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Integrative influence of sulfur, chicken manure and potassium silicate fertilization on growth and yield characters of muskmelon

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Abstract

Field experiments were carried out at a private farm in Fayoum governorate, Egypt during the summer seasons 2018 and 2019 to study the effect of sulfur, chicken manure, and potassium silicate on growth and productivity of muskmelon. Eighteen treatments were applied using sulfur (0 and 150 kg feddan^{-1}) (feddan = 4200 m² = 0.420 hectares = 1.037 acres) × chicken manure levels (0, 3 and 6 ton feddan^{-1}), and potassium silicate (0, 10 and 20 cm^3 /L). The experiments were arranged in a split-split plot based on randomized complete blocks design with three replications. Sulfur, chicken manure, and potassium silicate levels were randomly allocated in the main, sub- and sub-sub plots, orderly. Each experimental unit was planned to cover an area of 45 m^2 including two rows of 15 m long and 1.5 m wide. Data revealed that all treatments had a significant effect on all studied characters, *i.e.* number of branches and leaves/plant, leaf chlorophyll (A and B), total soluble sugar, number of fruits/plant , average fruits weight (g), fruits yield /plant (kg) and fruits yield/ feddan^{-1} (ton). Application of sulphur at 150 kg feddan^{-1}, chicken manure at 6 ton feddan^{-1} and potassium silicate at 10 or 20 cm^3 /L was the best treatment for all the studied attributes.
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Keywords: muskmelon, sulfur, chicken manure, potassium silicate, yield, chemical composition.

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1. Introduction

Muskmelon (*Cucumis melo* L.) is one of the important vegetables belonging to the cucurbitaceae. The cultivated area of cantaloupe in Egypt is 51.000 feddan, the total production was 586.000 tons and the average yield per feddan is 11.49 tons (Ministry of Agriculture, Egypt, 2018). Cantaloupe fruit is highly concentrated with excellent levels of beta-carotene, folic acid, potassium, dietary fiber and non-enzymatic antioxidant phyto-chemicals such as vitamin C. It is also one of the very few fruits that has a high level of vitamin B complex, ¾ B1 (thiamine), B3 (niacin), B5 (pantothenic acid), and B6 (pyridoxine) (Lester *et al*., 1996; 2002). Cantaloupe is also rich in other human health-bioactive compounds such as antioxidants that can help prevent cancer and heart diseases (Lester, 1997). Sulfur (S) is an essential nutrient for plants and is considered as the fourth major plant nutrient after nitrogen, phosphorous, and potassium. Total sulfur content in plant tissue ranges from 0.3% to 7.6%; the latter is found in plants from gypsum soils (Ernst, 1990; Tabatabai, 1986). It is essential for the growth and development of all crops, without exception. Like any essential nutrient, S also has some key functions in plants. For optimal growth, S requirement varies between 0.1 and 0.5% based on dry weight (Marschner, 1995). Sulfur is an essential nutrient for plant growth and metabolism. Responses in crop growth and yield to the addition of S have been reported (Chotchutima *et al*., 2016; Zhao *et al*.,1996; 1999). Potassium (K) is an important nutrient that has favorable effects on the metabolism of nucleic acids, proteins, vitamins, and growth substances. Furthermore, K plays an important role in the translocation of photosynthates from sources to sinks (Morteza *et al*., 2005). For example, potassium silicate has beneficial effects on strawberry plant metabolism (Wang and Galletta,1998). Animal manures have been used for plant production effectively for centuries. Chicken manure has long been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content (Ghanbarian *et al*., 2008). At the same time, application of manures to the soil not only resulted in reducing the disease severity but also increased plant height and tuber yield of potato plants (El-Fawy *et al*., 2013). Inorganic fertilizer was less suitable in lettuce production, as Lettuce may be grown using 60 ton/ha chicken manure for a more productive enterprise (Masarirambi *et al*., 2012). The objectives of this study were to evaluate the main effects of sulfur, potassium silicate, and chicken manure as a soil nourishment on some agronomic (growth and yield) characters of muskmelon.

2. Materials and methods

As well as their different degree of interactions on morphological characters, leaf photosynthetic pigments, osmoprotectants, and yield and segments of muskmelon (*Cucumis melo* L.) cv. Hybrid melon Major F1. In order to achieve the scope of the study, two field experiments were conducted during the summer seasons of 2018 and 2019 in a private farm, Fayoum, Egypt.

2.1 Physical and chemical properties of soil and chicken manure

Preceding the initiation of each experiment, soil samples to 25 cm depth from the experimental site were collected and analyzed at Soil Testing Laboratory, College of Agriculture, Al-Azar University (Assiut Branch), Assiut, Egypt and the obtained outcome are presented in Table (1). The chemical characteristics and nutrients status of the applied local chicken manure are presented in Table (2) according to published procedure (Wilde *et al.*, 1985).

Table (1): Some physical and chemical characteristics of the experimental site in 2018 and 2019 seasons.

Properties	2018	2019
Physical properties		
Clay (%)	17.3	17.3
Silt (%)	25.8	25.8
Fine sand (%)	56.9	56.8
Chemical properties		
pH	7.9	7.6
ECe (dsm^{-1})	10	9.5
Organic matter (%)	1.026	1.2
$CaCO_3$ (%)	3.97	3.95
Total N	0.0513	0.0520
Available elements (mg kg^{-1} soil)		
N	25.74 ppm	25.75 ppm
P	10.4 mg/k	10.6 mg/k
K	195 mg/k	197 mg/k

Table (2): The main chemical characteristics of chicken manure (dry weight basis).

