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RESPONSE OF SQUASH PLANTS GROWN UNDER SANDY SOIL AND HIGH IRRIGATION WATER SALINITY CONDITIONS TO FOLIAR SPRAY WITH POTASSIUM SILICATE AND INOCULATION WITH MYCORRHIZA

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ABSTRACT: An experiment was carried out at Wadi El-Natroon district Behiera Governorate, during the growth summer seasons of 2019 and 2020 to investigate the effect of inoculation with mycorrhiza (M) and/or foliar application of silicon as potassium silicate (KS) to improve squash plants growth parameters and yield and its components as well as fruits nutrient quality, which confronting the saline conditions in new reclaimed soils. The irrigation of squash plants was with well water that has salinity ranged between 3.4–3.6 dSm-1. The results revealed decreasing of all growth, yield and fruits nutrients quality characters as shown in control (well water). However, the application of mycorrhiza inoculum in squash seeds in accompined with foliar application of KS at 4 mlL-1 every 10 days after transplanting in the open field could be an effective procedure for significant enhancing the performances of squash plants grown under similar unfavorable conditions of increasing irrigation water salinity.

Key words: squash, *Cucurbita pepo*, salinity, mycorrhiza, potassium silicate, growth, yield.

INTRODUCTION

Due to urban transgression, the amount of traditional agricultural land in the Nile Delta has declined sharply in recent decades. In particular, in the last decade, Egypt has witnessed a steady increase in the agricultural area, which was by the reclamation of new land areas that irrigated by groundwater in most cases **(Quosy, 2019; Radwan, 2019)**. However, it is well known that the dominant problem on such new reclaimed areas in Egypt is the salinity **(Chhabra, 2017)**, which narrow the chances of growing many kinds of cash valuable vegetable crops,which exhibit significant reduction in productivity, especially if irrigated with saline water**(Machado and Serralheiro, 2107)**.

Salinity stress effects could be devoted in three aspects e.g., osmotic stress, specificness stress and oxidative stress; however, the oxidative stress is considered to be the most destructive**(Tanveer and Shabala, 2018)**. High salinity not only declines plant growth, biomass, yield, photosynthesis, and water use efficiency, but also resulted in physiological drought, ion toxicity in plants and imbalance nutrient uptake, which, consequently, reducing the agricultural productivity and yields of the stressed crop plants **(Safdar, 2019; Shahid, 2018 and Wungrampha, 2018).**

Among the domesticated Cucurbits, the squash (*Cucurbita pepo* L.) seeds was archeologically discovered in Mexico that are more than 9,000 years old **(Decker, 1988)**. According to the salinity tolerance scale, Squash is categorized as a moderately tolerant with thresholds estimated by 4.7 and 3.1 dSm^{-1} for soil and water salinity, respectively **(Ayers and Westcot, 1985)**.

There are many procedures were examined by researchers that could be effective in order to ameliorate the dangerous effects of salinity stress, including the inoculation with a beneficial microorganism, such as mycorrhiza fungi or treatment with some nutrients, such as silicon **(Machado and Serralheiro, 2107; Plaut *et al.*, 2013).**

Inoculation with mycorrhiza is considered as an effective strategy in alleviating plant growth under saline conditions. Many of investigations have exhibited that mycorrhiza inoculations improve growth by diminishing the development of reactive oxygen species (ROS) and alleviating antioxidant defense enzymes activities under salt stress conditions **(Wu, 2014)**. Accordingly, mycorrhiza inoculation was found to increase the different physiological parameters, e.g. chlorophyll content, photosynthetic process and nutrient uptake, especially N, P and K with association with decreasing Na uptake **(Begum *et al.*, 2019; Rahman *et al.*, 2019 and Ramadan, 2019)**, which reflects on enhancing growth and yield of plants grown under salinity stress.

Also, the exogenous application of silicon (Si) has been a recent eco-friendly approach to enhance the salinity stress response in plants **(Almeida, 2017)**. The application of silicon on the salinity stressed plants was found to ameliorate the deleterious effect of salinity stress in many ways as decreasing the rate of Na uptake, increasing root water uptake, reinforcement the cell walls, improve the efficiency of osmotic adjustment and enhancing the photosynthesis **(Zhu, 2019)**. The investigations about the roe of Si in vegetable dicots, however, are still far behind cereals**(Kaushik and Saini, 2019).**

Among the silicon-based fertilizers, potassium silicate (K_2O_3Si) was the most popular ware-soluble silicate fertilizer that that used as foliar spray **(Laane, 2018)**, which provides silicon (25% SiO_2) to the treated plants in addition to few amounts of potassium (10% K_2O). The use of this soluble silicate fertilizer as foliar application is due to their high cost for soil application **(Yan *et al.*, 2018)**.

