted seedlings. In healing chamber, temperature should be 28-29 ºC and increasing temperature above that may damage whole plants. Otherwise, foliar Ca application significantly increased success percentage of grafted tomato in both seasons as compared with non- treated plants. These results were also true between treated and non-treated tomato in both grafting dates. These results are in agreement with those mentioned by Jones and Lunt [19] who reported that calcium has main role in excess healing by induce callus formation at grafting area that play a main role in increasing percentage of grafting success. Also, calcium plays an important role in increasing stem thickness during increasing cell division and elongation which raise the chance of grafting success between the cultivated tomato and wild species.

Also, grafting date, Ca application and the interaction between them affected significantly on both of leaf temperature (LT) and leaf relative humidity (LRH) as shown in Table 2. Generally, LT in both seasons and LRH only in the first season were significantly higher in the summer grafting date than the winter grafting date, while LRH in the second season did not affect significantly with grafting date variation. On the other hand, LT only in the second season as well as LRH in both seasons significantly increased with foliar Ca treatment as compared with non-treated one, while no significant differences were recorded in LT with or without spraying

Table 3: Effect of grafting season and calcium spraying on photosynthesis (PS), stomatal conductance (SC), transpiration (T) and Ca concentration in tomato leaves during 2014 and 2015 seasons.

Treatment		Season of 2014				Season of 2015			
Grafting season	Ca	PS (µmol CO_2 $m^{-2}S^{-1}$)	SC (mmol m^{-2} S^{-1})	T (mmol H_2O m^{-2} S^{-1})	Ca (ppm)	PS (µmol CO_2 $m^{-2}S^{-1}$)	SC (mmol $m^{-2}S^{-1}$)	T (mmol H_2O $m^{-2}S^{-1}$)	Ca (ppm)
Summer season	With Ca	588.50	4.86	92.64	17.95	577.00	4.72	94.19	18.93
	Without Ca	573.70	3.75	99.52	16.99	483.40	3.70	101.60	17.95
Mean		581.10	4.30	96.08	17.47	530.20	4.21	97.89	18.44
Winter season	With Ca	569.70	4.34	87.81	18.11	483.00	3.92	87.95	17.87
	Without Ca	545.80	3.71	93.17	16.04	436.90	4.72	89.68	15.47
Mean		557.70	4.02	90.49	17.08	459.90	4.32	88.81	16.67
Ca application									
With Ca		579.10	4.60	90.22	18.03	530.00	4.32	91.07	18.40
Without Ca		559.80	3.73	96.35	16.52	460.20	4.21	95.64	16.71
LSD at 0.05%									
Grafting season		NS	NS	3.92	NS	35.26	NS	NS	1.44
Ca		NS	0.41	4.13	1.00	26.21	NS	3.33	0.77
Grafting season X Ca		NS	0.58	5.85	1.41	37.07	0.93	4.71	1.09

Ca in the first season. Moreover, foliar application of Ca in both grafting dates did not show any significant variation in LT in both seasons, except in the summer date in the second season which showed significant reduction in LT, as compared with non-treated plants. Conversely, Ca application in both seasons caused significant increment in LRH with both grafting dates, except in the winter grafting date in the second season that did not show significant differences between treated and non-treated plots with Ca, as compared with non-treated plants. In this regard, increasing LTand LRH in the summer grafting than the winter grafting reflects the effect of temperature in both of periods on plant. In contradiction, the increment of LTand LRH with Ca foliar application may be attributed to the indirect effect of activation of specific plant enzymes.

With respect to SPAD readings in leaves, data in Table 2 showed that grafting date in both seasons and Ca application in the second season as well as the interaction between them only in the second season did not appear any significant differences in SPAD readings of leaves. On the contrary, foliar calcium treatment gave significant excess in SPAD readings as compared with non-treated plants in the first season. Also in the first season, Ca application in the summer grafting date gave a significant increase in SPAD readings as compared with non-treated plots, whereas theses significant variations was not recorded in the winter season. The positive effect of calcium in raising SPAD readings confirms the results that mentioned by Jones and Lunt [19] in the role of calcium in activation plant growth.

Concerning the effect of grafting date, Ca application and the interaction between them on photosynthesis, stomatal conductance, transpiration and Ca concentration, data in Table 3 indicated that photosynthesis in the first season was not affected significantly with grafting date variation or with Ca application as well as with the interaction between them, whereas photosynthesis in the second season was significantly higher in the summer grafting date than the winter grafting date. Also, photosynthesis significantly increased with Ca application as compared with non-treated one.

These results also were true in both of summer and winter grafting dates. On the other hand, grafting date in both seasons and Ca application only in the second season had not any significant effects on stomatal conductance, while Ca application gave significant improvement of stomatal conductance as compared with non- treated plots. Moreover, stomatal conductance was better with using foliar application of Ca in both seasons whether in the summer or in the winter grafting dates. Likewise, transpiration was higher in the summer grafting date than the winter grafting date but this increment in transpiration was significant only in the first season. Ca application caused a significant decrease in transpiration in both seasons as compared with non-treated plots. Similarly, transpiration was significantly lower with using foliar application of Ca than non-treated plots in the summer grafting date in both seasons, whereas no significant differences were recorded with or without using Ca application in the winter grafting date on

transpiration in both seasons. With respect of Ca concentration in leaves, data revealed that Ca concentration was higher in the summer grafting date than the winter grafting date and this excess was significant only in the second season. Absolutely, foliar Ca treatment caused significant enhancement of Ca concentration in leaves in both seasons as compared with non-treated one. The effectiveness of foliar treatment of Ca did not appear obviously in the summer grafting date on Ca concentration in leaves, while in the winter grafting date Ca concentration in leaves was significantly higher with using Ca application as compared with non-treated plants in both seasons. The previous results of photosynthesis and transpiration in the summer or winter grafting reflect the temperature effectiveness on each grafting period on plant. Whereas, the results of Ca application on improvement photosynthesis and stomatal conductance confirmed the results that mentioned by Burstrom [20] and Jones and Lunt [19].

CONCLUSION

Foliar calcium application increased percentage of grafting success between cultivated tomato and wild species and also increased seedling quality.

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