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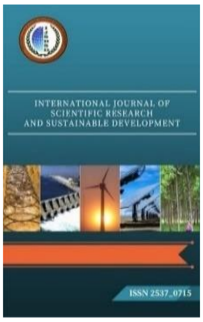

Effect of some anti-stress compounds on growth and production of tomato plants grown in winter season

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ABSTRACT

This investigation was achieved at the two successive winter seasons of 2020 /2021 and 2021/2022 in the Experimental Station of the Hort. Dept., of Agric. Fac., Benha Univ. to examine the influence of anti-stress compounds, i.e., lithovit (0.5 g\ L), fulvic acid (1.0 g\ L) and potassium silicate (2.0 g\ L) as foliage spray on vegetative growth, nutrients content, yield and fruit quality for both hybrids,. i.e., Super gold and Super streen of tomato cultivars grown under low tunnels covered with mesh (65%). Results indicated that tomato plants derived from Super gold F_1 exceeded significantly those derived from Super streen in both seasons regarding plant height, leaves area, branches No., leaves No. and fresh as well as dry weight per plant, N, P, K percentages, total chlorophyll, total proline, fruit set, and consequently total yield with better quality of fruits regarding T.S.S. percentage, total yield, firmness and vit. C. In this respect foliar spraying Super gold F_1 cultivar by potassium silicate at 2 g/l three times started after 30 days from transplanting and every 15 days as intervals recorded the highest values of plant height, branches No. and leaves No., leaves area, fresh and dry weight per plant as well as N%, P%, K%, total chlorophyll and proline, fruit set, T.S.S., total yield, firmness and vit. C. in comparison with the other treatments. Contrarily, using Super streen and spraying with tap water recorded the least values of the aforementioned characters, meanwhile using fulvic acid at 1g/l or lithovit Co_2 at 0.5 g/l as foliar sprays on Super gold cultivar came in between in this respect during both seasons.

Keywords: Tomato, cultivar, foliar spray, lithovit, fulvic acid and potassium silicate.

Introduction

Tomato (*Solanum lycopersicum*) is the most important vegetable crop in open field, greenhouses, and tunnels. The yearly cultivated area is assessment to be 599, 615 fed. which equalize 30% of the total vegetable area (Reclamation, Statistics of Ministry of Agriculture, Egypt 2020).

Low temperature in winter season is essential environmental factor that limits the productivity of cultivated tomato plants in Egypt. Low temperature stress below 15°C causes growth disturbances and low yields in serious proportions **(Weiss and Egea- Cortines, 2009)**. Tomatoes grown in greenhouse or tunnel conditions in winter season, show yield loss of serious proportions caused by low temperature stress **(Ahmed et al., 2016; Yousef and Ali, 2019; Midan et al., 2020; Mohamed et al, 2022)**. Varieties differ in their tolerance to low temperatures **(Mohamed et al., 2022)**. So, the selection of cultivars with high genetic potential in terms of fruit yield and quality under abiotic stress, along with application of synchronous agro-technical measures such as spraying plants with anti-stress compounds increases the yield per area and total tomato production.