Character	2018	2019
Weight of 1 m^3 (kg)	562	540
pH (1:10 water suspension)	7.07	7.04
EC (dS/m, 1:10 water extract)	6.24	6.54
Moisture content (%)	15.44	15.01
Organic matter (%)	48.45	50.97
Organic carbon (%)	38.78	40.36
Total N %	2.26	2.49
C/N ratio	14:1	15:1
Total P (%)	2.5	2.6
Total K (%)	1.24	1.51

2.2 Field experiments

Imported muskmelon hybrid seeds cv. Hybrid melon Major F1 (imported by Al-Sanabel for Trading from country of origin Holland) were hand sown in in row spacing of 40 cm between plants in the field on August 10th and 12, 2018 and 2019 seasons, respectively. The experimental design used was a split-

split-plot in randomized complete blocks with three replications, each replicate included 18 treatments. Sulphur in tow levels (0 and 150 kg $feddan^{-1}$) (feddan = 4200 m² = 0.420 hectares = 1.037 acres) occupied the main plots, while poultry manure rates (0, 3 and 6 ton $feddan^{-1}$) were randomly allocated to the sub-plots and potassium silicate concentrations (0, 10 and 20 cm^3 /L) were randomly allocated to the sub-sub-plots. Each experimental unit was planned to cover an area of 45 m^2 including two row of 15 m long and 1.5 m wide. Separate Sulphur and chicken manure amounts were soil applied broadcasted and incorporated during the soil preparation about five days before seed sowing. The potassium silicate concentrations were foliar sprayed, to run off, three times; 15, 30 and 45 days after seeds sowing. Irrigation was applied using the drip irrigation system. All experimental unites received identical doses of compost manure, N, P_2O_5, and K_2O at 5 m^3, 120, 200, and 170 kg $feddan^{-1}$, orderly. The respective forms of N, P_2O_5 and K_2O fertilizers were ammonium nitrate (33% N), single calcium phosphate (15.5% P_2O_5) and phosphoric acid (H_3PO_4 85%), and potassium sulfate (48% K_2O). respectively All compost manure and single calcium superphosphate at 100 kg $feddan^{-1}$ was broadcasted during soil preparation, whilst ammonium nitrate, phosphoric acid (70 L /$feddan^{-1}$), and potassium sulfate were add through drip irrigation system after 1 and 5 weeks of seed sowing date respectively. In addition to spraying all microelements on muskmelon plants in all experimental units. The other cultural practices for commercial muskmelon production as hoeing and spraying with insecticides and fungicides were carried out according to Market-Led Agrarian Reform (MLAR). Harvesting was done after 75 to 90 days from planting, in both seasons.

2.2.1 Plant sampling

In each experimental unit, plants of the first row were allocated for morphological characters, leaf photosynthetic pigments. While the other row was chosen to calculate fruit yield and its parts.

2.3 Data Recorded

2.3.1 Morphological characters

Fifty-five days following seed sowing date, three plants were haphazardly selected, in every test unite. The following morphological characters were measured:

- Number of branches $plant^{-1}$.
- Number of leaves $plant^{-1}$.
- Leaf chlorophyll (a) and (b): Leaf chlorophyll a, b and carotenoid contents (mg g^{-1} fresh weight) were measured and calculated according to Arnon (1949).
- Fruit yield its segments: Fruits in each experimental unit were picked through the entire harvesting period

(70-75) days after seed sowing and the following data were recorded: Number of fruits plant^{-1}, Average fruit weight (g); theoretically calculated by dividing weight over number of fruit yield plant^{-1}. Fruit yield plant^{-1} (kg); dividing weight of fruits over number of actually existed plants. Total fruit yield feddan^{-1} (ton); theoretically calculated by using the relationship between fruit yield treatment^{-1} and ratio between area treatment^{-1} and area feddan^{-1}.

2.4 Statistical analysis

All data were subjected to analysis of variance (ANOVA) for a split-split-plot system in a randomized complete blocks design, after testing for homogeneity of error variances according to the procedure outlined by Gomez and Gomez (1984) using InfoStat software estadistico (2016). Significant differences between treatments were compared at $P \leq 0.05$ by Duncan's Multiple Range Test.

3. Results and Discussion

The gained results of the two field experiments during 2018 and 2019 seasons to identify the main and interaction effects of sulphur, Chicken manure and potassium silicate will be presented under the following topics: morphological characters, membrane permeability, leaf pigments, osmoprotectants leaf elemental contents and fruit yield its segments of muskmelon.

3.1 Morphological Characters

The main and interaction effects of three factors under study on number of branches plant^{-1}, number of leaves plant^{-1} during the two consecutive seasons are presented in Table (3).

3.1.1 Number of branches and leaves plant^{-1}

The main effects of three studied factors (sulphur, poultry manure and potassium silicate) on number of branches and leaves plant^{-1} were significant and the trend was similar in both seasons (Table 3). Soil application of sulphur at 150 kg feddan^{-1} reflected significantly, the highest number of branches and leaves plant^{-1} compared to control in both seasons. Increasing amount of poultry manure from 0 to 3 and further to 6 m^3 feddan^{-1} accompanied, significant, increments on number of shoots and leaves plant^{-1} during the two successive seasons. Increasing foliar application of potassium silicate from 10 to 20 cm^3 /L^{-1} caused corresponding, significant, effects on number of shoots and leaves plant^{-1} compared the control, but the difference between potassium silicate applied at 10 and 20 cm^3 /L^{-1} on number of shoots and leaves plant^{-1} was at par in both seasons. Table (3) indicates the influence of interaction between any two studied factors on number of shoots and leaves plant^{-1}, in both experimental seasons. The effect of interaction between of sulphur × chicken manure on number of branches and leaves plant^{-1} was significantly, in both seasons. Generally, the interaction between sulphur at 150 kg feddan^{-1} × chicken manure at 6 ton feddan^{-1} achieved, intrinsically, the highest number of shoots and leaves plant^{-1} in 2018 and 2019 seasons. The statistical analysis between sulphur at 150 kg feddan^{-1} × potassium silicate at 10 or 20 cm L^{-1} water produced, significantly, the highest number of shoots and leaves plant^{-1} in both seasons. The response of interaction between chicken manure × potassium silicate on number of shoots and leaves plant^{-1} was significant, in two seasons. The interaction between chicken manure at 6 ton feddan^{-1} × potassium silicate at 10 or 20 cm^3 /L^{-1} produced, intrinsically, the highest number of branches and leaves plant^{-1}.

