Journal of Applied Horticulture, 23(2): 136-141, 2021

https://doi.org/10.37855/jah.2021.v23i02.26

Journal of Applied Horticulture

ISSN: 0972-1045

Efficiency of Lithovit-Guano 25 as affected by foliar spray or fertigation on salt-stressed-tomato crop

Saleh Mobarak Al Turki

*Department of Arid Land Agriculture, College of Agricultural and Food Sciences, King Faisal University, P.O. Box 400, Al Ahsa 31982, Kingdom of Saudi Arabia. *E-mail: smturki@kfu.edu.sa*

Abstract

The application of small-scale fertilizers is among methods tested to reduce the salinity-caused reductions in crop production. The efficiency of a certain fertilizer was shown to be significantly affected by its application method or place. Therefore, in the current study, Lithovit-Guano25 (Guano) was applied with a concentration of 2 $g.L^{-1}$ through two methods of fertigation (ferti) and foliar spraying (foliar) on tomato salt-stressed crop irrigated by four different NaCl solutions (EC 2, 6, 10 and 14 $dS.m^{-1}$). Control plants were those irrigated by NaCl solutions with no Guano application. Leaf number, fresh weights of plant parts, yield components, nutrient content, and total chlorophyll content, were reduced with salt stress. Salinity increased total soluble solids, titratable acidity and cell electrolyte leakage. Compared to control, Guano-foliar caused a reduction in soil EC by 0.09, 0.13, 0.2 and 0.22 $dS.m^{-1}$ respectively at EC2, EC6, EC10 and EC14. Fresh weights of shoots and roots were optimized mainly in Guano-foliar by 12.5, 10, 4 and 7.5 g compared to control, respectively at EC2, EC6, EC10, and EC14. When comparing methods of application, no significant difference was found between both methods on fruit diameter, fruit TSS, TTA and Mg content. Leaf area and fruit weight in Guano-foliar-treated plants were significantly higher (by 20 cm^2 and 2.5 g) compared to Guano-ferti-treated plants at EC14. Moreover, fruit number and yield were also maximized following Guano-foliar treatment. Guano-foliar treated plants accumulated less sodium at EC6 (by 0.2 %) and more phosphorus at all ECs (by 0.2 %) than those of Guano-ferti. Additionally, nitrogen, calcium, and total chlorophyll content were maximized in Guano-foliar-treated plants. When compared to fertigation, foliar spraying of guano had a better effect on mitigating salt stress.

Key words: Fertigation, foliar spray, Lithovit-Guano25, *Solanum lycopersicum*, salinity, tomato

Introduction

Tomato belonging to the family of Solanaceae order solanales (Knapp and Peralta, 2016) is a worldwide cultivated crop with high economic importance. It is sensitive to salt-stress especially at seedling stage (Raza *et al.,* 2016) due to physiological imbalances and nutrient deficiencies caused by this abiotic stress (Al-Taisan, 2010). Salinization is currently occurring in more than 45 million ha of irrigated soils (Shrivastava and Kumar, 2015). It is estimated that the rentability of agricultural commodities with be reduced in countries of low latitude which suffers from the elevation in temperatures and CO_2 (Gornall *et al.*, 2010). According to FAO (2018), in arid and semi-arid regions more than 20 km of lands are lost daily due to salinization. Soil and water salinity represent a challenge for the sustainability in agriculture in the Saudi Arabia (Elhag, 2016) where high salinity is found in most parts of AlAhsa oasis (Allbed *et al.*, 2014). In fact, in the last decades, the intensive agricultural activities have put pressure on groundwater use (Chowdhury and Al-Zahrani, 2015) leading to seawater intrusion and to an increase in the EC of groundwater (Sabtana and Shehata, 2003). According to Al-Dakheel *et al.* (2011), salinity in Al-Kharj groundwater ranged between 1.1 and 10.2 $dS.m^{-1}$.

Many previous methods were used to counteract the negative impacts of salinity on tomato; the application of fertilizers with low salt-index such as monopotassium-phosphate (MKP), spraying of osmoprotectants such as glycine betaine and the pulverization of auxin-like substances such as acetyl salicylic acid (Sajyan *et al.*, 2019a, b, c). Additionally, the use of small sized-fertilizers is gaining nowadays an importance especially as an efficient method to mitigate the adverse effect of salinity. Lithovit products are among those small sized-fertilizers which were previously implemented and applied on salt-stress crops. For instance, lithovit-standard improved yields and plant growth of tomato crops up to 8 $dS.m^{-1}$ (Sajyan *et al.*, 2018, 2019d, e). Regarding lithovit-standard, it was observed that its pulverization on plant foliage or its fertigation helped in reducing the inhibitory effects of salinity. However, foliar spraying was slightly better than the second method (Sassine *et al.*, 2020); it maximized macronutrients accumulation, roots and shoot growth and yielding capacity in stressed plants. Moreover, Lithovit-Guano25 which is composed of 28 % CaO; 5 % MgO; 4.5 % SiO_2; 1.5 % N; 0.6 % P_2O_5; 0.6 % K_2O; 0.5 % Fe and 0.07 % Mn seemed also to be highly efficient under salt-stress. Previously, it was sprayed on salt-stressed eggplant and improved the performance of the crop through an enhancement in nutrient uptake and photosynthetic pigments. Thus, it helped in reducing Na accumulation in plant shoots and fruits (Issa *et al.*, 2020). Additionally, based on its elemental composition, the separate application of each element found in Lithovit-Guano25 including N, P, K, Fe, Ca and Si was efficiently applied on many salt-stressed crops; and showed counteractive effects facing this abiotic stress (El-Fouly *et al.*, 2002; Tuna *et al.*, 2007; Tantawy *et al.*, 2009; Siddiqui *et al.*, 2014; Sadak *et al.*, 2015).

