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Effect of foliar spray with silicon, salicylic acid and cycocel on cucumber salt tolerance and fruit characteristics under green- house conditions

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Abstract: The effect of foliar spray with cycocel, Salicylic acid, and Silicon on cucumber fruit characteristics, and salt tolerance under greenhouse conditions, was studied, at research center of Al- Hennadi, related to Agriculture research center – Lattakia- Syria . The research concluded 14 treatments : 1-C , 2- SA 25, 3- SA50 , 4- CCC400 , 5-CCC600, 6-Si 100 , 7- Si 200, 8-S, 9 –S+SA25 , 10- S+SA50, 11-S+ CCC400 , 12- S+ CCC600, 13- S+ Si 100, 14- S+ Si 200.

The results showed that foliar spray with Si, SA and CCC improved fruit quality (dry matter, total sugars, soluble solids, total acids, and vitamin C).

The results showed as well, that silicon application (Si(100,200) increased significantly the studied parameters.

The results indicated that SA, CCC, and Si could alleviate the harmful effect of salinity, silicon was more effective.

Keywords Salinity – Silicon – Salicylic acid – Cycocel- Cucumber- Green House.

دور السيليكون وحمض السالسيلك والسيكوسيل في الصفات النوعية للثمار وتحمل نباتات الخيار لملوحة ماء الري في ظروف الزراعة المحمية

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المستخلص: تم تنفيذ البحث في محطة بحوث الهنادي، التابع لمركز البحوث العلمية الزراعية في اللاذقية، سورية، في العروة الربيعية للعام 2019 – 2020، حيث تمت دراسة كفاءة الرش الورقي بكل من حمض الساليسيليك SA، والسيكوسيل CCC، والسيليكون Si في تحمل نباتات الخيار للملوحة (6 ds/m)، والمزروعة في ظروف الزراعة المحمية.

تضمن البحث 14 معاملة: 1- شاهد ماء عادي C، 2- SA25 حمض السالسيلك تركيز (25 PPm)،

3- SA50 حمض السالسيلك تركيز (50 PPm)، 4- CCC400 السيكوسيل تركيز (400 PPm)،

5- CCC600 السيكوسيل تركيز (600 PPm)، 6- Si 100 سيلكون تركيز (100PPm)، 7- Si 200 سيلكون تركيز (200PPm)، 8- S شاهد ماء مالح، 9- S+SA25 (ماء مالح+ حمض السالسيلك تركيز (PPm25))، 10 - S+SA50 (ماء مالح+ حمض السالسيلك تركيز (50

11- S+ CCC400 (ماء مالح + السيكوسيل تركيز (400 PPm))، 12– S+ CCC600 (ماء مالح + السيكوسيل تركيز (600 PPm))، 13 – S+ Si 100 (ماء مالح + سيلكون تركيز(100PPm)) ، 14 – S+ Si 200 (ماء مالح + سيلكون تركيز(200PPm)).
أدى رش نبات الخيار بالسيلكون وحمض السالسيليك والسيكوسيل إلى تحسين نوعية الثمار من حيث المادة الجافة، السكريات الكلية، المواد الصلبة الذائبة، الأحماض الكلية، وفيتامينC.
وبينت النتائج تفوق معاملة الرش بالسيلكون Si(100,200) معنوياً في جميع المؤشرات المدروسة.
وأظهرت النتائج أيضاً إن الرش بالسيلكون وحمض السالسيليك والسيكوسيل قد خفف من الأثر الضار للملوحة، ولعب السيلكون S+Si200 الدور الأكبر في زيادة تحمل نباتات الخيار للملوحة.

الكلمات المفتاحية: الملوحة، السليكون، حمض الساليسيليك، السيكوسيل، الخيار، الزراعة المحمية.

Introduction:

Salt stress is one of the most important factors limiting plant growth and yield worldwide [1], Currently, more than 20% of the world's agricultural irrigated land is affected by salt excess. This problem continues to aggravate worldwide because of unsuitable fertilizers application, industrial pollution, and poor irrigation practices [2].