Table (3): Integrative impact of sulphur, chicken manure and potassium silicate on number of branches and leaves plant^{-1} of muskmelon plants grown in saline soil.

Chicken manure rates (ton feddan^{-1})	Potassium Silicate (cm^3/ L^{-1})	Number of Branches plant^{-1}						Number of leaves plant^{-1}					
		2018			2019			2018			2019		
		Sulphur level (kg feddan^{-1})						Sulphur level (kg feddan^{-1})					
		0	150	Mean	0	150	Mean	0	150	Mean	0	150	Mean
0	0	3.3 def*	3.8 cde	3.6 c	4.2 h	5.5 de	4.8 c	38.2 h	45.8 f	42.0 d	42.7 hi	56.2 de	49.4 f
	10	3.7 cdef	4.0 bcd	3.8 c	4.3 gh	5.5 de	4.9 c	41.3 g	52.3 de	46.8 b	45.0 h	63.8 c	54.4 e
	20	3.0 f	4.2 bc	3.6 c	4.3 gh	5.7 cde	5.0 cb	37.1 h	51.5 e	44.3 c	41.8 i	62.5 c	52.2 d
3	0	3.2 ef	4.2 bc	3.7 c	4.5 gh	5.7 cde	5.1 bc	41.3 g	50.8 e	46.1 bc	50.9 fg	63.0 c	57.0 c
	10	3.3 def	4.7 ab	4.0 b	4.5 gh	6.2 abc	5.3 b	44.2 fg	54.8 b	49.5 a	50.9 fg	64.8 bc	57.9 c
	20	3.3 def	4.7 ab	4.0 b	4.3 gh	6.3 ab	5.3 b	42.7 g	55.3 b	49.0 a	48.2 g	65.2 bc	56.7 c
6	0	3.5 cdef	4.7 ab	4.1 b	4.7 fgh	5.8 bcd	5.3 b	43.0 fg	56.2 ab	49.6 a	53.2 ef	67.3 ab	60.3 b
	10	3.8 cde	5.2 a	4.5 a	4.8 fe	6.5 a	5.7 a	43.7 fg	58.2 a	51.0 a	58.3 d	68.8 a	63.6 a
	20	3.8 cde	5.3 a	4.6 a	5.2 ef	6.5 a	5.8 a	43.3 fg	58.2 a	50.8 a	56.7 d	69.7 a	63.2 a
Main effects	0	3.3 c	4.2 b	3.8 B	4.4 c	5.7 b	5.1 B	40.8 d	50.9 b	45.9 B	48.9 d	62.2 b	55.6 B
	10	3.6 c	4.6 a	4.1 A	4.6 c	6.1 a	5.3 A	43.1 c	55.1 a	49.1 A	51.4 c	65.8 a	58.6 A
	20	3.4 c	4.7 a	4.1 A	4.6 c	6.2 a	5.4 A	41.0 d	55.0 a	48.0 A	48.9 d	65.8 a	57.3 A
0	-	3.3 d	4.0 c	3.7 B	4.3 d	5.6 b	4.9 C	38.9 e	49.9 c	44.4 C	43.2 f	60.8 c	52.0 C
3	-	3.3 d	4.5 b	3.9 B	4.4 cd	6.1 ab	5.3 AB	42.7 d	53.7 b	48.2 B	50.0 e	64.3 b	57.2 B
6	-	3.7 cd	5.1 a	4.4 A	4.9 c	6.3 a	5.6 A	43.3 d	57.5 a	50.4 A	56.1 d	68.6 a	62.4 A
	Mean	3.4 B	4.5 A	-	4.5 B	6.0 A	-	41.6 B	53.7 A	-	49.7 B	64.6 A	-

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character. Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

Table (3) branches the effect of interaction among three factors under study on number of branches and leaves plant^{-1}, in both experimental seasons. Comparisons of the eighteen mean values among sulphur × poultry manure × potassium silicate on number of branches and leaves plant^{-1}were, truly, in both seasons. According to the obtained results, generally the interaction among sulphur at 150 kg feddan^{-1}×chicken manure at 6 tons feddan^{-1}× potassium silicate at 10 or 20 cm^3 /L^{-1}, significantly, gained the highest number of branches and leaves plant^{-1} in both seasons.