The efficiency of a certain fertilizer or product was shown to be significantly affected by its application method or place. For instance, phosphorus applied through fertigation had the best efficiency on mungbean compared to its application through binding or broadcast (Shah *et al.*, 2006). Additionally, the effectiveness of the application method of a certain product was correlated with the type of fertilizer. Sassine *et al.* (2020) observed that the fertigation of monopotassium phosphate which is a traditional fertilizers rich in potassium and phosphorus optimized the performance of tomato under salinity conditions better than its foliar spraying. On the contrary, spraying of lithovit®-standard was more efficient than its fertigation on the same crop. In fact, choosing the optimal method when applying a product would increase its cost-effectiveness. Therefore, fertigation and foliar spraying of lithovit-Guano was compared in the current study to determine the optimal application method for the product.

Materials and methods

Experimental conditions: The research was done in 2020 in the Agricultural - Veterinarian Training and Research Station of King Faisal University (15 kilometers away from King Faisal University's main campus) Alahsa, Saudi Arabia. This region is situated at 150 m above sea level, characterized by a desertic climate; climatic conditions during the experiment were as follows: a relative humidity of 30 %, a day-night temperature of 30-35 ±8 °C. Seeds of tomato (var. Sila) were surface sterilized in 0.1 % sodium hypochloride for 20 min sown in plastic trays. One month after sowing, uniform seedlings of 3-4 true leaves were ready for transplantation. Tomato seedlings were transplanted in February in plastic pots of 30 cm in diameter filled with a mixture based on soil (2/3) and peat moss (1/3) prepared on volume basis. The initial soil EC was of 0.25 $dS.m^{-1}$. Ammonium sulfate (20.6 %N) and monopotassium phosphate (52 P_2O_5 and 34 % K_2O) were added with a rate of 6 $g.plant^{-1}$ and 3 $g.plant^{-1}$ at the fifth day after transplantation (DAT), respectively.

Experimental treatments: Seedlings were irrigated with fresh water (EC=0.15 dS/m) for the first 2 weeks and at the Day 16 saline irrigation started using four solutions of NaCl (2, 6, 10 and 14 dS/m). The application of Lithovit-Guano25 product was done through foliar spraying or fertigation at Day 20, 35, 50 and 65 using a concentration of 2 $g.L^{-1}$.

Growth traits: During the experiment, vegetative growth was assessed for all treatments; leaf number was counted, leaf area (cm^2) was measured by multiplying leaf length by leaf width. In addition, at 100 days after transplantation (DAT), representative samples were removed from each treatment, their plant parts were separated into shoots and roots. Fresh weight of shoot and root were weighed using a digital balance. Plant parts were oven dried at 100 °C until obtaining a constant weight. Based on dry weight, root mass fraction (RMF) and shoot to root ratio (S/R ratio) were calculated as follows:

RMF = Root dry weight/ Total plant dry weight;

S/R = Aboveground parts dry weight/ Underground parts dry weight.

Nutrient determination: For nutrient determination, dried samples of shoots were grinded, digested in a mixture of sulphuric and percloric acids; N was determined in % using kjeldahl method (Black, 1965), P was determined colorimetrically (Troug and Meyer, 1939), while K, Na, and Ca were determined by flame photometry as described by Brown and Lilleland (1946), and Mg by flame photometry as described by Andersen *et al.* (1962).

Total chlorophyll and cellular electrolyte leakage: Total chlorophyll content was determined on fully expanded leaves (5 g) which were macerated in acetone (80 %) in a mortar containing calcium carbonate until full discoloration. The supernatant was collected and centrifuged at 3000 rpm for 5 min. Chlorophyll content of the solution was quantified as described by arnon (1949). Cellular electrolyte leakage was determined as described by Lutt *et al.* (1996). Briefly, discs of 1g of fresh leaves were immersed in tubes containing deionized water at 25 °C and conductivity (EC1) of bathing solution was measured after 6 hours. Tubes were autoclaved at 120 °C for 20 min., cooled to 25 °C and then conductivity (EC2) was measured. Cell electrolyte leakage was calculated: CEL (%) = (EC1/EC2) x 100.

Yield traits and fruit quality: Representative mature fruits were picked from each treatment; weight and diameter of individual fruits were determined. Fruit number and fruit yield were also measured. For the determination of fruit quality, tomato juices were prepared from all treatments. Titratable acidity and total soluble solids were evaluated as described by Garner *et al.* (2005) and pH also was measured on tomato juices corresponding to each treatment.

Soil EC: For the determination of soil EC, three representative soil samples were collected from each treatment. Samples were dried and grinded; 1:5 soil:water suspension was prepared by adding 20 g air-dry soil to 100mL deionized water.

Statistical analysis: Data was analyzed using SPSS version 25. Means were compared by Duncan's multiple range tests at $P \leq 0.05$. A complete randomized block design was adopted with 3 replications, and treatments divided into 4 saline solutions and two method of Lithovit-Guano25 application. At each salinity level, control treatment was represented by plants only irrigated by NaCl solutions with no Lithovit-Guano25 application.

Results

Growth traits: Vegetative growth of plant parts was significantly inhibited by salinity with the lowest values obtained at EC10 and EC14 (Table 1). In control plants, leaf number, leaf area, fresh weight of shoots and fresh weight of roots were reduced respectively from 8.33 leaves, 179.1 cm^2, 40.2 g and 13.87 g at EC2 to reach a minimum of respectively 7.33 leaves, 137.1 cm^2, 32.43 g and 10.1 g at EC14. RMF was inhibited similarly by salinity while S/R ratio increased with increasing in salt-stress.