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Lithovet compound is a natural calcium carbonate (nano-$CaCO_3$) nano-fertilizer as a foliar fertilizer, containing 75% calcium carbonate, 5% silica, 4% magnesium carbonate and particles extremely small from natural limestone deposits, that enhance their ability to enter plant stomata, when sprayed **(Cai et al., 2009)**. Application lithovit as foliage spray significantly increased plant growth, yield and its quality **(Nassef and Nabeel, 2012** on broccoli**; Byan, 2014** on bean**; Farouk, 2015** on potato**; Abdelghafar et al., 2016** on onion**; Abo-Sedera et al., 2016** on snap bean**; Abdel Nabi et al., 2017** on lettuce**; Abo El-Hamd and Abd Elwahed, 2018** on okra**; Merwad et al., 2018** on garlic**).** Potassium silicate (K_2SiO_3) is an exporter of highly soluble K and Si so it is used as a silicon source to protect plants especially under abiotic stress and supplying the plants with potassium to get better quality of yield **(Tarabih et al., 2014)**. Potassium influences synthesis, transformation and storage of carbohydrates and improved fruits or tuber quality **(Ebert, 2009; Dkhil et al., 2011; Marschner, 2012)**. Silicon reduces multiple stresses in plants by preserve plant water potential, photosynthetic efficacy, stomatal administration, and leaves straightness **(Crusciol et al., 2009; Saud et al., 2014; Shaaban and Abou El- Nour, 2014; Das et al., 2017)**. Potassium silicate improved growth and yield for different crobs **(Salim et al., 2014; Abd El-Gawad et al., 2017** on potato plants**; Ghanaym et al., 2022** on snap bean**)**. As for fulvic acid, it plays an active role in increasing the permeability for the cellular membrane which made water and nutrient absorption more effective in the plant, which helps the movement of metals and their transfer in the plant. In addition to that, the enzymatic system becomes more efficient, the root system develops, cell division and dry material increases **(Meena *et al.*, 2017)**.

According to the reports on beneficial effects of potassium silicate, lithovit (nano-$CaCO_3$) and fulvic acid on improving yield quality and nutritional and health importance of plants especially under various stresses, thus, this study was administrated in order to evaluate the influence of potassium silicate, lithovit (nano-$CaCO_3$) and fulvic acid on vegetative growth, nutrients content, yield and quality of tomato plants grown in winter season under low tunnels.

Materials and methods

A field experiment was carried out during the two successive winter seasons of 2020/2021 and 2021/2022 in the Experimental Station of the Horticulture Dept., Agric. Fac., Benha Univ. to examine the impact of potassium silicate, lithovit and fulvic acid as foliar application on vegetative growth, nutrients content, yield and fruit quality of tomato plants grown under low tunnels covered with mesh (65%). The experimental soil analyses are tabulated in Table (1).

Table 1: Soil analysis of the experimental farm.

Mechanical			Textural Class	pH (1-2.5 Soil: water suspension)	EC: Soil paste 1:1 dS/m	Organic matter	
Sand	Silt	Clay	Clay	7.7	1.3	2.2%	
25%	19.9%	55.1%					
Soluble Anions and Cations							
Anions (meq./L)				Cations (meq./L)			
CO_3^{--}	HCO_3^{--}	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
1.4	2.0	3.4	0.80	2.50	1.20	1.27	1.23
Available macro and micro elements							
(mg/kg)			ppm				
N	P	K	Fe	Mn	Zn	Cu	
18.71	17.9	75	24.3	9.4	7.6	3.6	

Seeds of used cultivars, *viz.*, Super gold F_1 (Grand green company) and Super streen F_1 (United Genetics Italia company) were sown in trays containing mixture of peat moss and vermiculite (1:1) fertilized with macro and micro nutritional elements. After 35 days, the tomato seedlings were transplanted under tunnels

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protected on 11th and 15th of November in the first and second season, respectively, at 50 cm apart on one side of ridge 12.0 m long and 1m width with an experimental unit area of 12 m^2. The experiment treatments were designed as a complete randomize design with four replications and included 8 treatments which were the combinations between 2 two tomato cultivars (Super gold F_1 and Super streen F_1), and 4 foliar application treatments as the following:

1. Control (Tap water).

2. Lithovit Co_2 (0.5 g\ L)

3. Fulvic acid (1.0 g\ L)

4. Potassium silicate (2.0 g\ L)

Foliar application of different treatments was executed at 30 days after transplanting and repeated every 15 day intervals, the total number of foliar application reached 3 times. All cultural practices i.e., irrigation, hoeing as well as weeding, and fertilizer applications kept the same for all treatments.

Data recorded.