3.2 Interaction impact of sulfur, chicken manure, potassium silicate on chlorophyll a + b over both seasons

3.2.1 Chlorophyll a + b

Table (4) displays the main and interaction impact on Chlorophyll a + b of sulphur, poultry manure, and potassium silicate on in the two experimental seasons of 2018 and 2019. Soil application of sulphur at 150 kg feddan^{-1} reflected significantly, the increased chlorophyll a + b compared to control in both seasons. Soil application of poultry manure gave the heaviest significant values on Chlorophyll a + b as compared to control, whereas increasing the level of poultry manure from 3 up to 6 ton fed^{-1} was responsible for the statistically increments in chlorophyll a + b measurements previously mentioned during the two successive seasons. Spraying the foliage of muskmelon plants with potassium silicate at 10 or 20 cm^3 /L^{-1} reflected positive intrinsic effects on in comparison with the standard treatment whereas, the difference between potassium silicate 10 and 20 cm^3 /L^{-1} was at par in both seasons. The effect of interaction between of sulphur × chicken manure on chlorophyll a + b significantly, in both seasons. Generally, the interaction between sulphur at 150 kg feddan^{-1} × poultry manure at 6 ton fed^{-1} was, statistically, pioneer on Chlorophyll a + b in 2018 and 2019 seasons. The response of Chlorophyll a + b interaction between sulphur × potassium silicate was significant, in both experimental seasons. Generally, the interaction treatment of sulphur at 150 kg feddan^{-1} × potassium silicate at 10 or 20 cm^3 /L^{-1} gave, significantly, the best value of chlorophyll a + b. The sound of interaction between poultry manure × potassium silicate on Chlorophyll a + b was significant. Comparisons among the eighteen combined treatments illustrated that the best valuable combined treatment on chlorophyll a + b appeared to be the combination of sulphur at 150 kg feddan^{-1} × potassium silicate at 10 or 20 cm^3 /L^{-1}, in both seasons. Regarding potassium silicate spraying, the present findings were in partial agreement , with those reported by Al-Aghabary *et al*. (2005) who found that Si foliar application resulted in increasing dry matter accumulated in all parts of tomato plants under salt stress and the increase in leaf and total plant dry matter content was significant. The increase was to the extent of 19.5, 25.4, 13.4, and 21.2% with leaf, stem, root, and total plant, serially. The role of S in plants is to help in the formation of plant proteins, and it is essential for the formation of chlorophyll and improves root growth. Sulfur is involved in the formation of vitamins and enzymes required for the plant to conduct its biochemical processes (Scherer *et al*., 2008). Sulfur deficiency in the soil can not only reduce grain yield and quality of produce but also make a sharp impact in agrobased economy (Fismesa *et al*., 2000).

Table (4): Integrative impact of sulphur, chicken manure and potassium silicate rates leaf chlorophyll a+b of muskmelon plants grown in saline soil.

Chicken manure rates (ton feddan^{-1})	Potassium Silicate (cm^3/L^{-1})	Chlorophyll a + b (mg/mm^2 FW)					
		2018			2019		
		Sulphur level (kg feddan^{-1})					
		0	150	Mean	0	150	Mean
0	0	0.176^{hi*}	0.173^{i}	0.174^{f}	0.190^{h}	0.193^{gh}	0.191^{d}
	10	0.203^{ab}	0.189^{efg}	0.196^{ab}	0.215^{abcd}	0.203^{fg}	0.209^{b}
	20	0.193^{cdef}	0.192^{def}	0.193^{cd}	0.209^{ef}	0.210^{def}	0.210^{b}
3	0	0.182^{ghi}	0.185^{fgh}	0.183^{e}	0.195^{gh}	0.203^{fg}	0.199^{c}
	10	0.195^{bcde}	0.200^{abcd}	0.197^{ab}	0.209^{ef}	0.219^{abcd}	0.214^{ab}
	20	0.195^{bcde}	0.200^{abcd}	0.198^{ab}	0.209^{ef}	0.222^{abc}	0.215^{ab}
6	0	0.178^{hi}	0.194^{bcde}	0.186^{de}	0.194^{gh}	0.207^{ef}	0.201^{c}
	10	0.202^{abc}	0.207^{a}	0.205^{a}	0.213^{cdef}	0.224^{ab}	0.218^{a}
	20	0.202^{abc}	0.202^{abc}	0.202^{ab}	0.214^{bcde}	0.225^{a}	0.220^{a}
Main effects	0	0.179^{b}	0.184^{b}	0.181^{B}	0.193^{d}	0.201^{c}	0.197^{B}
	10	0.200^{a}	0.199^{a}	0.199^{A}	0.212^{b}	0.215^{ab}	0.214^{A}
	20	0.197^{a}	0.198^{a}	0.197^{A}	0.211^{b}	0.219^{a}	0.215^{A}
0		0.191^{bc}	0.185 c	0.188^{B}	0.205^{c}	0.202^{c}	0.204^{B}
3		0.191^{bc}	0.195 ab	0.193^{AB}	0.204^{c}	0.215^{ab}	0.209^{A}
6		0.194^{ab}	0.201^{a}	0.197^{A}	0.207^{bc}	0.219^{a}	0.^{213A}
	Mean	0.192^{A}	0.194^{A}		0.205^{B}	0.212^{A}	

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

However, further reports indicated that Si plays a major role for a variety of plant species as cucurbitaceae. A number of possible mechanisms through which silicate may increase salinity, heat and drought tolerance in plants have been proposed by various scientists as reviewed by Liang et al. (2015) including improved plant water status (Romero-Arnada *et al*., 2006); increased photosynthetic activity and ultra-structure of leaf organelles (Shu and Liu, 2001). Some investigators reported that plant foliar spray with silicon caused increase in vegetative growth, yield and quality of cucumber plants as (Jafari *et al*., 2015; Omar, 2017).

3.2.2 Total soluble sugar

The results of main and interaction on leaf total soluble sugar as affected by sulphur level, chicken manure rate and potassium silicate, in both seasons, are presented in Table (5). The main effect of soil application of sulphur total soluble sugar was statistically, in both seasons. Increasing sulphur level from 0 to 150 kg feddan^{-1} obviously increased, significantly, leaf total soluble sugar. The general of chicken manure rates on total soluble sugar was intrinsic, in both seasons. Application poultry manure rate 6 ton feddan^{-1}, significantly, attained the best mean value of total soluble sugar. Spraying the foliage of muskmelon plants with potassium silicate at 10 or 20 cm^3/L^{-1} reflected positive intrinsic effects on total soluble sugar comparison with the standard treatment whereas, the difference between potassium silicate at 10 or 20 cm^3 /L^{-1} was at par in both seasons. The statistical analysis of interaction between sulphur level × poultry manure rate on leaf total free amino acids and leaf total soluble sugar was true, in both seasons. The interaction between sulphur at 150 kg feddan^{-1} × poultry manure at 6 ton feddan^{-1} gave, truly, total soluble sugar. The impact of interaction between sulphur level × potassium silicate on leaf total free amino acids and leaf total soluble sugar was significant, in the two experimental seasons. The combined treatment of sulphur at 150 kg feddan^{-1} coupled with potassium silicate at 10 or 20 reflected, significantly, the maximum value of leaf total soluble sugar. In both seasons, the interaction between poultry manure × potassium silicate on soluble sugar was significant.