The application of Guano helped tomato in counteracting salt-stress by improving all vegetative attributes except RMF where treated and non-treated plants had similar averages at all EC levels. Fresh weight of shoots and roots was significantly higher in Guano-ferti and Guano-foliar-treated plants than in control plants at EC2, EC6 and EC10 with no significant differences between both treatments. Leaf number was improved significantly similarly by both Guano treatments. On the contrary, although treating plants with Guano (in both methods) improved leaf area compared to control, however, Guano-foliar was significantly better than Guano foliar. For instance, under EC2, EC10 and EC14, leaf area of tomato plants treated with Guano-foliar

Table 1. leaf number, leaf area, fresh weight of plants parts, RMF and S/R ratio of tomato plants under saline stress and application of Guano

Salinity (dS/m)	Treatment	LN	LA (cm^2)	FWS (g)	FWR (g)	RMF ($g.g^{-1}$)	S/R ratio ($g.g^{-1}$)
2	Control	8.33[abc]	179.10[c]	40.20[bc]	13.87[cd]	0.35[de]	1.91[a]
	Guano-ferti	9.67[de]	211.60[g]	51.17[f]	18.30[fg]	0.33[bcde]	2.08[abc]
	Guano-foliar	10.22[e]	222.63[h]	52.10[f]	19.90[g]	0.35[e]	1.87[a]
6	Control	8.00[ab]	159.70[b]	38.13[b]	12.27[bc]	0.34[cde]	1.97[ab]
	Guano-ferti	8.00[ab]	205.97[fg]	45.27[de]	16.30[ef]	0.29[abc]	2.40[bcd]
	Guano-foliar	9.44[cde]	208.90[g]	47.13[e]	17.43[f]	0.31[abcde]	2.25[abcd]
10	Control	8.56[abcd]	149.43[b]	41.00[bc]	11.50[ab]	0.28[ab]	2.52[cd]
	Guano-ferti	8.00[ab]	184.37[cd]	42.33[cd]	13.80[cd]	0.27[a]	2.68[d]
	Guano-foliar	8.67[bcd]	196.10[ef]	44.57[de]	14.97[de]	0.31[abcde]	2.25[abcd]
14	Control	7.33[a]	137.10[a]	32.43[a]	10.10[a]	0.29[ab]	2.52[cd]
	Guano-ferti	7.33[a]	175.03[c]	37.50[b]	11.33[ab]	0.29[abc]	2.42[bcd]
	Guano-foliar	8.44[abc]	193.50[de]	39.67[bc]	12.03[abc]	0.30[abcd]	2.31[abcd]

L.N: leaf number; L.A: leaf area; FWS: fresh weight of shoots; FWR: fresh weight of roots; Means (n=9) followed by the same letter within each column are not significantly different according to Duncan's multiple range tests.

(respectively of 222.63 cm^2, 196.1 cm^2 and 193.5 cm^2) was higher than the one of plants treated with Guano-ferti (respectively of 211.6 cm^2, 184.37 cm^2 and 193.5 cm^2). Leaf number under EC6 was similarly promoted by Guano-foliar compared to Guano-ferti.

Nutrient content in shoots: Nitrogen content in shoots reduced with increasing in salt-stress from EC2 to EC14 (Table 2). However, this reduction was not significant in control plants. Guano-foliar maximized N content at all EC levels. Guano-foliar-treated plants had an N content higher by two-fold compared to control at all EC levels. Guano-ferti also enhanced, but less than Guano-foliar, N content at all EC except EC14. Phosphorus and potassium contents were inhibited by salinity mainly in control plants (Table 2). Treating plants with Guano in both methods lowered the salinity-induced reductions at all ECs with the best effect observed at EC2. In fact, Guano-foliar improved significantly P content in shoots compared to Guano-ferti by 0.14 %, 0.15 %, 0.12 % and 0.13 % respectively at EC2, EC6, EC10 and EC14. No significant difference in K content was observed between both methods of Guano application.

As a result of P and K accumulation in Guano-treated plants, Na accumulation was inhibited significantly under salt-stress. Consequently, at EC2, EC6, EC10 and EC14, Na contents were lower in Guano-ferti-treated plants (respectively of 0.61 %, 0.84 %, 0.9 % and 1.14 %) and Guano-foliar-treated plants (respectively of 0.47 %, 0.64 %, 0.85 % and 0.93 %) compared to control (respectively of 0.99 %, 1.12 %, 1.2 % and 1.31 %). In general, Guano-foliar induced lower Na content than Guano-ferti. Ca and Mg content also were significantly minimized in control plants peaking at EC14 with respectively 0.38 % and 0.12 % in control plants. Fertigation and spraying of Guano improved both nutrients in shoots; this improvement was only significant for Ca content but not for Mg content. Guano-ferti induced higher Ca content compared to Guano-foliar with a non-significant effect between both treatments at all EC levels.