Moreover, there were many research papers demonstrate a synergistic effect between silicon and mycorrhiza, i.e. the mycorrhiza formation and functions were increased by Si, and; in turn, Si uptake was increased due to mycorrhization **(Frew, 2017; Moradtalab, 2019)**; which increase their effectiveness in alleviating the consequences of abiotic stress of the treated plants e.g., drought **(Azam Eidi and Najafabadi, 2014; Hajiboland *et al.*, 2018)**, heavy metals **(Garg and Singh, 2018)** and salinity **(Garg and Bhandari, 2016)** as well as under normal conditions**(Hajiboland *et al.*, 2018)**.

The aim of this study was to investigate the possibility of inoculation with mycorrhiza (M) and/or foliar application of silicon as potassium silicate (KS) to enhance the ability of squash plants to confronting the saline conditions in new reclaimed soils.

MATERIALS AND METHODS

The field experiment was conducted in the summer seasons of 2019 and 2020in a private farm, at Wadi El-Natroon region, Behiera Governorate, Egypt, under open field conditions in a sandy soil where this farm is suffering from salinity of irrigation water more than soil as shown in Tables 1 and 2.

Tables (1 and 2) showed the different physical and chemical parameters of the soil and irrigation water in the experimental location. The analyses were determined according to **Dewis and Freitas (1970)**.

The cultivar used for the experiment was “Aziad” squash hybrid, which was sown in transplant trays for 25 days, then seedling transplanted in the experimental field at 18th and 22th February of 2018 and 2019, respectively.

This experiment included six treatment. The experimental design was split plots with three replicates. The mycorrhiza inoculation treatments (M_- and M_+) occupied the main plots and the potassium silicate treatments (KS_0, KS_1 and KS_2) occupied the sub-plots at each replicate. Each sup-blot consisted of four rows, 6 m long and 70 cm width for each; also, each plot was surrounded with guard row, 70 cm width to minimizing the interferences between treatments.

The treatments of mycorrhiza inoculum (*Glomus* spp.) were pplied as a suspension of spores and root pieces after five days from sowing squash seeds in transplant trays. The mycorrhiza inoculum was derived from faculty of Agriculture, Saba Basha, Alex. Univ., Biofertilization Unit; whereas, the silicon treatments were applied as potassium silicate (K_2O_3Si). Three graded levels of potassium silicate (KS) were used as foliar application, e.g. control (well water), 2 and 4 mlL^{-1} that denoted as KS_0, KS_1 and KS_2, respectively. The foliar application of each examined concentration was applied after ten days from transplanting and was repeated every ten days until 15 days before the end of the season. All the agricultural practices that recommended for the squash production in the new reclaimed soils under drip irrigation system, e.g. fertilization, pest control and irrigation schedules, were followed.

Table 1. Physical and chemical analysis of the experimental soil in 2017/2018 seasons of study

Physical analysis*	2017	2018
Sand	93	92
Clay	4	5
Silt	3	3
Soil texture	Sand	Sand
Chemical analysis*		
pH	8.4	8.5
EC (dSm^{-1})	3.5	3.7
$CaCO_3$ (%)	5.4	5.6
Macro elements (ppm)		
N	16	14
P	17	20
K	61	63
Cations (meq L^{-1})		
Ca^{+2}	3.1	3.3
Mg^{+2}	2.4	2.7
K^{+}	1.6	1.6
Na^{+}	3.6	3.9
Anions (meq L^{-1})		
Cl^{-}	2.4	2.8
SO_4^{-}	7.5	7.6
CO_3^{-}	--	--
HCO_3^{-}	0.8	1.1
SAR	2.2	2.3

* These analyses were carried out at the Soil Reclamation and Agric. Engineering Dept., Agric. Fac., Damanhour University.

Table 2. Chemical analysis of the irrigation water (well water) used in the experiment in 2017 and 2018 seasons

Chemical analysis*	2017	2018
pH	7.5	7.7
EC (dSm^{-1})	3.5	3.7
Cations (meq L^{-1})		
Ca^{+2}	3.0	3.2
Mg^{+2}	3.3	3.3
K^{+}	2.7	3.1
Na^{+}	19.8	21.4
Anions (meq L^{-1})		
Cl^{-}	17.8	19.4
SO_4^{-}	6.2	6.5
CO_3^{-}	--	--
HCO_3^{-}	4.8	5.1
SAR	11.2	11.9

* These analyses were carried out at the Soil Reclamation and Agric. Engineering Dept., Agric. Fac., Damanhour University.