Salinity stress affects the morphological, physiological, and biochemical processes of plants [3], high salinity decreases plant growth, biomass, yield, photosynthesis, and water use efficiency, and leads as well to physiological drought and ion toxicity in plants, thus reducing agricultural productivity and yields [4].

Salinity stress causes ionic imbalances, osmotic effects, water use insufficiency, and nutrient (e.g. N, Ca, K, P, Fe, and Zn) deficiency, which ultimately leads to oxidative stress in plants [5].

Reactive oxygen species (ROS) are produced in plant cells under normal physiological conditions, either in a radical or non-radical form. However, excessive ROS production leads to oxidative damage to the proteins, lipids, nucleic acids, and plasma membrane[5].

Oxidative damage is one of the most important effects of salinity, due to the high rate of active oxygen species such as (O2-) Superoxide radical and (OH-) Hydroxyl radical, (H2O2) Hydrogen peroxide. Plants have developed a defense system against the oxidative damage of free radicals, which is an enzymatic system that includes peroxidase, superoxide dismutase and catalase, which are scavenging compounds for free radicals generated by salinity [6].

Salinity stress significantly reduces the uptake of phosphorus (P) and potassium (K), while increasing the uptake of toxic elements such as sodium (Na^+) and chlorine (Cl^-), which have negative effects on plant growth and productivity. Whereas, high concentrations of Na^+ create osmotic stress, which consequently leads to cell death [7].

The presence of salt in a large quantities is a limiting factor for agricultural production, where most of the cultivated plants belong to salt-sensitive species, and their yield under these conditions is very low [8].

Cucumber, (Cucumis sativus L.), is one of Cucurbitaceae family, which prefers hot climate , and cultivated widely in the world. It is characterized by rapid growth and early maturity, that realize a high economic income. Cucumber fruits contain a big number of enzymes that help in digesting fatty and protein substances, and their mineral salts have an alkaline effect which help in adjusting stomach acidity, and dissolve kidney gravels and increase urine [9].

Cucumber plants are classified as salt sensitive, they tolerate until to 2.5 ds/m of salinity ,yield decreases by 13% when salinity increases up of threshold [10].

Many studies have been conducted to reduce salinity damage and increase salt plant tolerance , different technics were used, such as plant treatment with growth regulators(like salicylic acid, cycocel) or mineral elements(silicon), [11].

salicylic acid (SA):

It is a kind of phenolic acids (monohydroxybenzoic acid), containing an aromatic ring bearing a hydroxyl group (OH), and colorless naturally, extracted from some plants such as white willow and meadow sweet. It is produced by the metabolism of phenylpropanoid [12].

SA contributes to plant growth and development, it has an important role in many physiological processes, and in protecting plants from many biotic and abiotic stresses [13].

It was found as well that treatment with silicon or salicylic acid or both increased leaf area, wet and dry weight, relative water content, total phenols, anthocyanins, flavonoids, plant potassium content, and the activity of phenylalanine ammonia lyase enzyme in cucumber seedlings [14].

Another study conducted to investigate the effect of salicylic acid (0, 0.25, 0.50, 1mM) on growth , chlorophyll ,and mineral elements content in cucumber plants under salinity stress conditions (0, 60, 120ds/m NaCl) showed that SA increased shoots and roots wet and dry weight and reduced leaf electrolyte leakage and increased leaves nutrients concentration in cucumber plants [15].

They found that SA treatment increased protein content in chickpea plants[16], and leaf area in broccoli [17], leaf relative water content, total soluble solids (TSS), vitamin C. and lycopene in tomato [18], and potato tubers yield [19].

Cycocel CCC (Chloromequat chloride): is a plant growth regulator (a gibberellin inhibitor) widely used in agricultural experiments especially on ornamental plants (to improve the quality and yield of flowering plants). Cycocel-treated plants are characterized by short, internod and stems , greener leaves. Scarisbrik *et al.*, [20] indicated that cycocel affects plant growth and development, and this effect varies according to the plant variety and species.