Table 2. Variation in nutrient content of tomato shoots under saline stress in different treatments

Salinity (dS/m)	Treatment	N (%)	P (%)	K (%)	Ca (%)	Na (%)	Mg (%)
2	Control	0.54[a]	0.17[a]	1.46[cd]	0.84[cd]	0.99[cd]	0.31[bc]
	Guano-ferti	1.08[d]	0.57[e]	2.23[fg]	1.44[f]	0.61[ab]	0.30[bc]
	Guano-foliar	1.18[d]	0.71[f]	2.41[g]	1.34[f]	0.47[a]	0.40[c]
6	Control	0.46[a]	0.16[a]	1.28[bc]	0.66[bc]	1.12[de]	0.27[bc]
	Guano-ferti	0.88[bc]	0.43[cd]	2.04[f]	1.13[e]	0.84[c]	0.25[ab]
	Guano-foliar	1.05[d]	0.58[e]	2.13[f]	0.95[de]	0.64[b]	0.30[bc]
10	Control	0.41[a]	0.12[a]	1.06[a]	0.51[ab]	1.20[ef]	0.17[ab]
	Guano-ferti	0.75[b]	0.36[bc]	1.82[e]	0.87[cd]	0.90[c]	0.25[ab]
	Guano-foliar	0.90[c]	0.48[de]	1.81[e]	0.75[cd]	0.85[c]	0.27[bc]
14	Control	0.48[a]	0.15[a]	1.11[ab]	0.38[a]	1.31[f]	0.12[a]
	Guano-ferti	0.56[a]	0.32[b]	1.66[de]	0.74[cd]	1.14[de]	0.23[ab]
	Guano-foliar	0.79[bc]	0.45[cd]	1.73[e]	0.67[bc]	0.93[c]	0.26[abc]

Means (n=3) followed by the same letter within each column are not significantly different according to Duncan's multiple range tests; N: nitrogen; P: phosphorus; K: potassium; Ca: calcium; Na: sodium; Mg: magnesium.

Yield traits: In control plants, weight and diameter of fruits (Table 3) was reduced significantly with increasing in salt-stress; from a maximum of respectively 21.41 g and 2.84 cm at EC2 to a minimum of respectively 11.3 g and 1.78 cm at EC14. Similar reduction was observed in treated plants with a lower extent. The application of Guano improved significantly both indicators with a better effect obtained by Guano-foliar mainly on fruit weight. For instance, fruit weight in plants treated with Guano-ferti was significantly higher at all ECs than the one of the control (by a range of 3 to 7 g) and significantly lower than the one of Guano-foliar (by a range of 1 to 2 g). Fruit diameter of treated plants (by Guano-ferti and Guano-foliar) did not differ significantly among both Guano treatments. Fruit number reduced under salinity effect. This reduction peaked at EC14 in control plants.

Treating plants with Guano-foliar improved significantly fruit number (Table 3) up to approximately two-fold mainly at EC6. Foliar spraying of Guano similarly improved this trait compared to control at all EC levels. Consequently, yield of Guano-treated plants was significantly enhanced compared to control at all EC levels. At EC2, EC6, EC10 and EC14, yields were of 202.69 g, 151.16 g, 82.5 g and 30.87 g respectively in Guano-foliar-treated while it was of 81 g, 50.04 g, 37.86 g and 13.43 g respectively in control plants.'

Total soluble solids in fruits (Table 4) were maximized in control compared to Guano-foliar and Guano-ferti with the highest value obtained at EC14 (11.1 °Brix). Similarly, titratable acidity was improved by salinity. It was lower in Guano-treated plants than the control at EC2, EC6, EC10 and EC14. Fruit pH of salt-stressed plants were reduced in control plants reflecting higher acidity than treated-plants.

Total chlorophyll content and cell electrolyte leakage: As seen in the Table 5, T Chl which was reduced by increasing in salt-stress, increased following fertigation or foliar spraying of Guano. At all EC levels, no significant difference was found between both method of application. However, foliar spraying of Guano was always slightly better than its fertigation, in improving T Chl content compared to control at all EC levels. T Chl in Guano-foliar-treated plants was of 1.87 $mg.g^{-1}$ fresh weight, 1.703 $mg.g^{-1}$ fresh weight, 1.567 $mg.g^{-1}$ fresh weight and 1.537 $mg.g^{-1}$ fresh weight respectively at EC2, EC6, EC10 and EC14.

Cell electrolyte leakage (Table 5) followed an opposite pattern than previous traits; it was increased with increasing

Table 3. Variation in yielding traits of tomato under saline stress in different treatments

Salinity (dS/m)	Treatment	FW (g)	FD (cm)	FN	Yield (g. plant^{-1})
2	Control	21.41^{e}	2.84^{ef}	3.78^{de}	81.00^{c}
	Guano-ferti	27.26^{h}	3.69^{g}	6.67^{f}	182.08^{f}
	Guano-foliar	28.86^{i}	3.78^{g}	7.00^{f}	202.69^{f}
6	Control	17.99^{c}	2.52^{bcd}	3.00^{cd}	54.04^{bc}
	Guano-ferti	24.73^{f}	2.88^{ef}	4.56^{e}	112.96^{d}
	Guano-foliar	25.88^{g}	3.02^{f}	5.89^{f}	151.16^{e}
10	Control	15.41^{b}	2.34^{b}	2.44^{bc}	37.86^{ab}
	Guano-ferti	18.67^{c}	2.60^{cd}	3.11^{cd}	57.89^{bc}
	Guano-foliar	20.02^{d}	2.71^{de}	4.11^{de}	82.50^{c}

Table 4. Variation in yielding traits of tomato under saline stress in different treatments