Table (5): Integrative impact of sulphur, chicken manure and potassium silicate on total soluble sugar of muskmelon plants.

Chicken manure rates (ton feddan^{-1})	Potassium Silicate (cm^3/L^{-1})	Total soluble sugar (%)					
		Season 2018			Season 2019		
		Sulphur level (kg feddan^{-1})					
		0	150	Mean	0	150	Mean
0	0	11.7 f	12.2 e	11.9 e	12.3 f	13.3 de	12.8 d
	10	12.3 e	12.9 d	12.6 d	12.8 e	14.0 bc	13.4c
	20	12.5 de	13.7 b	13.1 bc	13.0 e	14.2 ab	13.6 bc
3	0	12.3 e	12.5 de	12.4 d	12.7 e	13.8 bcd	13.2 cd
	10	12.7 d	13.3 c	13.0 c	13.2 de	14.0 bc	13.6 bc
	20	13.0 d	13.8 b	13.4 b	14.0 bc	14.2 ab	14.1 ab
6	0	12.8 d	13.3 c	13.1 bc	13.2 de	14.0 bc	13.6 bc
	10	13.7 b	14.1 a	13.9 a	13.8 bcd	14.8 a	14.3 a
	20	13.5 c	14.2 a	13.8 a	13.8 bcd	14.5 ab	14.2 a
Main effects	0	12.3 e	12.7 d	12.5 b	12.7 c	13.7 b	13.2 b
	10	12.9 cd	13.4 b	13.2 a	13.3 b	14.3 a	13.8 a
	20	13.0 c	13.9 a	13.4 a	13.6 b	14.3 a	13.9 a
0	-	12.2 d	12.9 bc	12.5 c	12.7 d	13.8 b	13.3 c
3	-	12.7 c	13.2 b	12.9 b	13.3 c	14.0 ab	13.6 b
6	-	13.3 b	13.9 a	13.6 a	13.6 b	14.4 a	14.0 a
Mean		12.7 b	3.3a	-	13.2 b	14.1 a	-

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

Comparisons among the nun combined treatments illustrated that the best valuable combined treatment total soluble sugar appeared to be the combination of chicken manure at 6 ton feddan^{-1}× potassium silicate at 10 or 20 cm^3 /L^{-1}, in both seasons. The effect of 2nd order interaction among three factors on total soluble sugar was significant, in both seasons. The comparisons among the eighteen combined treatments illustrated that the best valuable combined treatment on total soluble sugar appeared to be the combination of sulphur at 150 kg feddan^{-1} × chicken manure at 6 ton feddan^{-1} × potassium silicate at 10 or 20 cm litter water^{-} in both experimental seasons. AL-Rubaye and Atia (2016) illustrated that the highest total soluble solids of carbohydrates of squash fruits were found to be due to applying Si at 5 mM concentration compared with the other concentration. The role of S in plants is to help in the formation of plant proteins, and it is essential for the formation of chlorophyll an improves root growth. Sulfur is accumulated in plants in low concentrations compared to N, but is an essential element as a constituent of proteins, cysteine-containing peptides such as glutathione (an anti-oxidant) or numerous secondary metabolites (Abdallah *et al*., 2010; Scherer *et al*., 2008) and synthesis of vitamins and chlorophyll in the cell (Kacar and Katkat, 2007). Al-Rubaye and Atia (2016) illustrated that the highest total soluble solids of carbohydrates of squash fruit were found to be due to applying Si at 5mM compared with the other concentration. Furthermore, Kazemi (2014) found that total soluble solids and titratable acidity content of tomato fruit had, significantly, affected by the application of salicylic acid. On the other hand, Buttaro *et al*. (2009) illustrated that fruit TSS and titratable acidity of melon were not affected by root application of Si. Also, Jayawardana *et al*. (2014) on pepper reported that titratable acidity was not affected by Si application.

3.2.3 Number of fruit plant^{-1} and average fruit weight

Data presented in Table (6) shows, the main and interaction of three factors under study (sulphur, chicken manure and potassium silicate) on number of fruits plant^{-1} and average fruits weight, in both seasons. The main effect of soil application of sulphur level on number of fruits plant^{-1} and average fruit weight was significant, in both seasons. Increasing sulphur level from 0 to 150 kg feddan^{-1} obviously increased, significantly, the number of fruits plant^{-1} (2.43 and 2.59) and average fruit weight (842 and 852 g) in 2018 and 2019 seasons. The general of chicken manure rates on number of fruits plant^{-1} and average fruits weight was intrinsic, in both seasons except number of fruits plant^{-1}in 2018 season. Application chicken manure applied at 6 m^3 feddan^{-1}, significantly, attained the best mean value of number of fruits plant^{-1} (2.53) and average fruit weight (881 and 918 g) in 2018 and 2019. Spraying the foliage of muskmelon plants with potassium silicate at 10 or 20 cm L^{-1} reflected positive intrinsic effects on number of fruits plant^{-1} comparison with the standard treatment whereas, the difference between potassium silicate at 0 and 10, 20 cm L^{-1} on average fruits weight was at par in both seasons. The statistical analysis of interaction between sulphur level × poultry manure rate on number of fruit plant^{-1} and average fruits weight was true, in both seasons. The interaction between sulphur at 150 kg fed^{-1} × poultry manure at 6 m^{3} fed^{-1}gave, truly, the highest mean value of number of fruit plant^{-1} (2.50 and 2.76) and average fruits weight (979 and 970 g) in 2018 and 2019 seasons. The impact of interaction between sulphur level × potassium silicate on number of fruit plant^{-1} and average fruits weight was significant, in the two experimental seasons. The combined treatment of sulphur at 150 kg feddan^{-1} coupled with potassium silicate at 10 or 20 reflected, significantly, the maximum value of number of fruits plant^{-1} and average fruits weight.In both seasons, the interaction between poultry manure × potassium silicate on number of fruits plant^{-1} and average fruits weight was significant. Comparisons among the nun combined treatments illustrated that the best valuable combined treatment on number of fruits plant^{-1} and average fruits weight appeared to be the combination of poultry manure at 6 m^{3} fed^{-1}× potassium silicate at 10 or 20 cm L^{-1}, in both seasons. The effect of 2nd order interaction among three factors on number of fruits plant^{-1} and average fruit weight was significant, over both seasons.