Parmar *et al.*, [21] found in a study conducted on tomato variety (GT-2) to know the effect of cycocel (0, 250, 500 mgl^{-1}) on fruits growth and quality under salt stress conditions, S1 (control 0.2 ds/Ece), S2 (2 ds/Ece), S3 (4 ds/Ece), S4 (6 ds/Ece), S5 (8 ds/Ece), a significant difference in growth characteristics by cycocel treatments, and they found as well that plants treated with 250 ppm recorded best plant height, , dry weight, fruits number and weight / plant, yield, vitamin C and soluble total solids, and less days to flower induction in saline soil, and increased salt tolerance of tomato plants.

Astudy conducted to investigate the effect of Cycocel application on growth, production and some physiological characteristics of wheat (Triticum aestivum.L) under salinity stress conditions,showed a decrease in Na+ content and of Na+/K+ ratio and high potassium accumulation in the treated plants, which improved their salt tolerance [(22)].

Wang and Xiao, [(23)] found that cycocel treatment may increase chloroplast number, chlorophyll and carotenoids concentration, photophosphorylation rate and photosynthesis, which positively affects fruit quality.

Silicon (Si) is an eco-friendly mineral that has been used in recent years to reduce the harmful effects of salinity on plants [(24)]., Agricultural activity has removed large amounts of this element from the soil [(25)].

Silicon is not classed as an essential nutrient, but it is involved in a number of metabolic pathways that increase plants tolerance to environmental stress, such as drought and salinity stress [(26)]. It is currently considered one of the important factors that contribute to increasing plants' tolerance to biotic and abiotic stresses [(27)], it regulates the rate of transpiration and consequently water loss and water plant content, which increases their tolerance to drought stress, and reduces the flow of sodium ions from the soil solution to plants, as well. It increases K^+ / Na^+ ratio in the plant and thus reduces the intracellular osmotic potential, which increases plant tolerance to salinity.

It was found that the application of Si can improve the soluble solids and dry matter content of cucumber fruits [(28)]

It was confirmed in a study conducted to improve the salinity tolerance of two tomato cultivars by spraying with potassium silicate K2SiO3 (Si 38%), included 40 treatments 4 concentrations of irrigation water salinity (2.5, 5, 7.5, 10 ds/m), two tomato hybrid cultivars and five silicon concentrations (0, 50, 100, 150, 200 mg/l), that irrigation with salinity water(7.5 and 10 ds/m) decreased significantly growth indicators, and silicon treatment led to a significant increase yield under these conditions[(29)]

Therefore, this research aimed to study the ability of cucumber plants to tolerate irrigation water salinity and to improve growth and fruits quality by salicylic acid, cycocel and silicon treatment.

3. Materials and Methods:

3.-1 Plant material and growth conditions.:

cucumber hybrid, variety prins was used, the seedlings were produced at Al-Hanadi Research Station, by planting seeds in cork trays containing 120 holes (67.4 cm^3 size), filled with torf material as a supporting medium for seed germination ,on 5/2/2019, then transferred to a greenhouse and planted when two true leaves were appeared, in plastic bags on 7/3/2019 filled with8 kg/bag of prepared soil after addition of minerals and organic fertilizers for every 1 m^3 of soil as follows: ammonium nitrate 33%, superphosphate 46%, potassium sulfate 50% according to the recommendations used for cucumber plants .

The soil was characterized as a sandy, non-saline loam soil poor in nutrients.

planting soil were analyzed as presented in table (1)

When seedlings have 4 true leaves, they were sprayed with adequate concentration of ccc, salicylic and silicon solutions. The treatment was repeated 3 times, at 15 days interval.

The plants were irrigated with saline water (sea water diluted to 6 ds/m), and to avoid the osmotic shock of salinity stress, the salinity treatments were imposed incrementally by daily increasing the concentration until a final salinity concentration was achieved.

Soil solution EC was measured periodically, and when exceeded the adequate EC, normal water was added to adjust the EC required.

Table (1) Physical and chemical properties of planting soil.

Mg^{-1}					Organic matter (%)	EC ds/m	PH	MECHANICAL ANALYSIS		
available magnesium	available calcium	available potassium	Available phosphorous	mineral nitrogen				Clay	slate	sand
348	1720	44	5	7	2.93	0.21	7.75	16	5	79

3.4 Treatments:

C: control (irrigated with fresh water).

S :salt control irrigated with Salt water EC = 6 ds/m.

SA25: plants sprayed with SA (25 ppm).