Three plants from each experimental plot were randomly taken at 75 days after transplanting and the following data were recorded:

1. Morphological characters:

- Plant height (cm).

- Amount of branches /plant.

- Number of leaves and flowers /plant.

- Fresh and dry matter of shoots (g/plant).

2. Chemical determination analysis:

Total chlorophyll reading was determined according to the equations previously represented by **Wettestin (1957)**.

Nutrient elements were determined from the dry plant samples as follows:

- N% was determined by modified micro Kjeldahle method as described by **Pregl (1945)**.

- P% was determined colorimetrically according to **Jackson (1967)**.

- K% was determined using Spectrophotometer (A Perkin-Elmer, Model2380.USA) according to the methods of **Chapman and Pratt (1982)**.

- Proline concentration was measured according to the method of **Bates et al. (1973)**.

- TSS% was determined by using refractometer but vitamin C, and titratable acidity were estimated according to **A.O.A.C. (1990)**.

3. Yield and its quality

At flowering stage, fruit set percentage was calculated according to the following equation: Fruit set % = No. of fruit / No. of Flowers × 100.

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At harvesting time yield was expressed as number of fruits per plant and yield per plant (kg). Total yield as kg/plot were recorded, then calculated as tons/fed. Fruit firmness was measured on the two opposite sides of fruit using Effige penetrometer, 2 mm probe and data in LbF was recorded.

Statistical analysis

Data were subjected to the statistical analysis by the method of Duncan's multiple range tests as reported by **Gomez and Gomez (1984)**.

Results and discussion:

Morphological characters: -

The effect of anti-stress compounds, i.e., lithovit (0.5 gl\ L), fulvic acid (1.0 g\ L) and potassium silicate (2.0 g\ L) as foliar application on the growth of two F_1 tomato genotypes are tabulated in Table (2). Results indicate that tomato plants derived from Super gold F_1 exceeded significantly those derived from Super streen in both seasons regarding plant height, leaves area, branches No., leaves No., fresh and dry weight per plant. Differences between tomato cultivars were also observed by **Mohamed et al. (2022).** The difference in the tomato growth may be due to the difference in the genetic makeup of different cultivars where, each variety requires different environmental conditions for proper growth and development to produce optimum yield **(Mesa et al., 2022 and Mohamed et al., 2022)**.

Table 2. Effect of potassium silicate, fulvic acid or lithovit as foliar sprays on some vegetative growth characters of tomato plants of both Super gold and Super streen genotypes in 2020/2021 and 2021/2022 winter seasons.

Treatments		Plant height (cm)		Branches No. /plants		Leaves No./plants		Fresh weight (g)		Dry weight (g)		Leaves area (cm^2)	
		2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022
Super gold F_1	Potassium silicate	75.3^{a}	72.3^{a}	5.3^{a}	5.0^{a}	60.3^{a}	55.3^{a}	614.3^{a}	590.7^{a}	98.0^{a}	93.7^{a}	1415.3^{a}	1372.7^{a}
	Fulvic acid	72.0^{b}	68.3^{c}	4.7^{ac}	4.3^{ab}	50.7^{b}	45.0^{bc}	548.3^{b}	542.7^{b}	83.7^{c}	82.7^{b}	890.7^{bc}	1141.3^{c}
	Lithovit Co_2	73.3^{b}	70.3^{b}	5.0^{ab}	4.7^{a}	51.0^{b}	48.3^{b}	595.3^{a}	566.7^{ab}	90.7^{b}	88.3^{ab}	1296.0^{ab}	1238.0^{b}
	Control	69.7^{c}	66.0^{d}	4.0^{cd}	3.7^{bc}	48.3^{b}	43.0^{cd}	490.3^{c}	466.0^{c}	79.7^{c}	74.3^{c}	877.7^{bc}	822.0^{f}
Super streen F_1	Potassium silicate	70.0^{c}	67.0^{cd}	4.3^{bc}	3.7^{bc}	50.3^{b}	43.0^{cd}	466.3^{c}	419.0^{d}	81.7^{c}	75.7^{c}	1150.3^{ac}	1113.7^{cd}
	Fulvic acid	64.0^{e}	61.0^{f}	3.3^{de}	3.0^{c}	38.7^{cd}	35.3^{e}	365.0^{d}	351.7^{ef}	63.0^{e}	61.7^{de}	1016.3^{ac}	963.3^{e}
	Lithovit Co_2	66.7^{d}	64.0^{e}	3.3^{de}	3.3^{c}	43.3^{c}	41.0^{d}	392.7^{d}	374.0^{e}	70.3^{d}	64.3^{d}	1092.3^{ac}	1042.7^{de}
	Control	59.3^{f}	58.3^{g}	3.0^{e}	3.0^{c}	35.0^{d}	33.3^{e}	358.0^{d}	334.7^{f}	59.3^{e}	55.3^{e}	846.3^{c}	794.7^{f}