The measured characters were divided to four groups as follow:

Vegetative growth characters

After 40 days from transplanting, stem length, leaves number plant^{-1}, fresh and dry weight of shoot (stems and leaves) were recorded.

Leaf chlorophyll and mineral constitute

Total Chlorophyll: was measured after 40 days from transplanting by non-destructive method using SPAD-502 chlorophyll meter **(Markwell *et al.*, 1995).**

Leaves mineral contents: minerals were determined as illustrated by **Kalra (1998)**; nitrogen (N) was determined using micro-kjeldahl method, phosphorus (P), potassium (K) and sodium (Na) were estimated using flam photometer. Moreover, K+/Na+ ratio that was calculated.

Yield and its components

After 40 days from transplanting, the fruits were harvested from each plot every 3 days and the following data were recorded: Fruit number plant^{-1}, average fruit weight (which was derived from the average of ten fruits weight in grams), fruit yield plant^{-1} and yield faddan^{-1}.

Fruit quality

The macro- and micro-elements of N, P, K, Ca, Cu, Zn and Fe in squash fruits were determined following the steps that demonstrated by **Kalra (1998)**.

Statistical analysis

All recorded data were statistically analyzed by CoStat software **(COSTAT, 2005)** version 6.4 from cohort software. Least significant difference test (LSD) was applied at 0.05 confidence level to compare means of different treatments using the same program.

RESULTS AND DISCUSSION

Vegetative growth characters

Data in Table 3 showed that the M inoculation provide significant increases in all vegetative growth characters (stem height, leaves number plant^{-1}, shoot fresh weight and shoot dry weight) if compared with uninoculated plants irrigated with saline water without inoculation.

Concerning the effect of KS treatments, the results revealed significant enhancing effect for the KS foliar treatments on vegetative growth traits of squash plants grown under saline conditions when compared with control (KS_0), in both seasons of study. The foliar application of KS_2 was the best stem height, leaf number, shoot fresh and dry weight.

The interaction between M and KS indicated that the foliar application with KS_2 of the squash plants inoculated with M was the superior application over all the other interaction combinations, in both seasons of study.

These results revealed significant ameliorative effect for each of mycorrhiza inoculation or potassium silicate foliar application on vegetative growth of squash plants grown under saline conditions, in both seasons of study. At the same trend of the results of this study, many other researchers illustrated the important effect of mycorrhiza inoculation on improving the vegetative growth characters of plants grown under saline conditions **(Cantrell and Linderman, 2001** on lettuce and onion**; Colla *et al.*, 2008** on zucchini and **Haghighi and Barzegar, 2017** on sweet pepper**)**.

The ameliorative effect of M inoculation could be due to occurring an enhancement of activity of different antioxidant enzymes in salt affected plants that indicating lower oxidative damage **(Abdel Latef *et al.*, 2011)**. Also, the M fungi were found to produce different types of hormone-like substances e.g., gibberellins and cytokinins **(Amballa and Bhumi, 2017)**. In addition, mycorrhiza has the ability to extending the absorbing zones of host plant roots that ensure a reduction in nutrient loss **(Cavagnaro, 2015)**. Consequently, the mycorrhiza has the ability to enhance all of vegetative growth characters of the host plants.

Concerning the KS effect, it could due to the effect e.g., the effect of potassium and the effect of silicon. potassium is a vital for plant survival under physiological and stress conditions because its role in many physiological and biochemical processes **(Wang *et al.*, 2013)**. Moreover, **Shafeek *et al.* (2013)** on cucumber and **Fekry (2016)** on summer squash reported that potassium foliar application enhanced the vegetative growth characters. On the other side, many researchers demonstrated the important role of silicon on alleviating the growth parameters of many crop plants under normal or stressed conditions by enhancing water relations, decreasing the Na uptake, increasing photosynthesis rate, nutrients uptake and antioxidant enzymes **(Laane, 2018)** as well as impacting the phytohormones that commonly involved in controlling stress conditions **(Luyckx *et al.*, 2017)**. Moreover, many research studies revealed that the spraying of potassium silicate has favorable effect on growth parameters of many of vegetable crops **(Amirossadat *et al.*, 2012** on cucumber**; Hussein and Muhammed, 2017**on eggplant**; Merwad, 2018** on pea**; Abd-Elaziz *et al.*, 2019 and Shehata and Abdelgawad, 2019** on squash and **Yaghubi *et al.*, 2019** on strawberry**)**.