SA50: Plants sprayed with SA (50 ppm).

C400: plants sprayed with CCC (400 ppm.)

C600: plants sprayed with CCC 600 ppm.

Si100: plants sprayed with Si 100 ppm.

Si200: plants sprayed with Si 200 ppm.

S + SA25: salt water (EC=6 ds/m) + 25 ppm SA.

S + SA50: salt water (EC=6 ds/m) + 50 ppm SA.

S + C400: salt water (EC=6 ds/m) + CCC at 400 ppm.

S + C600: salt water (EC=6 ds/m) + CCC at 600 ppm.

S + Si100: salt water (EC=6 ds/m) + Si of 100 ppm.

S + Si200: salt water (EC=6 ds/m) + Si at 200 ppm.

3.5 Experimental Design and Statistical Analysis:

A complete random design was adopted, and the experiment included 14 treatments, with three replications , and ten plants for each experimental unit, the total number of plants were 420 plants.

The results were statistically analyzed using the statistical analysis program Genstat-12. The least significant difference (LSD) was calculated at the 0.05 level of significance in comparison between the means.

When fruits achieved maturity, fruit quality measurements were analyzed :

1. Dry matter (%) by using the oven (105° C) until weight is stable[30].
2. TTS (%) by refractmeter.
3. Total sugars (%), [31].
4. Titrable acidity (%) , [32].
5. Ascorbic acid (vitamin C) estimated in mg/100g of fresh weight by titration method with 2-6-dichlorophenol indophenol according to [31].

4. Results:

4.1 Effect of treatment with cycocel, salicylic acid and silicon on the fruits quality:

4.1.1 Dry matter:

The results showed that irrigation with saline water affected fruit quality. Dry matter decreased significantly in stressed cucumber fruits, by 21% compared to the control. Treatment with (SA, CCC, Si) recovered partially salinity effect, silicon treatment Si(100,200) was more effective and increased salt tolerance in cucumber plants, (4.92, 4.90%) respectively, compared the control (S) (4.02%).

The results showed as well, that treatment with SA and Si enhanced fruit dry matter under normal water irrigation by 8.45% , and 14.93% respectively, (fig 1).

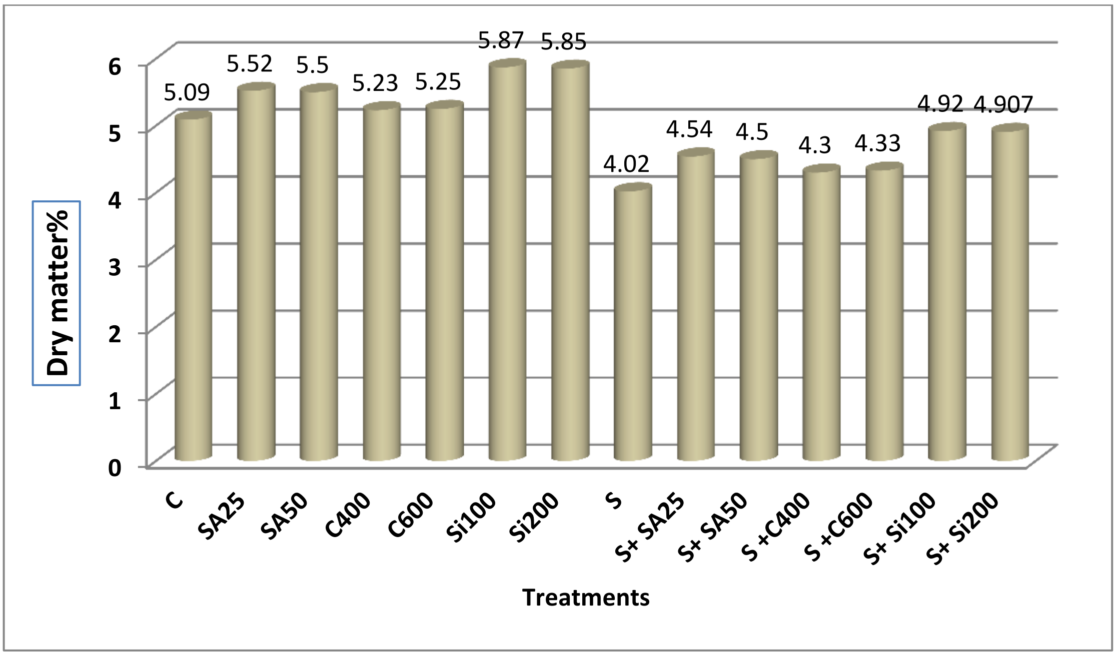

Fig (1)Dry matter in cucumber fruits under normal and salt conditions. ($LSD_{5\%}$: 0.142)