Values within a column which linked by the same letter are not significantly different ($P \leq 0.05$) based on Duncan's test

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In this respect foliar spraying Super gold F_1 plants by potassium silicate at 2 g/l three times started after 30 days from transplanting and every 15 days as intervals produced the best plant height, branches No., leaves No., leaves area as well as fresh and dry weight per plant in comparison with the other treatments. In this respect, **Salim et al. (2014)** as well as **Abd El-Gawad et al. (2017)** on potato plants and **Ghanaym et al., (2022)** on snap bean plants stated that the highest values of growth parameters were observed with foliar application of potassium silicate treatment.

Contrarily, using Super streen and foliar spraying with tap water produced the lowest values of all vegetative growth parameters, meanwhile using fulvic acid at 1g/l or lithovit Co_2 at 0.5 g/l as foliar spraying on Super gold cultivar came in between in this respect during both seasons. These results are in regularity with those determined by **Farouk (2015)** on potato, **Abo-Sedera *et al.* (2016)** on snap bean, **Abdel Nabi *et al.* (2017)** on lettuce, **Merwad et al. (2018)** on garlic and **Abo El-Hamd and Abd Elwahed (2018)** on okra, who found that spraying plants with lithovit gave the highest values of vegetative growth than unsprayed ons.

Such improvement in vegetative growth of tomato plants resulted from foliar application with potassium silicate at 2 g/l may be due to the individual influence of both potassium and silica which play a great role in the metabolism of plant and the assimilation of protein which is necessary for cells formation and consequently increased dry matter in plant which are perfect indicators for plant growth **(Gong et al., 2005 and 2008; Gong and Chen, 2012)**. Also, Si induces dehydration tolerance at the tissue or cellular levels by improving the water situation and adverb facilitates the plant to access photosynthesis at a higher rate **(Ahmed et al., 2013)**. Foliar fertilization of potassium silicate may be more beneficial for silica deposition in the required key points which keep very healthy hairy roots enabling better water, macro, and micronutrient absorption. Also, this may be due to the physiological function of silicon is based on relations between silicon deposition at certain points and enhanced resistance to various stresses **(Shaaban and Abou El Nour, 2014; Das et al., 2017)**. It also modifies the plane of osmolytes and antioxidant enzymes which are the first line of protection in stress, also reducing the oxidative stress factors such as hydrogen peroxide **(Sapre and Vakharia, 2016)**. In this study, the improving effects of lithovit are to increase CO_2 levels within the plant leaf's structure and by modulation promote photosynthetic efficiency. Lithovit also includes nano-Mg, which plays a substantial role in many plants physiological processes, such as photosynthesis, sugar synthesis, starch translocation, control of nutrient uptake. It also works as an enzyme activator, a constituent of many enzymes and a carrier of phosphorus in the plant (**Allison *et al*., 2001; Kumar, 2011; Maswada and Abd El-Rahman 2014**; **Rawat and Melkania, 2015** and **Abd El-baset, 2018)**.