Table (6): Integrative impact of sulphur, chicken manure and potassium silicate on number of fruits plant^{-1} and average fruits weight of muskmelon plants grown in saline soil.

Chicken manure rates (ton feddan^{-1})	Potassium Silicate (cm L^{-1})	Number of fruits plant^{-1}						Average fruits weight (g)					
		2018			2019			2018			2019		
		Sulphur level (kg feddan^{-1})						Sulphur level (kg feddan^{-1})					
		0	150	Mean	0	150	Mean	0	150	Mean	0	150	Mean
0	0	1.95 ^{d*}	2.19 ^{abcd}	2.07 ^{b}	2.10 ^{e}	2.30 ^{cde}	2.20 ^{c}	603 ^{efg*}	754 ^{cde}	679 ^{b}	600 ^{g}	794 ^{bcde}	697 ^{cd}
	10	2.10 ^{cd}	2.40 ^{abc}	2.25 ^{ab}	2.10 ^{e}	2.57 ^{abc}	2.33 ^{bc}	598 ^{fg}	772 ^{cd}	685 ^{b}	658 ^{fg}	751 ^{cdef}	704 ^{cd}
	20	2.10 ^{cd}	2.40 ^{abc}	2.25 ^{ab}	2.10 ^{e}	2.48 ^{bcd}	2.29 ^{bc}	579 ^{g}	742 ^{cdef}	660 ^{b}	655 ^{fg}	719 ^{ef}	687 ^{d}
3	0	2.10 ^{cd}	2.25 ^{abcd}	2.18 ^{ab}	2.25 ^{de}	2.33 ^{cde}	2.29 ^{bc}	658 ^{defg}	787 ^{cd}	723 ^{b}	670 ^{fg}	834 ^{bc}	752 ^{bcd}
	10	2.25 ^{abcd}	2.55 ^{ab}	2.40 ^{a}	2.25 ^{de}	2.65 ^{ab}	2.45 ^{ab}	660 ^{defg}	807 ^{cd}	733 ^{b}	732 ^{def}	830 ^{bc}	781 ^{b}
	20	2.10 ^{cd}	2.57 ^{a}	2.33 ^{ab}	2.25 ^{de}	2.70 ^{ab}	2.48 ^{ab}	712 ^{cdefg}	782 ^{cd}	747 ^{b}	689 ^{fg}	822 ^{bcd}	756 ^{bc}
6	0	2.15 ^{cd}	2.40 ^{abc}	2.28 ^{ab}	2.23 ^{de}	2.63 ^{ab}	2.43 ^{ab}	770 ^{cd}	971 ^{ab}	870 ^{a}	826 ^{bcd}	969 ^{a}	898 ^{a}
	10	2.17 ^{bcd}	2.55 ^{ab}	2.36 ^{a}	2.35 ^{cde}	2.80 ^{a}	2.58 ^{a}	825 ^{bc}	983 ^{a}	904 ^{a}	889 ^{ab}	977 ^{a}	933 ^{a}
	20	2.19 ^{abcd}	2.55 ^{ab}	2.37 ^{a}	2.30 ^{cde}	2.83 ^{a}	2.57 ^{a}	813 ^{c}	982 ^{a}	898 ^{a}	881 ^{ab}	965 ^{ab}	923 ^{a}
Main effects	0	2.07 ^{b}	2.28 ^{ab}	2.17 ^{B}	2.19 ^{c}	2.42 ^{b}	2.31 ^{B}	677 ^{b}	837 ^{a}	757 ^{A}	699 ^{c}	866 ^{a}	782 ^{A}
	10	2.17 ^{b}	2.50 ^{a}	2.34 ^{A}	2.23 ^{c}	2.67 ^{a}	2.45 ^{A}	694 ^{b}	854 ^{a}	774 ^{A}	759 ^{b}	853 ^{a}	806 ^{A}
	20	2.13 ^{b}	2.51 ^{a}	2.32 ^{AB}	2.22 c	2.67 ^{a}	2.44 ^{A}	701 ^{b}	835 ^{a}	768 ^{A}	742 ^{bc}	835 ^{a}	789 ^{A}
0		2.05 ^{c}	2.33 ^{ab}	2.19 ^{A}	2.10 ^{d}	2.45 ^{bc}	2.28 ^{B}	593 ^{d}	756 ^{bc}	675 ^{C}	638 ^{d}	755 ^{c}	696 ^{C}
3		2.15 ^{bc}	2.46 ^{a}	2.30 ^{A}	2.25 ^{cd}	2.56 ^{ab}	2.41 ^{AB}	677 ^{cd}	792 ^{b}	734 ^{B}	697 ^{cd}	829 ^{b}	763 ^{B}
6		2.17 ^{bc}	2.50 ^{a}	2.33 ^{A}	2.29 ^{cd}	2.76 ^{a}	2.53 ^{A}	803 ^{b}	979 ^{a}	891 ^{A}	865 ^{b}	970 ^{a}	918 ^{A}
	Mean	2.12 ^{B}	2.43 ^{A}		2.21 ^{B}	2.59 ^{A}		691 ^{B}	842 ^{A}		733 ^{B}	851 ^{A}	