4.1.2. Total soluble solids:

The results indicated that salinity water decreased fruit TSS by 32% compared to the control.

Under normal irrigating water, SA, CCC, Si increased significantly TSS% in cucumber fruit 4.09, 3.92, 4.35% respectively, compared to control C (3.09%). Si treatment was more effective in enhancing TSS% compared to the other treatments.

Under salinity conditions, SA, CCC, Si treatments ameliorated significantly plant tolerance to salinity, especially Si treatment which recovered salinity effect and increased TSS%(3%) nearly to the control irrigated by normal water (3.09%), (fig 2).

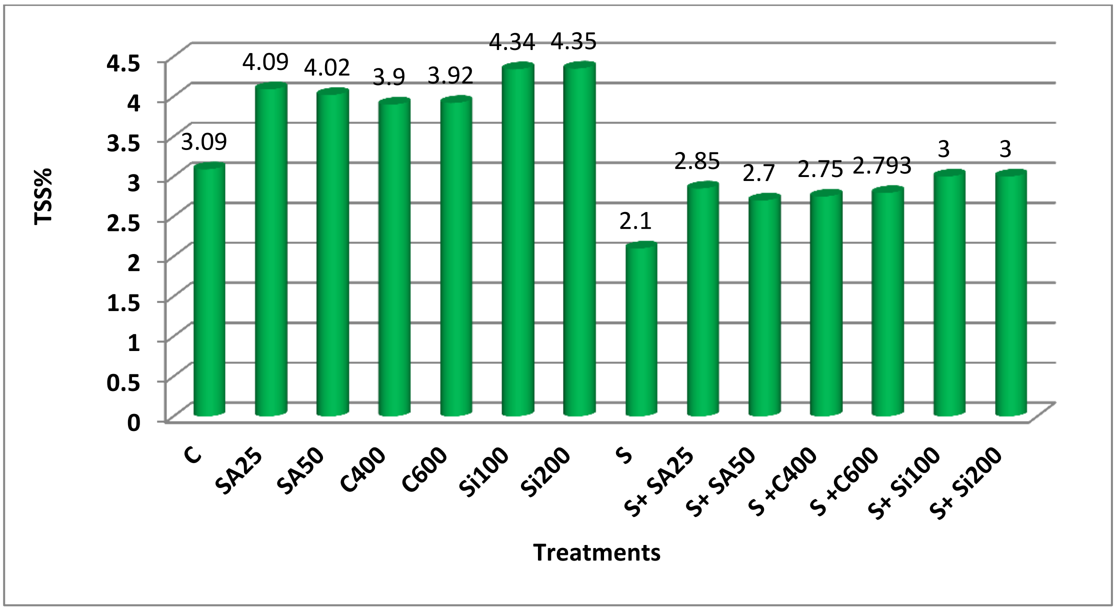

Fig 2 TSS% content in cucumber fruits under normal and salt conditions. ($LSD_{5\%}$: 0.467)

4.1.3. Titrable acidity (%):

The results showed a significant decrease in fruit acidity as a result of salt treatment, (0.1, 0.08%) respectively. SA, CCC, Si treatments significantly increased TA% compared to the control without any significant difference between treatments, in normal and saline water conditions.

Under normal water conditions, Si treatment was more effective in ameliorating TA% compared to the control (40%) and other treatments. Whereas, under saline conditions, Si treatment surpassed salt effect (0.099%) compared normal control (0.1%), and was more effective in enhancing salt tolerance in increasing TA% cucumber fruits than other treatments, (fig 3).