Salinity (dS/m)	Treatment	pH	TTA (meq. L^{-1})	TSS (°Brix)
2	Control	3.87^{ef}	1.19^{c}	8.50^{a}
	Guano-ferti	3.98^{f}	1.10^{b}	8.60^{a}
	Guano-foliar	3.98^{f}	1.01^{a}	8.80^{ab}
6	Control	3.63^{bc}	1.32^{de}	9.57^{cd}
	Guano-ferti	3.82^{de}	1.25^{cd}	9.00^{b}
	Guano-foliar	3.81^{de}	1.16^{bc}	9.07^{b}
10	Control	3.40^{a}	1.44^{f}	10.70^{e}
	Guano-ferti	3.73^{cd}	1.36^{ef}	9.47^{c}
	Guano-foliar	3.66^{bc}	1.36^{ef}	9.53^{cd}
14	Control	3.34^{a}	1.67^{g}	11.10^{f}
	Guano-ferti	3.54^{b}	1.36^{ef}	9.60^{cd}
	Guano-foliar	3.53^{b}	1.44^{f}	9.87^{d}

Means (n=3) followed by the same letter within each column are not significantly different according to Duncan's multiple range tests; TTA: titratable acidity; TSS: total soluble solids.

in salinity conditions peaking at EC14 in control plants (89.33 %). The application of Guano through foliar and fertigation reduced significantly cell electrolyte leakage. In fact, at EC2, EC6, EC10 and EC14, cell electrolyte leakage was, of 61.59 %, 66.27 %, 75.9 % and 78.37 % respectively in Guano-foliar-treated plants, of 73.28 %, 77.5 %, 82.03 % and 83.33 % respectively in Guano-ferti-treated plants and of 81.57 %, 83.6 %, 85 % and 89.83 % respectively in control plants.

Soil EC: Soil EC followed a similar pattern. It decreased following Guano application compared to control with no significant difference between both methods (Table 5). In treated plants and despite the levels of EC applied, soil EC was maintained lower or equal to 0.4 dS.m^{-1}. However, in control plants soil EC reached 0.45 dS.m^{-1}, 0.51 dS.m^{-1}, 0.59 dS.m^{-1} and 0.62 dS.m^{-1} at EC2, EC6, EC10 and EC14 respectively.

Table 5. Variation in total chlorophyll content, cell electrolyte leakage and soil EC under saline stress in different treatments

Salinity (dS/m)	Treatment	T chl (mg/g fresh weight)	Cell electrolyte leakage (%)	Soil EC (dS/m)
2 dS/m	Control	1.537dc	81.57efg	0.45e
	Guano-ferti	1.813fg	73.28c	0.36a
	Guano-foliar	1.87g	61.59a	0.37ab
6 dS/m	Control	1.433bc	83.6g	0.52f
	Guano-ferti	1.593de	77.5cde	0.37ab
	Guano-foliar	1.703ef	66.27b	0.39bc
10 dS/m	Control	1.333ab	85g	0.59g
	Guano-ferti	1.49cd	82.03fg	0.39bc
	Guano-foliar	1.567cd	75.9cd	0.39cd
14 dS/m	Control	1.293a	89.83h	0.63h
	Guano-ferti	1.483cd	83.33g	0.4cd
	Guano-foliar	1.537cd	78.37def	0.41d

Discussion

Increasing in salt-stress caused a gradual decrease and inhibition in all vegetative and physiological. In fact, salinity symptoms are similar to those caused by drought (Munns *et al.*, 2002). Leaf area of salt-stressed plants was minimized at EC14. Similar results were reported by Azarmi *et al.* (2010). The reduction in leaf area could be attributed to the disturbance in water balance and inhibition in cell division. Moreover, according to Zhang *et al.* (2016) is due to the stomatal enclosure and accumulation of Na^{+} and Cl^{-} in leaves. This was observed in the current study were salinity promoted Na accumulation in shoots and reduced P and K contents. Many authors reported the winning competition of Na with the remaining ions such Ca^{2+}, Fe^{2+}, Mg^{2+} and others (Deb *et al.*, 2013; Farooq *et al.*, 2015). Moreover, Na^{+} interfered with K^{+} uptake causing disturbance in stomatal regulations (Siddiqi *et al.*, 2011).

The application of Guano counteracted the adverse effects of salinity. Its spraying or fertigation improved vegetative growth, enhanced fruit dimension and weight, and improved nutrient content in shoots. Regarding the method of application of Guano, spraying method was observed to be better than fertigation. Under salt-stress, spraying of Guano helped tomato crops in storing N, P, K, Ca and Mg elements and avoid Na accumulation. In fact, the presence of Guano in root zone could had the ability to prevent Na accumulation and uptake by root hairs more than its foliar spraying. Previously, few studies reported the best method of application of P and K fertilizers (fertigation or spraying). On mungbean, the application of phosphorus by fertigation was the most effective method compared to binding or broadcast (Shah *et al.*, 2006). On the other hand, the translocation scheme of K element could clarify its efficiency when fertigated; the absorbed K portion is either distributed in root cells or translocated through xylem to shoots (Siebrecht *et al.*, 2003). In both cases, roots will be unable to absorbs Na element from root zone. In parallel, K cations are also recycled from shoots downward through phloem vessels for recirculation (Marschner *et al.*, 1995). Foliar spraying of Guano might have a lower contribution in the mechanism described above compared to fertigation. This finding could be related to the scale and size of Guano particles.

As seen in the current study, foliar spraying of lithovit-Guano was better than fertigation. It improved macronutrient content in shoots (Table 2), total chlorophyll content (Fig. 1), vegetative and reproductive traits (Table 1 and 3) more than fertigation. According to Tilman *et al.* (2001), hindrances of foliar application of some fertilizers are related to the lack of good formulations readily absorbed by crop's leaves. This have caused the success of foliar application of many powdered forms of macronutrient rich fertilizers including Guano, diammonium phosphate, triple superphosphate and monoammonium phosphate (Torres, 2011; Issa., *et al.*, 2020).