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at P = 0.05. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

The comparisons among the eighteen combined treatments illustrated that the best valuable combined treatment effect on number of fruits plant^{-1} and average fruits weight appeared to be the combination of sulphur at 150 kg feddan^{-1} × poultry manure at 3 and /or 6 m^{3} feddan^{-1} × potassium silicate at 10 and/or

20 cm L^{-1} in both experimental seasons. Respecting Si application, the postulated results agree, also, with those obtained by Omar (2017) who illustrated that foliar application of Si at 100 ppm caused: significant increase on cucumber fruit yield compared to control plants. Matichenkov and Bocharnikova (2008) found that cucumber yield was increased, significantly either by foliar silicon with 10 kg ha^{-1} at the 3rd leaf stage and subsequent bi-weekly application during the season or by soil Si applications (40 kg ha^{-1}).

3.2.4 Fruits yield plant^{-1} and total fruits yield feddan^{-1}

Data presented in Table (7) shows the main and interaction of three factors under study (sulphur, chicken manure, and potassium silicate) on fruit yield $plant^{-1}$ and total fruit yield $feddan^{-1}$, in both seasons. The main effect of soil application of sulphur level on fruits yield $plant^{-1}$ and total fruit yield $feddan^{-1}$ was significant, in both seasons. Soil application of sulphur at 150 kg $feddan^{-1}$ produced increased, in fruit yield $plant^{-1}$ by (40%) and total fruits yield $feddan^{-1}$ by (22% and 16%) comber to control in 2018 and 2019 seasons orderly. The general of poultry manure rates on fruits yield $plant^{-1}$ and total fruits yield $fed^{-1}$was intrinsic, in both seasons. Application of chicken manure rate at 6 ton $feddan^{-1}$ produced an increase, in fruit yield $plant^{-1}$ by (41% and 47%) and total fruit yield $feddan^{-1}$ by (10% and 32%) comber to control in 2018 and 2019 seasons orderly. Spraying the foliage of muskmelon plants with potassium silicate at 10 cm litter $water^{-}$ produced increased, in fruits yield $plant^{-1}$ by (9%) and total fruits yield $feddan^{-1}$ by (2.25% and 3.07%) comber to control in 2018 and 2019 seasons orderly Whereas, the difference between potassium silicate at 10 and 20 cm^3 L^{-1} on average fruit yield $plant^{-1}$ and total fruits yield $feddan^{-1}$ at par in both seasons. The statistical analysis of interaction between sulphur level × chicken manure rate on fruits yield $plant^{-1}$ and total fruits yield $feddan^{-1}$ was true, in both seasons. The interaction between sulphur at 150 kg $feddan^{-1}$ × poultry manure at 6 ton $feddan^{-1}$ gave, truly, the highest mean value of fruits yield $plant^{-1}$ (2.43 and 2.67 kg) and total fruit yield $feddan^{-1}$ (11.92 and 13.62 ton) in 2018 and 2019 seasons orderly. The impact of interaction between sulphur level × potassium silicate on fruit yield $plant^{-1}$ and total fruits yield $fed^{-1}$was significant, in the two experimental seasons. The combined treatment of sulphur at 150 kg $feddan^{-1}$ coupled with potassium silicate at 10 reflected, significantly, the maximum value fruit yield $plant^{-1}$ (2.12 and 2.27 kg) and total fruits yield fed^{-1} (10.38 and 11.70 ton) in 2018 and 2019 seasons orderly. The interaction between chicken manure × potassium silicate on fruits yield $plant^{-1}$ and total fruits yield $feddan^{-1}$ was significant. The combined treatment of poultry manure at 6 ton $feddan^{-1}$ × potassium silicate at 10 cm L^{-1} water, gave, truly, the highest mean value of fruits yield plant^{-1} (2.14 and 2.41 kg) and total fruit yield feddan^{-1} (9.98 and 11.98 ton) in 2018 and 2019 seasons orderly.

Table (7): Integrative impact of sulphur, chicken manure and potassium silicate on fruits yield plant^{-1} and total fruits yield feddan^{-1} of muskmelon plants grown in saline soil.