في ظل ظروف المياه العادية ، كانت معاملة Si
أكثر فاعلية في تحسين TA٪ مقارنةً بالشاهد
(40٪) حيث تم حساب الفعالية
$\frac{TA\ Si200-TA\ C}{TA\ C} * 100$:

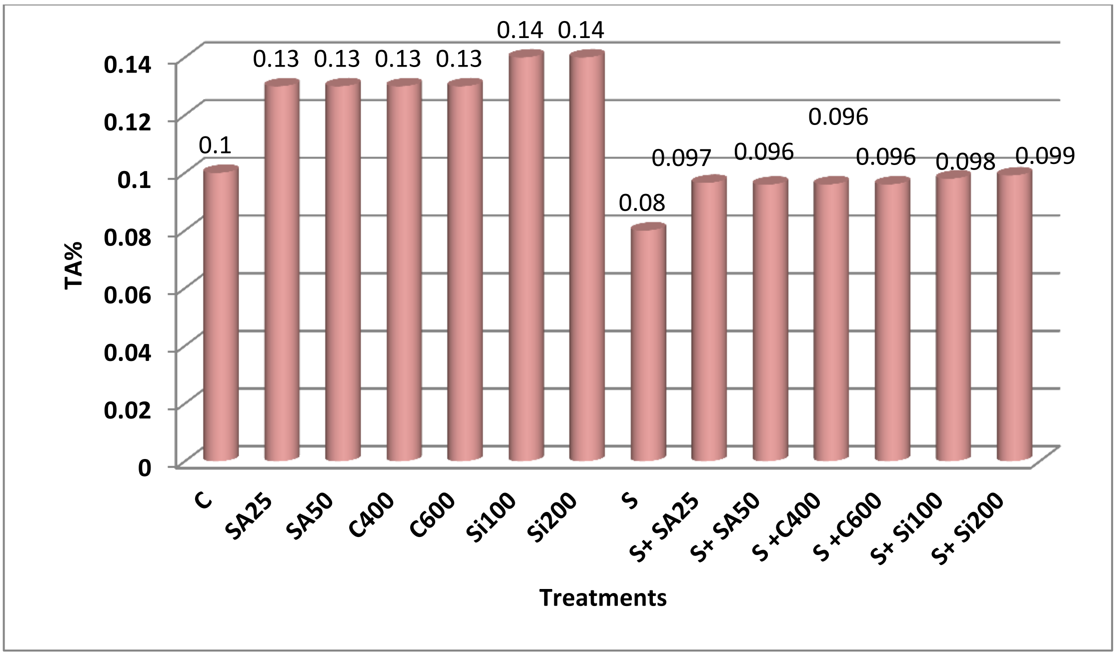

Fig (3) TA% content in cucumber fruits under normal and salt conditions. ($LSD_{5\%}$: 0.0165)

4.1.4. Vitamin C:

Salt water irrigation decreased significantly Vit.C content in cucumber fruits (10.31%) compared to the normal control (12.9%) by 20%.

Under normal water conditions, Si, SA,CCC, improved fruit Vit.C content (14.4, 13.9, 13.3%) respectively compared to the control (12.9%).

Under salt water conditions, Si, SA,CCC, increased Vit.C content in cucumber fruits (12.5, 12.2, 11.8% respectively) compared to the control (10.31%). Si treatment was more effective in increasing Vit.C content nearly to VC content in normal water control, (fig 4).