The interaction between M inoculation and KS application was found to give more ameliorative effect on vegetative growth characters of squash plants than the single treatments, which illustrated by the increment percentages in vegetative growth characters comparing to control in the case of single or combined treatments, in both seasons of study. These enhancement effect of the combined treatment could be a result of some kind of synergistic relationship between M and KS as suggested by **Frew *et al.* (2017);** and **Moradtalab *et al.* (2019)**. In addition**, Garg and Bhandari (2016)** found in *Cicer arietinum* genotypes that the mycorrhiza increased the endogenous amounts of silicon and the application of silicon enhanced the efficiency of mycorrhiza fungi. Moreover, they suggested that the Si-mycorrhiza application could be effective treatment for overcoming the salinity conditions.

Leaf chlorophyll and mineral constitute

As shown in Table 4, the results revealed significant effect of the M inoculation on leaf chlorophyll as well as N, P, K and K/Na ratio but decreased Na, in both seasons of study. The increased values of the uninoculated squash plants were 23.69% for chlorophyll (SPAD), 59.88% for N, 39.25% for P, 59.17% for K and 105.15% for K/Na. However, the leaves content of Na was decreased due to inoculation with M, in both seasons of study with percentage of **-**23.15% compared with control as both seasons average.

According the mean values of the KS foliar applications, with the exception of Na, the KS_2 treatment gave the highest mean values of each of chlorophyll, N, P, K and K/Na ratio in squash leaves, in both seasons of study. However, the KS_2 treatment decreased, significantly, the squash leaf values of Na, in both seasons of study.

Table 3. Effect of mycorrhiza inoculation, potassium silicate foliar applications and their interaction on vegetative growth of squash plants 2017 and 2018 seasons

Treatments	2017*			2018*		
	M_-	M_+	Mean	M_-	M_+	Mean
			Stem length (cm)			
KS_0	12.72 e	19.78 b	**16.25 C**	13.16 f	17.58 c	**15.37 C**
KS_1	16.27 d	20.70 b	**18.49 B**	15.95 e	19.05 b	**17.50 B**
KS_2	18.34 c	23.21 a	**20.77 A**	16.75 d	21.59 a	**19.16 A**
Mean	**15.78 B**	**21.23 A**		**15.29 B**	**19.41 A**	
			Leaf number $plant^{-1}$			
KS_0	9.36 f	14.97 c	**12.17 C**	8.89 f	13.89 c	**11.39 C**
KS_1	11.41 e	15.97 b	**13.68 B**	10.25 e	15.33 b	**12.79 B**
KS_2	13.30 d	17.99 a	**15.65 A**	12.22 d	16.89 a	**14.56 A**
Mean	**11.36 B**	**16.31 A**		**10.45 B**	**15.37 A**	
			Shoot fresh weight (gm)			
KS_0	327.26 e	432.59 c	**379.92 C**	318.77 f	407.31 c	**363.05 C**
KS_1	362.91 d	458.30 b	**410.60 B**	340.69 e	451.63 b	**396.16 B**
KS_2	366.70 d	486.57 a	**426.63 A**	362.61 d	472.94 a	**417.78 A**
Mean	**352.29 B**	**459.15 A**		**340.69 B**	**443.96 A**	
			Shoot dry weight (gm)			
KS_0	46.66 d	64.62 c	**55.64 C**	45.80 e	53.93 c	**49.87 C**
KS_1	58.92 c	71.66 b	**65.29 B**	47.72 d	55.76 b	**51.74 B**
KS_2	60.19 c	80.81 a	**70.50 A**	49.08 d	58.46 a	**54.77 A**
Mean	**55.26 B**	**72.36 A**		**47.54 B**	**56.05 A**	

* Mean values with the same alphabetical letter (s) did not differ significantly at $p < 0.05$ confidence level according to LSD test.

Moreover, the effect of interaction between M inoculation and KS treatments was found to be significant for all characters, in both seasons of study. Also, the interaction between M_+ with KS_2 foliar application gave, the highest mean values of N, P, K and K/Na ratio, in both seasons of study, but decreased the values of Na, in both seasons of study.

The outcomes of this investigation showed that the application of mycorrhiza or potassium silicate effectively increased leaf chlorophyll content and the activity of nutrients uptake of N, P and K in parallel with decreasing the Na contents of squash leaves that was reflected on increasing the K/Na ratio comparing with the squash plants grown under saline conditions. Also, there was superiority of mycorrhiza inoculation over potassium silicate in increasing chlorophyll content and nutrients content and K/Na ratio and decreasing Na content of squash leaves.

