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Improving Salinity Tolerance of Cucumber Plants Grown under Shadehouse Conditions by Grafting onto Some Genotypes and F1 Hybrids of Cucurbit Rootstocks

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ABSTRACT

Grafted seedlings has become important agricultural practice in many parts of the world for the production and protection of cucurbitaceous crops from biotic and abiotic stress. Salinity is one of the major abiotic stresses which cause reduction in the growth and productivity of cucumber in Egypt. This study aims to investigate the performance of commercial greenhouse cucumber hybrid (Hesham) grafted onto some genotypes and F1 hybrids rootstocks under salinity stress conditions (Salinity of the experimental soil and irrigation water were about 70.9 and 2.77 dS/m, respectively), at El-Anwar Farm, Cairo-Alexandria Desert Road, during summer seasons of 2020 and 2021under shade house conditions. This experiment was done in a randomized complete block design with 3 replicates. The experiment contained fourteen treatments, consisted of six genotypes rootstocks in additions to 7 F1 hybrid rootstocks compared to un-grafted control. The results indicated that grafting cucumber onto all rootstocks gave a significant improve of plant height, leaves area, fruit weight, fruit length, fruit diameter, yield and photosynthesis in both seasons, compared to non-grafted one, whereas grafted cucumber onto Kalabsha, Lagenaria siceraria PI 554556, C. maxima, C. moschata, Kalabsha x PI 534556 and Lagenaria siceraria PI 554556 x Lagenaria siceraria PI 491365 rootstocks had larger internode length than non-grafted plants in the first season. The highest values of carbohydrates content in fruits were noticed when cucumber grafted onto C. maxima x C. moschata rootstock in both seasons, whereas the highest proline content were estimated in cucumber leaves that grafted onto kalabsha rootstock in both seasons.

KEYWORDS: *Cucumis sativus*, salinity stress, rootstock, vegetative growth, fruit Characters, yield, nutrients.

1. INTRODUCTION

Salinity is one of the major abiotic stresses which cause reduction in the growth and productivity of the crop. Salinity leads to negative effects on plant growth, increasing sodium and chloride ions uptake that cause cytotoxicity and nutritional imbalance (Isayenkov and Maathuis, 2019). About 25% to 30% of cultivated lands are salt-affected. The salt-affected soil countries located in arid and semi-arid regions (Zaman et al., 2018). Salt-affected land around the world is about 1125 million hectares, includes about 76 million hectares induced salinization by human. About 50% of suitable lands for cultivation will loss if salinization of lands continues in increasing by 2050.Egypt is one of the significant salt-affected soil countries (Hossain, 2019).

Cucumber (*Cucumis sativus* L.) is one of the most popular cucurbit crops in Egypt. Egypt is one of the pioneer's cucumber producing countries. According FAO statistics, Egypt ranked as the tenth largest producing country around the world (http://faostat.fao.org). According to department of agricultural Statistics in Egyptian Ministry of Agriculture and Land Reclamation, Egypt 's production of cucumber in 2020 was 443035 tons, area cultivated was 46728 feddans, and average production was 9.4 tons / feddan. Significant reduction in cucumber seeds germination, plant growth parameters such as plant height, leaf area and yield under salinity conditions (Chartzoulakis, 1992 and Khan et al., 2013).

Grafting is a suitable method to overcome some abiotic stresses effects in vegetable crops such as salinity and drought (Colla et al, 2010 and Thakur and Savita, 2020). First Research on grafting cucumber began in the late 1920s, while the commercial use did not start until 1960 (Kubota et al, 2008).Research on grafting cucumber also started in the late 1920s, but wider commercial applications did not happen until 1960 (Sakata et al., 2008). Grafting is a promising practice to increase salinity tolerance in some vegetable crops plants such as in tomato (Di Gioia et al, 2013 andSingh et al 2020), in melon (El-Kafafi et al, 2017 and Ulas et al, 2019) and in watermelon (Sharf-Eldin et al,2018 and Yanyan et al, 2018).

In cucumber, El-Shraiy and Mostafa (2016) reported that using grafting onto salt tolerant rootstock (Shintosa supreme pumpkin) significantly enhanced cucumber growth, yield, relative water content and antioxidant enzymes activity under salinity conditions, in addition to increasing chlorophyll, carotenoid, proline and total soluble protein content and reducing membrane permeability and malondialdehyde (MDA) content in leaves. Elsheery et al. (2020) tested four rootstocks (bottle gourd, pumpkin, winter squash, and Nubian watermelon) to study biochemical, and physiological mechanisms of salinity stress tolerance using grafting and compared them with self-grafted cucumber cv. 1010 under three levels of salinity (0, 50, 100 mM) of NaCl solution at an early stage. Grafted plants had better growth and yield parameters than non-grafted plants, in addition to improve photosynthetic activity and membrane stability. Grafting increased plant hormones such as auxin, gibberellin, cytokinin, and salicylic acid compared with non-grafted plants, while abscisic acid was decreased under salinity stress. Soubeih et al. (2018) evaluated two rootstocks, namely, Star and Super Shantoza which belongs to *Cucurbita moschata* Duch and compared them with non-grafted cucumber cv. F11101 to improve cucumber productivity under salt stress. Star rootstock showed the highest growth, yield parameters, except shoot/root ratio, Na+ content and K+/Na+ ratio. Farajimanesh and Haghighi (2020) tested four rootstocks, namely, Tanbal (*Cucurbita maxima*),Ghalyani (*Lagenaria siceraria*), Karela (*Momordica charantia*), Khoreshi (*Cucurbita pepo*) and compared them with non-grafted commercial cucumber cv. DAVIS II which used as scion under three concentrations of salinity (0, 30 and 60 mM). Karela and Khoreshi rootstocks improved the physiological parameters under salinity conditions. Khoreshi and Tanbal rootstocks decreased the transpiration, on the other hand nongrafted plants had the highest transpiration. Thus, grafting technology has recently emerged as a potential and alternative approach to the comparatively sluggish conventional breeding procedures for increasing tolerance to abiotic stressors, soil pathogens, and improving