The efficiency of the method of application of a product depend on its composition and formulation. For instance, Girma *et al.* (2007) stated that potassium phosphate monobasic dried quickly which lead to its poor entry to the leaf. Therefore, its application on plant through fertigation would be better than its foliage spraying. Similarly, Sassine *et al.* (2020) found that fertigation of monopotassium-phosphate on salt-stressed tomato crop mitigated the adverse effect of salinity more than spraying method. On the contrary, spraying of lithovit-standard on the same crop induced better ameliorative effect than fertigation. The applied product in the current study was able to combine all the separate effects observed in the separate application of each element (Ca, Mg, N, P, K, Si, Fe, Mn). According to Rico *et al.* (2011), the small-scale particle of elements improved their absorbance and translocation in plant vessels especially for cations uptake Fe, Ca, Mg and Mn (Taiz and Zeiger, 2002). The single application of calcium on tomato crop maintained nutrient uptake under salt-stress. In previous study, the efficiency of spraying method regarding calcium rich fertilizers was directly related to the form of the product; foliar spraying of nano-calcium was better than chelated-calcium (Tantawy *et al.*, 2014).

The foliar application of Ca was observed to improve photosynthetic pigments and uptake of Ca and K. Calcium nitrate efficiently stimulate the chlorophyll content and in salt-stressed cowpea and strawberry (Kaya *et al.*, 2003; Murillo-Amador *et al.*, 2006). Magnesium spraying or fertigation boosted the performance of salt-stressed tomato and strawberry (Carvajal *et al.*, 1999; Yildirim *et al.*, 2009). Additionally, under salinity conditions, the separate application of Si also showed stimulatory impact on water use efficiency and net photosynthesis of tomato crop (Romero-Aranda *et al.*, 2006) and in activating the defense mechanism of squash (Siddiqui *et al.*, 2014; Tantawy *et al.*, 2015). The limiting factor improving the efficiency of Lithovit-Guano25 was the size of the particles found in the product. Its fertigation or spraying reduced the accumulation of sodium starting from roots and in shoots. However, the direct exposure of foliage through spraying was better than the application of Lithovit-Guano25 in soil.

Previous study investigated the efficiency of fertigation method as affected by soil textural profile. Elasbah *et al.* (2019) reported that maximum efficiency of nitrogenous fertilizers applied through drip irrigation is observed in sandy soil. Lower efficiency was observed in loamy sand soil or sandy loam soil. Additionally, the efficiency of calcium nitrate and potassium phosphate applied through foliar spraying was reported to be related to the dose of application more than the type of fertilizer (Peyvast *et al.*, 2009).

Improving the ameliorative effect of a product under saline or non-saline conditions is coupled with many factors such as the application dose, form or place. In the current study, the place of application, soil or foliage was observed to improve the efficiency of Lithovit-Guano25.

In conclusion,the application of Lithovit-Guano25 maximized the growth of salt-stressed tomato under a saline solution up to 10 $dS.m^{-1}$. In specific, foliar spraying of Lithovit-Guano25 seemed to be better than its fertigation at all the tested EC levels. Future works should focus on the dose of Lithovit-Guano25 application using foliar spraying on other salt-stressed vegetables including pepper, eggplant, zucchini, cucumber etc.

Acknowledgement

Authors thankful to TRIBOdyn AG Company for providing the Lithovit-Guano25 product.

References

Al-Dakheel, Y.Y, 2011. Assessing NDVI spatial pattern as related to irrigation and soil salinity management in Al-Ahsa Oasis, Saudi Arabia. *J. Indian Soc Remote Sens*., 39(2): 171–180

Allbed, A., A.L, Kumar. and Y.Y, Aldakheel, 2014. Assessing soil salinity using soil salinity and vegetation indices derived from IKONOS high spatial resolution imageries: Applications in a date palm dominated region. *Geoderma*, 230: 1–8.

Al-Taisan, W.A., A.A, Al-Qarawi. and M.S, Alsubiee, 2010. Effect of water stress by Polyethylene Glycol 8000 and Sodium Chloride on germination of *Ephedra alata* Decne seeds. *Saudi J. Biol Sci*., 17 (3): 253–257.

Andersen, C.J., B.N, Jensen. and N.R, Keiding, 1962. Magnesium determination by flame photometry. Scand. *J. Clin. Lab. Invest. Suppl*., 14 (5): 560-562.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol*., 24: 1- 15.

Azarmi, R., R.D, Taleshmikail. and A, Gikloo, 2010. Effects of salinity on morphological and physiological changes and yield of tomato in hydroponics system. *J. Food Agric. Environ*., 8(2): 573-576.

Black, C.A. 1965. Methods of soil analysis. Part 2. American Society of Agronomy. Madison, Wisconsin, USA: INC.

Brown, J.D. and l, Lilleland, 1946. Rapid determination of potassium and sodium in plant material and soil extracts by flame photometry. *Proc. Amer. Soc. Hort. Sci*., 48: 341-346.

Carvajal, M., V, Martineze. and A, Cerda, 1999. Influence of magnesium and salinity on tomato plants growing hydroponics culture. *J. Plant Nutr.,* 22: 177-190.

Chowdhury, S. and M, Al-Zahrani, 2015. Characterizing water resources and trends of sector wise water consumptions in Saudi Arabia. *J. King Saud Univ Eng Sci*., 27: 68–82.