This could be due to that the mycorrhiza provide more surface area for nutrients absorption of the host plant roots, which promotes nutrients uptake not only phosphorus but nitrogen and potassium too, comparing with uninoculated plants **(Begum *et al.*, 2019)**. Also, the decreasing of Na content due to mycorrhiza inoculation could be due to its ability to excluding Na^+ ions, through discriminating its uptake from the soil or during its transfer to plants, thus acting as a first barrier for ion selection. Consequently, the K/Na ratio as well as with the other nutrients were increased **(Hammer *et al.*, 2011; Garg and Bhandari, 2016)**. Moreover, mycorrhiza was found to have a vital role in increasing the leaf content of photosynthetic pigments of the host plants as shown with **Cantrell and Linderman (2001)** on lettuce and onion and **Colla *et al.* (2008)** on zucchini.

Concerning the positive effect of KS, it could be due to the role of each of potassium and silicon in enhancing the ability of plant to confront salinity. Potassium plays important role in mentainace of plant grown under different types of abiotic stresses **(Römheld and Kirkby, 2010; Wang *et al.*, 2013)**. Also, the silicon proportion significantly affected the different nutrients uptake under normal or saline conditions as illustrated by **Korkmaz *et al.* (2018)** on tomato and **Merwad (2018)** on pea.

In addition, **Abd-Elaziz *et al.* (2019)** and **Shehata and Abdelgawad (2019)** found that the squash leaf values of N, P and K as well as chlorophyll were increased, significantly, due to the KS foliar application. Under salinity, potassium silicate was found to have ameliorating effect where Si blocks Na entrance and enhances K uptake as well as other nutrients, and significantly increasing K/Na ratio as proposed by **Cantrell and Linderman**

(2001) on lettuce and onion, **Savvas *et al.* (2009)** on zucchini and **Yaghubi *et al.* (2019)** on strawberry.

These may suggested that the application of KS increase the capability of mycorrhiza in acquisition of more nutrients from the soil comparing with the only inoculated plants, which improve the endogenous nutrients profile of plants grown under salinity stress **(Garg and Bhandari, 2016)**.

Table 4. Effect of mycorrhiza inoculation, potassium silicate foliar applications and their interaction on leaf content of chlorophyll, N, P, K, Na and K/Na ratio 2017 and 2018 seasons

Treatments	2017*			2018*		
	M_-	M_+	Mean	M_-	M_+	Mean
			Chlorophyll (SPAD)			
KS_0	34.02 d	44.98b	**39.50 C**	34.67 e	44.11 b	**39.39 C**
KS_1	38.87 c	47.42 ab	**43.15 B**	36.78 d	45.74 b	**41.26 B**
KS_2	41.30 c	50.83 a	**46.06 A**	41.22 c	47.55 a	**44.39 A**
Mean	**38.06 B**	**47.74 A**		**37.56 B**	**45.80 A**	
			N%			
KS_0	1.132 e	2.070 b	**1.601 C**	1.062 d	1.797 b	**1.429 C**
KS_1	1.293 d	2.366 a	**1.830 B**	1.422 c	2.001 a	**1.712 B**
KS_2	1.578 c	2.449 a	**2.014 A**	1.536 c	2.145 a	**1.841 A**
Mean	**1.335 B**	**2.295 A**		**1.340 B**	**1.981 A**	
			P%			
KS_0	0.270 f	0.386 c	**0.328 C**	0.263 d	0.335 c	**0.299 C**
KS_1	0.297 e	0.421 b	**0.359 B**	0.275 d	0.358 b	**0.319 B**
KS_2	0.316 d	0.456 a	**0.386 A**	0.279 d	0.410 a	**0.342 A**
Mean	**0.294 B**	**0.421 A**		**0.272 B**	**0.368 A**	
			K%			
KS_0	1.199 f	2.222 c	**1.710 C**	1.211 e	1.810 c	**1.511 C**
KS_1	1.470 e	2.468 b	**1.969 B**	1.478 d	2.147 b	**1.812 B**
KS_2	1.819 d	2.783 a	**2.301 A**	1.601 d	2.556 a	**2.079 A**
Mean	**1.496 B**	**2.491 A**		**1.430 B**	**2.171 A**	
			Na			
KS_0	0.697 a	0.533 cd	**0.615 A**	0.743 a	0.534 d	**0.639 A**
KS_1	0.618 b	0.486 de	**0.552 B**	0.666 b	0.496 de	**0.581 B**
KS_2	0.546 c	0.450 e	**0.498 C**	0.591 c	0.469 e	**0.530 C**
Mean	**0.621 A**	**0.490 B**		**0.667 A**	**0.499 B**	
			K/Na ratio			
KS_0	1.721 f	4.173 c	**2.947 C**	1.630 f	3.396 c	**2.513 C**
KS_1	2.346 e	5.086 b	**3.716 B**	2.223 e	4.335 b	**3.279 B**
KS_2	3.327 d	6.222 a	**4.775 A**	2.708 d	5.454 a	**4.081 A**
Mean	**2.465 B**	**5.160 A**		**2.187 B**	**4.395 A**	

* Mean values with the same alphabetical letter (s) did not differ significantly at $p < 0.05$ confidence level according to LSD test.