Chicken manure rates (ton fed^{-1})	Potassium Silicate (cm^3 L^{-1} water)	Fruits yield plant^{-1} (kg)						Total fruits yield fed^{-1} (ton)					
		2018			2019			2018			2019		
		Sulphur level (kg feddan^{-1})						Sulphur level (kg feddan^{-1})					
		0	150	Mean	0	150	Mean	0	150	Mean	0	150	Mean
0	0	1.16^{h}	1.65^{e}	1.40^{f}	1.25^{m}	1.83^{i}	1.54^{f}	4.07^{m}	7.13^{gh}	5.60^{e}	5.12^{j}	8.32^{f}	6.72^{f}
	10	1.24^{h}	1.84^{d}	1.54^{de}	1.37^{l}	1.92^{fg}	1.64^{e}	5.10^{kl}	8.64^{d}	6.87^{d}	5.60^{i}	9.70^{d}	7.65^{d}
	20	1.19^{h}	1.77^{d}	1.48^{e}	1.37^{l}	1.78^{i}	1.57^{f}	4.83^{l}	8.37^{de}	6.60^{d}	5.67^{i}	8.91^{e}	7.29^{e}
3	0	1.37^{g}	1.77^{d}	1.57^{d}	1.51^{k}	1.94^{fg}	1.72^{d}	5.62^{jk}	7.90^{ef}	6.76^{d}	6.69 h	8.94^{e}	7.81^{d}
	10	1.49^{f}	2.04^{c}	1.76^{c}	1.65^{j}	2.17^{cd}	1.91^{c}	6.59^{hi}	10.17^{c}	8.38^{c}	7.29^{g}	11.13^{c}	9.21^{c}
	20	1.48^{f}	2.00^{c}	1.74^{c}	1.55^{k}	2.22^{c}	1.89^{c}	6.18^{ij}	10.18^{c}	8.18^{c}	6.91^{gh}	11.77^{b}	9.34^{c}
6	0	1.64^{e}	2.31^{b}	1.97^{b}	1.85^{hi}	2.55^{b}	2.20^{b}	6.90^{h}	10.92^{b}	8.91^{b}	8.14^{f}	12.20^{b}	10.17^{b}
	10	1.78^{d}	2.49^{a}	2.14^{a}	2.09^{df}	2.73^{a}	2.41^{a}	7.63^{fg}	12.33^{a}	9.98^{a}	9.70^{d}	14.27^{a}	11.98^{a}
	20	1.78^{d}	2.49^{a}	2.14^{a}	2.03^{ef}	2.73^{a}	2.38^{a}	7.73^{efg}	12.51^{a}	10.12^{a}	9.24^{de}	14.40^{a}	11.82^{a}
Main effects	0	1.39^{d}	1.91^{b}	1.65^{B}	1.53^{e}	2.11^{b}	1.82^{B}	5.53^{d}	8.65^{b}	7.09^{B}	6.65^{d}	9.82^{b}	8.23^{B}
	10	1.50^{c}	2.12^{a}	1.81^{A}	1.70^{c}	2.27^{a}	1.99^{A}	6.44^{c}	10.38^{a}	8.41^{A}	7.53^{c}	11.70^{a}	9.62^{A}
	20	1.48^{c}	2.09^{a}	1.79^{A}	1.65^{d}	2.24^{a}	1.94^{A}	6.25^{c}	10.35^{a}	8.30^{A}	7.27^{c}	11.69^{a}	9.48^{A}
0		1.20^{e}	1.75^{c}	1.47^{C}	1.33^{f}	1.84^{d}	1.58^{C}	4.67^{f}	8.05^{c}	6.36^{C}	5.46^{e}	8.97^{c}	7.22^{C}
3		1.44^{d}	1.94^{b}	1.69^{B}	1.57^{e}	2.11^{b}	1.84^{B}	6.13^{e}	9.41^{b}	7.77^{B}	6.96^{d}	10.61^{b}	8.79^{B}
6		1.73^{c}	2.43^{a}	2.08^{A}	1.99^{c}	2.67^{a}	2.33^{A}	7.42^{d}	11.92^{a}	9.67^{A}	9.03^{c}	13.62^{a}	11.32^{A}
	Mean	1.46^{B}	2.04^{A}		1.63^{B}	2.21^{A}		6.07^{B}	9.79^{A}		7.15^{B}	11.07^{A}	

*Values marked with the same letter(s) within the main and interaction effects are statistically similar using Duncan's multiple range test at $P = 0.05$. Uppercase letter(s) indicate differences between main effects, and lowercase letter(s) indicate differences within interaction of each character.

The role of S in soil is very crucial for plant growth and nutrition for optimizing crop yield and quality (Jez, 2008). High yields of good quality produce become possible only when crops have access to optimum levels of S. Results of a field trial conducted by Ur Rahman *et al*. (2014) reported that the poultry manure application at about 2 ton h^{-1} significantly increased pod length, number of pods plant^{-1} and seed yield m^{-2} of bean plants when compared with untreated plants. Some investigators reported that plant foliar spray with silicon caused increase in vegetative growth, yield and quality of cucumber plants as (Jafari *et al*., 2015; Omar, 2017). There are additional benefits for Si including stimulation of fruit formation and accelerated fruit maturation. Also, Buttaro et al. (2009) illustrated that fruit fresh and dry weights of melon were not affected by root application of Si. Respecting Si application, the postulated results agree, also, with those obtained by Omar (2017) who illustrated that foliar application of Si at 100 ppm caused; significant increase on cucumber fruit yield compared to control plants. The effect of 2nd order interaction among three factors on fruit yield plant^{-1} and total fruit yield feddan^{-1} was true, in both seasons. The combination of sulphur at 150 kg feddan^{-1} × chicken manure at 6 m^3 feddan^{-1} × potassium silicate at 20 cm^3 L^{-1} gave, truly, the highest mean value of fruit yield plant^{-1} (2.49 and 2.73 kg) and total fruits yield feddan^{-1} (12.51 and 14.40

ton) in 2018 and 2019 seasons, orderly. Matichenkov and Bocharnikova (2008) found that cucumber yield was increased, significantly either by foliar silicon with 10 kg ha^{-1} at the 3rd leaf stage and subsequent bi-weekly application during the season or by soil Si applications (40 kg ha^{-1}). There are additional benefits for Si include stimulation of fruit formation and accelerated fruit maturation. Also, Buttaro *et al*. (2009) illustrated that fruit fresh and dry weights of melon were not affected by root application of Si. Si plays a major role for a variety of plant species as cucurbitaceae. A number of possible mechanisms through which silicate may increase salinity, heat, and drought tolerance in plants have been suggested by various scientists as reviewed by Liang *et al*. (2015) including improved plant water status (Romero-Arnada *et al*., 2006), increased photosynthetic activity and ultra-structure of leaf organelles (Shu and Liu, 2001). Some investigators reported that plant foliar spray with silicon caused increase in vegetative growth, yield and quality of cucumber plants (Jafari *et al*., 2015; Omar, 2017). From the obtained results, it could be concluded that he combination of sulphur at 150 kg $feddan^{-1}$ × poultry manure at 6 m^3 $feddan^{-1}$ × potassium silicate at 20 cm^3 L^{-1} was the highest effect on all the studied characters.

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