Deb, S.K., P, Sharma., M.K, Shukla. and T.W, Sammis, 2013. Drip-irrigated pecan seedling response to irrigation water salinity. *Hortscience.*, 48: 1548–1555.

Elasbah, R., T, Selim., A, Mirdan., R, Berndtsson, 2019. Modeling of fertilizer transport for various fertigation scenarios under drip irrigation. *Water*, 11, 893.

El-Fouly, M.M., Z.M, Moubarak. and Z.A, Salama, 2002. micronutrient foliar application increases salt tolerance of tomato seedlings. *Acta Hort.,*, 573: 467-474.

Elhag, M. 2016. Evaluation of different soil salinity mapping using remote sensing techniques in arid ecosystems, Saudi Arabia. *J. Sens*., 7596175.

FAO. 2018, Food and Agriculture Organization. http://www.fao.org/soils-portal/soil-management/management-of-some-problem-soils/salt-affected-soils/more-information-on-salt-affected-soils/en/

Farooq, M., M, Hussain., A, Wakeel. and K.H.M, Siddique, 2015. Salt stress in maize: effects, resistance mechanisms, and management. A review. *Agron. Sustain. Dev*., 35: 461–4811.

Garner, D., C.H, Cristo. and P, Wiley, 2005. Measurement of pH and titratable acidity. In: *Quality Evaluation Methodology*. USA: Kearney Agricultural Center.

Girma, K., K.L, Martin, K.W, Freeman., J. Mosali., R.K, Teal, W.R, Raun *et al*, 2007. Determination of optimum rate and growth stage for foliar applied phosphorus in corn. *Commun. Soil. Sci. Plant. Anal*., 38 (9-10): 1137-1154.

Gornall, J., R, Betts., E, Burke., R, Clark., J, Camp., K, Willett. and A, Wiltshire, 2010. Implications of Climate Change for Agricultural Productivity in the Early Twenty-first Century. *Philos T R Soc B*., 365: 2973–2989.

Issa, D.B., S.M, Alturki., T.K, Sajyan. and Y.N, Sassine, 2020. Sorbitol and Lithovit-Guano25 mitigates the adverse effects of salinity on eggplant grown in pot experiment. *Agron. Res*., 18(1): 113-126.

Kaya, C., D, Higgs., F, Ince., B.M, Amador., A, Cakir. and E, Sakar, 2003. ameliorative effects of potassium phosphate on salt-stressed pepper and cucumber. *J. Plant Nutr*., 26(4): 807-820.

Knapp, S. and I.E, Peralta, 2016. The Tomato (*Solanum lycopersicum* L., Solanaceae) and Its Botanical Relatives. In: Causse M., Giovannoni J., Bouzayen M., Zouine M. (eds). The Tomato Genome. Compendium of Plant Genomes. Springer, Berlin, Heidelberg. pp, 7-21.

Lutts, S., J.M, Kinet. and J, Bouharmont, 1996, NaCl-induced senescence in leaves of rice (*Oryza sativa* L.) cultivars differing in salinity resistance. *Ann. Bot*., 78: 389–398.

Marschner, H. 1995. Mineral Nutrition of Higher Plants, 2nd edn. Academic Press, London, UK., pp: 889.

Munns, R., S, Husain, A.R., Rivelli, A.J, Richard, A.G, Condon., P.L, Megan., S.L, Evans., D.P, Schachtman. and R.A, Hare, 2002. Avenues for increasing salt tolerance of crops, and the role of physiologically based selection traits. *Plant Soil.,* 247: 93–105.

Murillo-Amador, B., E, Troyo-Diéguez., J.L, García-Hernández., B, López-Aguilar., N.Y, Ávila-Serrano., S, Zamora-Salgado., E.O, Rueda-Puente., C. and Kaya. C, 2006. Effect of NaCl salinity in the genotypic variation of cowpea (*Vigna unguiculata*) during early vegetative growth. *Sci Hort.*, 108: 423–431.

Peyvast, G., J.A. Olfati, P.R. Kharazi and S.K. Shahmaleki. 2009. Uptake of calcium nitrate and potassium phosphate from foliar fertilization by tomato. *J. Hort. For*., 1: 7-13.

Raza, M.A., Saeed, A., Munir, H., Ziaf, K., Shakeel, A., Saeed, N., Munawar, A., and Rehman, F, 2016. Screening of tomato genotypes for salinity tolerance based on early growth attributes and leaf inorganic osmolytes. *Arch. Agron. Soil Sci*., 4: 501–512.

Rico, C.M., Majumdar, S., Duarte-Gardea, M., Perlata-Videa, J.R. and Gardea-Torresdey, J.L, 2011. Interaction of nanoparticles with edible plants and their possible implications in the food chain. *J. Agric. Food Chem*., 59: 3485-3498.

Romero-Aranda, M.R., Jurado, O., Cuartero, J, 2006. Silicon alleviates the deleterious salt effect on tomato plant growth by improving plant water status. *J. Plant Physiol*., 163: 847–855.

Sabtana, AA. and W.M, Shehata, 2003. Hydrogeology of Al-Lith Sabkha, Saudi Arabia. *J. Asian Earth Sci*., 21: 423–429

Sadak, M., M.T, Abdelhamid. and U, Schmidhalter, 2015. Effect of foliar application of aminoacids on plant yield and some physiological parameters in bean plants irrigated with seawater. *Acta Biol. Colomb*., 20: 141–152.

Sajyan, T.K., N, Shaban., J, Rizakallah. and Y.N, Sassine, 2018. Effects of monopotassium-phosphate, nano-calcium fertilizer, acetyl salicylic acid and glycinebetaine application on growth and production of tomato (*Solanum lycopersicum*) crop under salt-stress. *Agron. Res*., 16 (3): 872-883.