Yield and its components

The mycorrhizal inoculation resulted in increasing percentages estimated of yield and its components by 25.33% for fruit numberplant^{-1}, 11.89% for average fruit weight, 31.27% for fruit yield plant^{-1} and 35.08% for fruit yield faddan^{-1}, as average of both seasons of study if compared with uninoculated squash plants.

Also, the foliar application of KS, the treatment of KS_2 was the most effective concentration for increasing all yield and its components traits of squash plants if compared with KS_1 or KS_0, in both seasons of study. The estimated average of increasing due to the foliar application with KS_2 in both seasons was 17.61% for fruit numberplant^{-1}, .8.25% for average fruit weight, 23.67% for fruit yield plant^{-1} and 26.80% for fruit yield faddan^{-1} comparing with control (KS_0).

The mean values concerning the interaction between M and KS was clarified significant effect on all yield traits, in both seasons of study. The inoculated squash plants with M and treated with KS_1 or KS_2 gave the highest interaction mean values without significant differences between them for all the yield characters except with fruit yield plant^{-1} and fruit yield faddan^{-1}, only in the second season where the M_++KS_2 treatment gave the higher mean values comparing with M_++KS_1. If the relationship between M_++KS_2 and control, e.g. M_-+KS_0 is taken into consideration. The average of increments in interaction mean values of M_++KS_2 over the control were 20.25, 22.1, 36.96 and 75.86% for fruits No. plant^{-1}, average fruit weight, fruit yield plant^{-1} and fruit yield faddan^{-1}, respectively.

The enhancing of yield and its components is always considered as consequence for improvement in nutrient contents and vegetative growth parameters. From the above-mentioned results, the same trend of effect of M or KS was found on the studied yield and its components characters. Concerning the mycorrizal effect, many researchers demonstrated the important role of such fungus in increasing the uptake of many nutrients including nitrogen, potassium, phosphorus, photosynthetic pigments as well as decreasing the uptake of sodium, which reflects on enhancing vegetative growth performance, which led to improve the yield and its component characters of the host plants especially under saline conditions **(Rahman *et al.*, 2019 and Ramadan, 2019).**

Concerning the KS treatments, there ameliorative effect was found for yield and its components traits of squash plants. Potassium element is well known for enhancing the yield and its components of many of vegetable crops under normal **(Shafeek *et al.*** on cucumber**, 2013; Fekry** on summer squash**, 2016)** or under salinity stress conditions **(Römheld and Kirkby, 2010; Wang *et al.*, 2013)**. Also, silicon demonstrated by many researchers as a beneficial element, which was found to contribute to increasing yield and its components especially under saline conditions **(Korkmaz *et al.*** on tomato**, 2018)**. The Si effect could be because of its role in significant increase in the activities of antioxidants, decrease in the contents of electrolytic leakage percentage and adjustment of osmotic stress **(Zhu *et al.*, 2019)**, which reflects positively on yield. Many other researchers reported the significant effect for KS foliar application on enhancing the yield and its components of the treated plants **(Hussein and Muhammed, 2017** on eggplant; **Abd-Elaziz *et al.*, 2019** and **Shehata and Abdelgawad, 2019** on squash**).**

There was synergistic effect for the interaction between mycorrhiza and potassium silicate where increased the mean values of yield and its components characters as fruit No. plant^{-1}, average fruit weight, fruit yield plant^{-1} and fruit yield faddan^{-1}comparing with the solo treatments. This enhancing effect of KS and AM combined applications might to be related to improving vegetative growth (Table 3) and nutrient status (Table 4), increasing the expression of the antioxidant enzymes and elevating water uptake and its use efficiency **(Garg and Bhandari, 2016; Moradtalab *et al.*, 2019)**. These enhancements could be due to existence of synergistic relationship between KS and AM **(Hajiboland *et al.*, 2018)**.