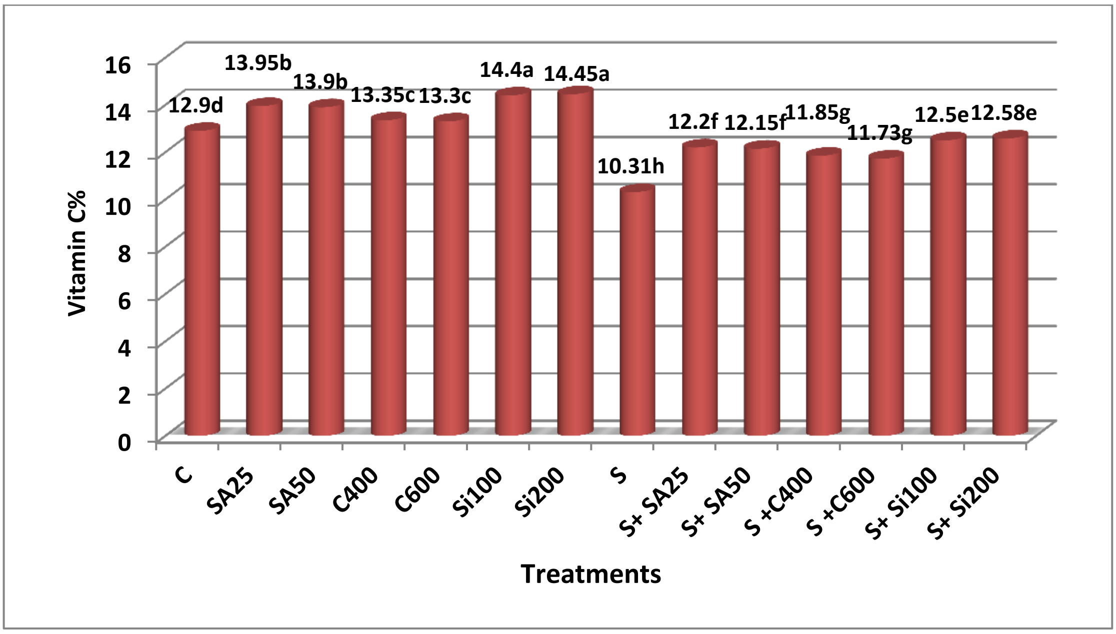

Fig (4) VC content in cucumber fruits under normal and salt conditions. ($LSD_{5\%}$: 0.116)

4.1.5. Total sugars(%):

Total sugars were reduced significantly when saline water was used in plant irrigation by 21.6% compared to the normal water.

When normal water was used in plant irrigation, SA, CCC, Si treatments increased Total sugars (1.47, 1.45, 1.58% respectively), compared to the control (1.43%). The enhancement in total sugars with Si treatment was superior compared to the other treatments.

Treatment with SA, CCC, Si under saline conditions, enhanced as well total sugars (1.27, 1.23, 1.29%respectively), compared to the control (1.12%). Compared to the irrigation with normal water, treatment with Si, ameliorated total sugars content(1.29%) more than other treatments (SA, CCC) (1.27, 1.23% respectively), (fig 5).