Sajyan, T.K., J, Rizkallah., Z, Sebaaly., N, Shaban. and Y.N, Sassine, 2019a. Investigating the potential use of mono-potassium phosphate (MKP: 0-52-34) applied through fertigation as a method to improve salinity tolerance of tomato plants. *Acta Hort.*, 1253: 1-8.

Sajyan, T.K., W, Allaw., N, Shaban. and Y.N, Sassine, 2019b. Effect of exogenous application of glycine betaine on tomato plants subjected to salt stress. *Acta Hort.*, 1253: 41–48.

Sajyan, T.K., M, Chokor., N, Shaban. and Y.N, Sassine, 2019c. Enhancing salt tolerance of tomato (*Solanum lycopersicum*) by foliar application of aspirin (acetyl salicylic acid). *Acta Hort.*, 1253: 49-54.

Sajyan T.K., N, Shaban., J, Rizakallah. and Y.N, Sassine, 2019d. Performance of salt-stressed tomato crop as affected by nano-$CaCO_3$, glycine betaine, MKP fertilizer and aspirin application. *Agriculture and Forestry*., 65 (1): 19-27.

Sajyan, T.K., L, Naim., Z, Sebaaly., J, Rizkallah., N, Shaban. and Y.N, Sassine, 2019e. Alleviating the adverse effects of salinity stress on tomato crop (*Solanum lycopersicum*) using nano-fertilizer as foliar application. *Acta Hort.*, 1253: 33-40.

Sassine, Y.N, S.M, Alturki, M, Germanos., N, Shaban., M.N, Sattar. and T.K, Sajyan, 2020. Mitigation of Salt Stress on Tomato Crop by Using Foliar Spraying or Fertigation of Various Products. *J. Plant Nut*., 43 (16): 2493-2507

Shah, S.K.H., M, Aslam., P, Khan., M.Y, Memon., M, Imtiaz., E, Siddiqui. and S.H, Nizamuddin, 2006. Effect of different methods and rates of phosphorus application in mungbean. *Soil and Environ.*, 25: 55-58.

Shrivastava, P. and R, Kumar, 2015. Soil salinity: a serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi J. Biol Sci*., 22(2): 123–131.

Siddiqi, E.H., M, Ashraf., F, Al-Qurainy. and N.A, Akram, 2011. Salt-induced modulation in inorganic nutrients, antioxidant enzymes, proline content and seed oil composition in safflower (*Carthamus tinctorius* L.). *J. Sci. Food Agric*., 91: 2785–2793.

Siddiqui, M.H., M.H, Al-Whaibi., M, Faisal. and A.A, Al Sahli, 2014. Nano-silicon dioxide mitigates the adverse effects of salt stress on *Cucurbita pepo* L. *Env. Toxicol. Chem*., 33: 2429–2437.

Siebrecht, S., K, Herdel., U, Schurr. and R, Tischner, 2003. Nutrient translocation in the xylem of poplar – diurnal variations and spatial distribution along the shoot axis. *Planta.*, 217: 783–793.

Taiz, L. and E, Zeiger, 2002. *Plant Physiology.* 3rd ed. Sinauer, Sunderland, United Kingdom, pp. 690.

Tantawy, A.S., A.M.R, Abdel-Mawgoud., M.A, El-Nemr. and Y.G, Chamoun, 2009. Alleviation of salinity effects on tomato plants by application of amino acids and growth regulators. *Eur. J. Sci. Res*., 30: 484–494.

Tantawy, A.S., Y.A.M, Salama., A.M.R, Abdel-Mawgoud. and A.A, Ghoname, 2014. Comparison of chelated calcium with nano calcium on alleviation of salinity negative effects on tomato plants. *Middle East Journal of Agriculture Research*., 3(4): 912-916.

Tantawy, A.S., Y.A.M, Salama., M.A, El-Nemr. and A.M.R, Abdel-Mawgoud, 2015. Nano silicon application improves salinity tolerance of sweet pepper plants. *Int. J. Chem Tech Res*., 8: 11–17.

Tilman, D., J, Fargione., B, Wolff., C, D'Antonio., A, Dobson., R, Howarth. *et al*, 2001. Forecasting agriculturally driven global environmental change. *Science*., 292(5515): 281-284.

Troug, E. and A.H, Meyer, 1939. Improvement in deiness colormetic method for phosphorus and arsenic. *Industrial and Engineering Chemistry, Analytical Edition*., 1: 136-139.

Torres, G.M, 2011. Foliar phosphorus fertilization and the effect of surfactants on winter wheat Triticum aestivum L. M.S. thesis, Oklahoma State University.

Tuna, A.L., C, Kaya, M, Ashraf., H, Altunlu., I, Yokas. and B, Yagmur, 2007. The effects of calcium sulphate on growth, membrane stability and nutrient uptake of tomato plants grown under salt stress. *Environ. Exp*., 59:173-178.

Yildirim, E., H, Karlidag. and M, Turan, 2009. Mitigation of salt stress in strawberry by foliar K, Ca and Mg nutrient supply. *Plant Soil Environ*., 55: 213– 221.

Zhang, P.F., M.T, Senge., K.H, Yoshiyama., K.G, Ito., Y.Y, Dai. and F.P, Zhang, 2016. Effects of low salinity stress on growth, yield and water use efficiency of tomato under soilless cultivation. *J. Irrig Drain E-ASCE*., 304: 15-21.

Received: January, 2021; Revised: February, 2021; Accepted: February, 2021