Fruits nutrients quality

The main effects of M inoculation and KS foliar applications as well as their interaction on squash fruits nutrients quality were illustrated in Table (6). The main effect of M inoculation was found to be positive significant for all fruit nutrients quality parameters, e.g. N, P, K, Ca, Cu, Zn and Fe, in both seasons of study. also, fruits of the M inoculated squash plants were provided more nutrient contents comparing with the fruits of the uninoculated squash plants. the average increments were estimated by 61.40, 45.62, 80.61, 28.68, 26.70, 8.54 and 12.55% for each of N, P, K, Ca, Cu, Zn and Fe, respectively for both seasons.

In case of the effect of KS foliar treatments, the KS_2 application was the most effective in increasing the fruit content of N, P, K, Ca, Cu and Zn, in both seasons of study. However, the effect between KS_2 and KS_1 did not differ significantly in Fe values, in both seasons. Percentage of increasing in nutrients concentrations in squash fruits due to KS_2 application when compared with KS_0 were estimated by 27.99, 25.25, 57.23, 16.02, 14.04, 5.63 and 7.74 for each of N, P, K, Ca, Cu, Zn and Fe as an average of both seasons of study, respectively.

Table 5. Effect of mycorrhiza inoculation, potassium silicate foliar applications and their interaction on yield and its components, in 2017 and 2018 seasons

Treatments	2017*			2018*		
	M_-	M_+	Mean	M_-	M_+	Mean
			Fruits No. plant^{-1}			
KS_0	8.78 d	11.22 b	**10 C**	8.22 d	12.22 ab	**10.22 C**
KS_1	9.89 c	12.22 a	**11.06 B**	9.89 c	12.44 a	**11.17 B**
KS_2	10.78 bc	12.78 a	**11.78 A**	11.21 b	12.78 a	**12.00 A**
Mean	**9.81 B**	**12.07 A**		**9.78 B**	**12.48 A**	
			Average fruit weight (gm)			
KS_0	149.35 d	166.22 b	**157.79 C**	142.81 d	170.44 b	**156.63 C**
KS_1	157.59 c	172.42 a	**165.01 B**	155.77 c	174.43 ab	**165.10 B**
KS_2	163.44 b	177.70 a	**170.57 A**	160.74 c	178.83 a	**169.78 A**
Mean	**156.80 B**	**172.11 A**		**153.11 B**	**174.57 A**	
			Fruit yield plant^{-1} (kg)			
KS_0	1.26 e	1.77 bc	**1.51 C**	1.21 e	1.74 bc	**1.49 C**
KS_1	1.49 d	1.88 ab	**1.69 B**	1.52 d	1.91 b	**1.72 B**
KS_2	1.62 cd	2.10 a	**1.86 A**	1.62 cd	2.06 a	**1.85 A**
Mean	**1.46 B**	**1.92 A**		**1.45 B**	**1.90 A**	
			Fruit yield faddan^{-1} (ton)			
KS_0	10.09 e	14.49 bc	**12.29 C**	9.68 e	13.97 bc	**11.83 C**
KS_1	12.11 d	15.57 ab	**13.84 B**	11.74 d	15.27 b	**13.51 B**
KS_2	13.21 cd	17.33 a	**15.27 A**	12.84 cd	17.42 a	**15.13 A**
Mean	**11.80 B**	**15.80 A**		**11.42 B**	**15.56 A**	

* Mean values with the same alphabetical letter (s) did not differ significantly at $p < 0.05$ confidence level according to LSD test.

The interaction effect of each of M with KS was found to be significant, in both seasons of study. The foliar application of KS_2 under M inoculation (M_++KS_2) was found to be the most pronounced than KS_1 or KS_0 in both seasons of study in the case of squash fruits content of N, P, K and Cu, in both seasons. On the other hand, the KS foliar application levels under M inoculation did not affect the nutrients content of fruits of Ca, Zn and Fe, in both seasons of study.

However, the M_++KS_2 treatment was still giving the highest mean values of fruits nutrients content comparing with the corresponding mean values of the squash plants grown in saline conditions without receiving any ameliorative treatment. The increasing of squash fruits nutrients content due to M_++KS_2 treatment were 105.69, 83.05, 205.28, 59.09, 46.71 15.49 and 22.98 for N, P, K, Ca, Cu, Zn and Fe as an average of both seasons of study, respectively.