Chemical composition of plant foliage:

Data tabulated in Table (3) reveal that Super gold plants exceeded mostly the those of Super streen regarding N, P, K percentages, total chlorophyll, and total proline during both seasons (**Mohamed *et al.*, 2022)**. Results also indicate that planting Super gold cultivar then foliar spraying the plants with potassium silicate at 2 g/l three times starting after 30 days from transplanting and every 15-day intervals produced the best and significant values regarding total chlorophyll, N, P and K percentages and total proline content during both seasons of the experiment as compared with other used treatments. These results are compatible with those obtained by **Salim *et al.* (2014)** as well as **Abd El-Gawad *et al.* (2017)** on potato plants and **Ghanaym *et al.*, (2022)** on snap bean plants stated that foliar application of potassium silicate treatment improved chemical constituents of the plant.

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Table 3. Effect of potassium silicate, fulvic acid or lithovit as foliar sprays on some chemical composition of plant of tomato plants of both Super gold and Super streen genotypes in 2020/2021 and 2021/2022 winter seasons.

Treatments		Total chlorophyll (mg/g Dr.wt)		Nitrogen (%)		Phosphorus (%)		Potassium (%)		Total proline (µg/g Dr.Wt)	
		2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022
Super gold F_1	Potassium silicate	6.71[a]	6.67[a]	2.24[a]	2.38[a]	0.59[a]	0.69[a]	2.46[a]	2.62[a]	1052.7[a]	1034.3[a]
	Fulvic acid	5.59[de]	5.22[d]	1.86[e]	1.87[e]	0.49[e]	0.54[e]	2.05[c]	2.05[c]	934.0[b]	887.3[bc]
	Lithovit Co_2	6.20[bc]	6.07[b]	2.07[c]	2.17[c]	0.54[c]	0.63[c]	2.27[b]	2.38[b]	1021.7[ab]	963.0[ab]
	Control	5.13[e]	4.99[d]	1.71[f]	1.78[f]	0.45[f]	0.52[f]	1.88[e]	1.96[e]	830.3[c]	766.0[c]
Super streen F_1	Potassium silicate	6.53[ab]	6.33[ab]	2.18[b]	2.26[b]	0.57[b]	0.65[b]	1.96[d]	2.03[d]	945.0[b]	886.7[bc]
	Fulvic acid	5.12[e]	4.56[e]	1.71[f]	1.63[g]	0.45[f]	0.47[g]	1.54[g]	1.46[g]	623.3[d]	532.3[d]
	Lithovit Co_2	5.94[de]	5.68[c]	1.98[d]	2.03[d]	0.52[d]	0.59[d]	1.78[f]	1.83[f]	890.0[c]	812.0[c]
	Control	4.06[f]	3.90[f]	1.35[g]	1.39[h]	0.36[g]	0.40[h]	1.22[h]	1.25[h]	458.3[d]	423.7[d]

Values within a column which linked by the same letter are not significantly different ($P \leq 0.05$) based on Duncan's test

Contrarily, using Super streen and spraying with tap water produced the least values in all parameter's total chlorophyll, N, P, K and total proline, meanwhile planting Super gold and spraying with either fulvic acid at 1g/l or lithovit at 0.5g/l came in between in this respect during both seasons. In this respect, **Cai *et al.*, (2009), Byan (2014), Abdel Nabi *et al*. (2017) and Abd El-baset (2018)** indicated that foliar spraying with lithovit improved chemical constituents of plant, i.e., nitrogen, phosphorus, and potassium % as compared to normal water (control).