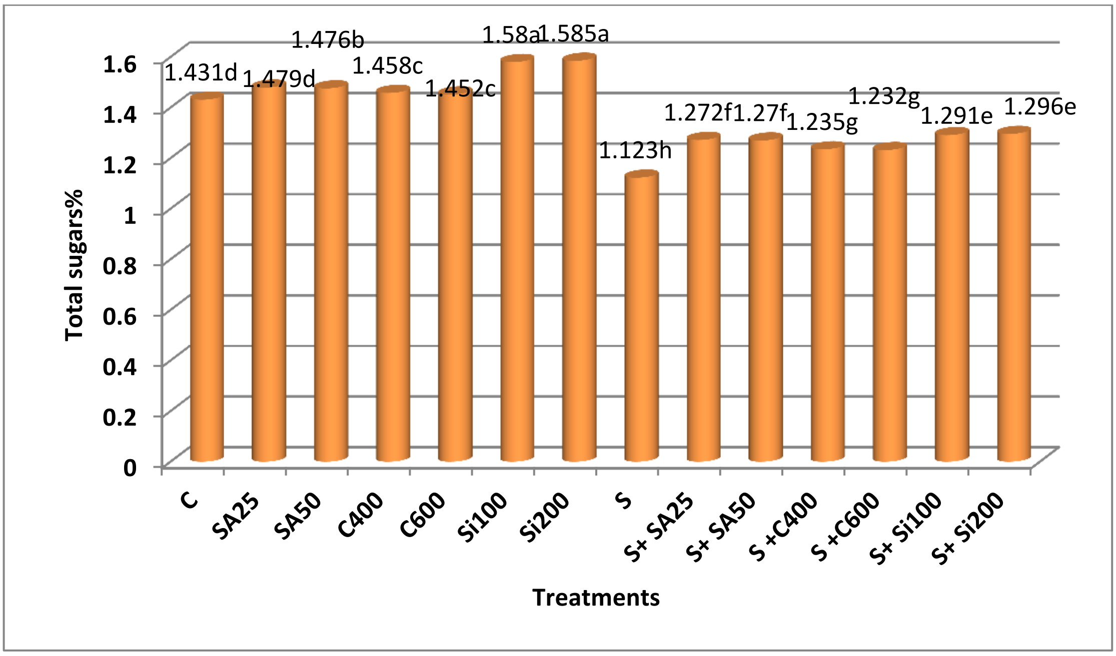

Fig (5)Total sugars content in cucumber fruits under normal and salt conditions. ($LSD_{5\%}$: 0.008)

5. Discussion:

Irrigation with saline water decreased the percentage of dry matter, soluble solids, total sugars, total acids and vitamin C in cucumber fruits compared to fruits of plants irrigated with normal water. This is attributed to the fact that salinity stress causes many physiological and metabolic changes such as decreasing photosynthesis due to ion toxicity and nutritional imbalance[(33)]. In addition to the accumulation of sodium and chloride ions, which discourages the absorption of essential nutrients [(34)]. Salinity accelerates as well the production of harmful reactive oxygen species (ROS), which cause oxidative damage to proteins, lipids, and nucleic acids and affecting normal cellular metabolism [(35)].

Si treatment improved chemical indicators, Yildirim etal[(15)] showed that external application of silicon on capsicum plants enhanced stomata conductivity, leaf area, and water potential in stressed plants. This improvement was associated with an increase in gaseous exchange in the leaves, which led to an increase in the photosynthetic activity under saline conditions. The positive effect of silicon treatment can be explained by the formation of a leaf outer layer that acts as a barrier (silica gel), and as well as on the roots and stem vascular tissues that reduce evaporation [(36)].

Silicon contributes to water use efficiency in plants by improving leaf water retention, and photosynthesis under abiotic stress conditions [(37)].

cucumbers fruits total sugars in stressed and unstressed plants, has increased as a result of silicon treatment, and as sugars form part of the dry matter, this leads to an increase in the dry matter.

polysaccharides act as a protective osmosis in cucumber leaves and roots of exposed to salinity stress plants [(38)].

The positive effect of salicylic acid in improving dry matter ratio of salt-stressed plants may be due to an increased response to antioxidants and its role in protecting cell membranes that improve plant tolerance to damage [39]. SA can as well increase carbon dioxide (CO2) assimilation, photosynthetic rate, and as consequence, the increase of dry matter, [40].

The improvement of vitamin C and TSS ratio as a result of SA treatment can be attributed to the increase in the activity of catalase, superoxide dismutase, peroxidase enzymes, which leads to the breakdown of ROS radicals, and auxin oxidation [41], which improves plant growth.

These results are in consistent with the results of [42], which showed an increase in Vit.C amount and lycopene in tomato fruits when treated with SA (10^{-2}M), it may be attributed to the effect of salicylic acid in activating some enzymes such as Ascorbate peroxidase. They also indicated that the external application of SA increased the amount of total dissolved solids (TDS) in tomato (Brix index). This may be due to the improvement of the permeability of the cell membrane and the utilization of mineral elements.

The positive effect of cycocel, may be due to the improvement of cell growth by decreasing osmotic potential [43], and increases the relative water content (RWC) and stomata resistance under stress conditions [44].

Cycosel as well may delay leaf aging, chlorophyll breakdown and improve the soluble proteins synthesis and enzymes, thus leading to more assimilation surface area [43].

Cycocel could partially compensate growth and yield inhibition, biochemical characteristics resulting from drought or salinity stress. These effects may be due to various reasons such as stomata close, increasing chlorophyll content and intercellular CO2 concentration, and activate physiological and biochemical changes, [45]

Conclusion:

The results showed that salinity stress reduced cucumber plant growth and fruit quality. SA, CCC, Si treatment, enhanced dry matter, total sugars, TSS, total acids, and Vit.C, in cucumber fruits. SA, CCC, Si treatment alleviated harmful effects of salinity, Si(100,200ppm), gave the better effects compared to the control and other treatments.

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