Many of other research papers demonstrated the vital role of mycorrhiza inoculation in increasing the nutrient uptake **(Colla *et al.*, 2008; Goussous and Mohammad, 2009; Bhattacharjee and Sharma, 2015; Amballa and Bhumi, 2017).**

The foliar application with KS was found, in many research articles, to be appropriate treatments for enhancing the nutrient quality of squash fruits **(Abd-Elaziz *et al.*, 2019; Rashad *et al.*, 2019).**

Moreover, the interaction between M and KS was found to be the most superior than the single treatments, which pointed to some kind of synergistic effect between M and KS asemphasyses through the research papers of **Hajiboland *et al.* (2018)** and **Moradtalab *et al.* (2019)**

According to the results of this investigation, it could be concluded that growing of squash plants c.v. "Aziad" under saline irrigation water (3.4-3.6 dSm^{-1}) resulted in decreasing all growth, yield and fruit nutrients quality characters as shown in control. However, the application of mycorrhiza inoculum in squash seeds a combined with foliar application of potassium silicate at 4 mlL^{-1} every 10 days after transplanting in the open field could be an effective procedure for increasing the vegetative growth of squash plants grown under similar unfavorable conditions of increasing irrigation water salinity.

Table 6. Effect of mycorrhiza inoculation, potassium silicate foliar applications and their interaction on fruit content of N, P, K, Ca, Cu,Zn and Fe, in 2017 and 2018 seasons

Treatments	2017*			2018*		
	M_-	M_+	Mean	M_-	M_+	Mean
			N%			
KS_0	0.903 e	1.542 c	**1.222 C**	.843 d	1.220 c	**1.032 C**
KS_1	1.059 d	1.753 b	**1.406 B**	.941 d	1.460 b	**1.201 B**
KS_2	1.189 d	1.929 a	**1.559 A**	.983 d	1.667 a	**1.325 A**
Mean	**1.050 B**	**1.741 A**		**0.923 B**	**1.449 A**	
			P%			
KS_0	0.361 e	0.550 c	**0.457 C**	0.364 d	0.480 c	**0.422 C**
KS_1	0.398 d	0.956 b	**0.497 B**	0.416 cd	0.557 b	**0.486 B**
KS_2	0.415 d	0.671 a	**0.534 A**	0.471 c	0.656 a	**0.564 A**
Mean	**0.391 B**	**0.609 A**		**0.417 B**	**0.565 A**	
			K%			
KS_0	1.626 f	3.387 c	**2.506 C**	1.424 f	3.197 c	**2.311 C**
KS_1	2.412 e	4.144 b	**3.278 B**	2.143 e	3.941 b	**3.042 B**
KS_2	3.039 d	4.746 a	**3.983 A**	2.651 d	4.538 a	**3.594 A**
Mean	**2.359 B**	**4.092 A**		**2.073 B**	**3.892 A**	
			Ca%			
KS_0	0.225 d	0.374 a	**0.300 C**	0.249 d	0.351 a	**0.299 C**
KS_1	0.271 c	0.374 a	**0.323 B**	0.278 c	0.351 a	**0.315 B**
KS_2	0.336 b	0.387 a	**0.362 A**	0.301 b	0.364 a	**0.333 A**
Mean	**0.278 B**	**0.378 A**		**0.276 B**	**0.355 A**	
			Cu (ppm)			
KS_0	4.072 d	5.722 b	**4.897 C**	4.111 d	4.728 bc	**4.420 C**
KS_1	4.416 cd	5.971 b	**5.193 B**	4.455 c	4.913 b	**4.684 B**
KS_2	4.600 c	6.788 a	**5.694 A**	4.673 bc	5.209 a	**4.941 A**
Mean	**4.362 B**	**6.160 A**		**4.413 B**	**4.950 A**	
			Zn (ppm)			
KS_0	42.016 d	47.303 ab	**44.660 C**	41.556 c	45.948 ab	**43.752 b**
KS_1	44.783 c	48.712 a	**46.748 B**	44.108 b	46.694 a	**45.401 A**
KS_2	45.683 bc	49.144 a	**47.41 A**	44.579 b	47.375 a	**45.978 A**
Mean	**44.161 B**	**48.387 A**		**43.414 B**	**46.673 A**	
			Fe (ppm)			
KS_0	43.521 c	50.894 a	**47.208 B**	42.277 d	50.744 ab	**46.511 B**
KS_1	47.350 b	52.458 a	**49.904 A**	46.708 c	51.365 a	**49.036 A**
KS_2	47.838 b	53.014 a	**50.426 A**	48.594 bc	52.481 a	**50.537 A**
Mean	**46.237 B**	**52.122 A**		**45.860 B**	**51.530 A**	

* Mean values with the same alphabetical letter (s) did not differ significantly at $p < 0.05$ confidence level according to LSD test.

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