Yield and its quality,

Data tabulated in Table (4) indicate that using Super gold plants significantly exceeded those of Super streen regarding fruit set, T.S.S. percentage, total yield, firmness and vit. C. Results also indicate that foliar spraying Super gold plants with potassium silicate three times started after 30 days from planting and every 15 days as intervals produced the best and the highest significant values regarding total yield, fruit set, firmness, T.S.S. and vit .C during both seasons of the experiment. This might be due to the increase in vegetative growth traits (Table, 2), reflecting a significant increase in dry matter contents and thus may lead to improving total fruit yield and its quality. **El-Hedek, 2013** on wheat, **Salim *et al.* (2014)** as well as **Abd El-Gawad *et al.* (2017)** on potato and **Ghanaym *et al.*, (2022)** on snap bean plants stated that foliar application of potassium silicate treatment improved the yield and its components. Contrarily, using Super streen combined with foliar spraying with tap water produced the least values in total yield per fed., fruit set, firmness, T.S.S. as well as vit. C during both seasons. Meanwhile, using Super gold combined with either fulvic acid or lithovit came in between in this respect during both seasons. Similar findings were also obtained by **Byan (2014)** on snap bean, **Farouk (2015)** on potato and **Abo El-Hamd and Abd Elwahed (2018)** on okra, who found that plants sprayed with lithovit at 0.75 g/l. recoded the maximum values of yield and its components compared to the unsprayed plants.

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Table 4. Effect of potassium silicate, fulvic acid or lithovit as foliar sprays on some yield and its component of tomato plants of both Super gold and Super streen genotypes in 2020/2021 and 2021/2022 winter seasons.

Treatments		Fruit set (%)		Total yield (ton/fed)		Firmness (kg/cm²)		T.S.S (%)		Vit. C (mg/100 ml juice)	
		2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022	2020 /2021	2021 /2022
Super gold F_1	Potassium silicate	71.73^{a}	64.87^{a}	3.870^{a}	3.683^{a}	2.50^{a}	2.33^{a}	5.68^{a}	5.06^{a}	25.67^{a}	25.33^{a}
	Fulvic acid	59.00^{c}	57.20^{c}	3.550^{cd}	3.420^{c}	2.27^{b}	2.07^{cd}	4.96^{b}	4.45^{b}	25.00^{ab}	24.33^{a}
	Lithovit Co_2	66.13^{b}	61.03^{b}	3.683^{b}	3.560^{b}	2.37^{ab}	2.23^{ab}	5.49^{a}	4.62^{b}	25.00^{ab}	24.67^{a}
	Control	52.67^{d}	49.20^{ef}	3.423^{e}	3.313^{d}	2.10^{cd}	1.97^{ce}	4.51^{c}	4.04^{c}	25.67^{ab}	22.67^{b}
Super streen F_1	Potassium silicate	65.70^{b}	52.33^{d}	3.613^{bc}	3.417^{c}	2.33^{b}	2.10^{bc}	4.16^{d}	3.94^{c}	24.67^{ab}	24.33^{a}
	Fulvic acid	57.00^{c}	46.53^{fg}	3.317^{f}	3.083^{e}	2.03^{de}	2.23^{ab}	3.48^{e}	3.30^{d}	24.67^{ab}	21.33^{bc}
	Lithovit Co_2	60.13^{c}	50.57^{de}	3.480^{de}	3.293^{d}	2.23^{bc}	1.93^{de}	3.66^{e}	3.50^{d}	22.33^{b}	22.33^{b}
	Control	51.83^{d}	44.47^{g}	3.190^{g}	2.987^{f}	1.93^{e}	1.87^{e}	3.13^{f}	2.98^{e}	22.33^{b}	20.33^{c}

Values within a column which linked by the same letter are not significantly different ($P \leq 0.05$) based on Duncan's test

Conclusion

From the aforementioned study, it could be recommended that planting Super gold F_1 of tomato seedlings in winter season under low tunnels conditions and spraying plants with potassium silicate (2 g/l) or lithovit (0.5 g/l) three times started after 30 days from transplanting and every 15 days as intervals resulted in the best vegetative growth, total yield, fruit set, firmness, T.S.S. and vit. C under the condition of this experiment.

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