production and quality features in fruit vegetables. Grafting has been used commercially on watermelons, muskmelon, cucumbers, tomatoes, sweet peppers, and eggplants to increase plant tolerance to a variety of abiotic conditions, such as soil salinity, drought, waterlogging, high or low temperatures, and heavy metal toxicity, as well as to increase vegetable crop output and quality characteristics (Bahadur et al., 2024) . Generally, all rootstocks improved fruit quality traits. Bayoumi et al. (2021) used five rootstocks (Ferro, Cobalt, VSS-61 F1, Bottle gourd, and Super Shintoza) and cucumber hybrid Gianco F1 was used as a scion under combined heat and salinity and compared them with non-grafted plants to assess the growth, productivity, physiological, and mineral composition under stress conditions. Grafted plants were better than non-grafted plants in the most studied characters. Plants grafted onto VSS-61 F1 and Ferro had the highest early and total marketable yields, also they had the higher scion vigor, lower flower abortion rates and higher chlorophyll contents. On the other hand, the fruit quality and N, P, and K content in the leaves were a few relevant changes compared with the non-grafted plants. Furthermore, El-Aidy et al. (1996) showed that grafting led to increase in N, P and K of cucumber leaves. This study was aimed to investigate the improvements in salinity tolerance of cucumber in respect to the growth, yield and fruit quality traits when grafted on different rootstocks.

2. MATERIALS AND METHODS

2.1.Location and growth conditions:

Thirteen cucurbits genotypes, compared to control, were evaluated in this study as rootstocks in summer seasons of 2020 and 2021 under shade net house conditions, at El-Anwar Farm, Kilo 75 Cairo-Alexandria Desert Road. Wadi El Natrun, El-Beheira Governorate, Egypt (Latitude: 30° 24' 59.99" N, Longitude: 30° 19' 60.00" E). Some of these genotypes were chosen based on previous results according to their salinity tolerance (Taffouo et al., 2008; Farajimanesh and Haghighi, 2020). The commercial cucumber cultivar "Hesham" were used as the scion. The effect of grafting cucumber onto the previous rootstocks on plant growth, some physical and chemical fruit quality traits and productivity under salinity conditions (Salinity of the experimental soil and irrigation water were about 70.9 and 2.77 dS/m, respectively) were studied and compared with non-grafted cucumber (*Cucumis sativus*).Water and soil analyses were carried out before starting the experiment according to Black et al., (1965) and Jackson (1973) and the data are shown in Tables (1 and 2).

Table 1. Chemical composition of irrigation water

Ionic concentration (Meq/l)										
CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{-2}	Ca^{+2}	Mg^{+2}	Na^+	K^+	EC* (dS/m)	pH	SAR*
0.00	4.30	15.73	6.62	7.42	6.39	12.61	1.34	2.77	7.45	5.40

EC means the average electrical conductivity, SAR means sodium adsorption ratio.

Table 2. Some initial chemical and physical properties of the experimental soil.

Chemical properties	pH	ECe (dS/m)	CaCO3 (%)	Organic matter (%)	N (%)	P (mg/kg soil)	K (mg/kg soil)	Fe (mg/kg soil)	Mn (mg/kg soil)	Zn (mg/kg soil)	Cu (mg/kg soil)
Value	7.80	70.90	4.73	1.20	0.006	528.3	70.80	3.50	9.94	0.78	0.60
Physical properties		**Sand %**			**Silt %**			**Clay %**			**Texture class**
Value		79.29			10.21			10.50			Loamy sand

2.2.Plant materials:

Seeds of four genotypes of *Lagenaria siceraria* (*L. s.* PI 534556, *L. s.* PI 491365, *L. s.* PI 554556 and Local Kalabasha gourd), in addition to local cultivar of *Cucurbita moschata* and local cultivar of *Cucurbita maxima* were self-propagated in the period from 15th march 2019 to the end of August 2019in the greenhouse at Vegetable Crop Department, Faculty of Agriculture, Cairo University, Giza, Egypt. Thereafter, in first week of September 2019 until end of February 2020. we produced 7 F_1 hybrid, namely, Gourd 1: *Lagenaria siceraria* (PI 534556) X *Lagenaria siceraria* (PI 491365), Gourd 2: *Lagenaria siceraria* (Kalabsha) X *Lagenaria siceraria* (PI 491365), Gourd 3: *Lagenaria siceraria* (PI 534556) X *Lagenaria siceraria* (PI 554556), Gourd 4: *Lagenaria siceraria* (Kalabsha) X *Lagenaria siceraria* (PI 534556), Gourd 5: *Lagenaria siceraria* (PI 554556) X *Lagenaria siceraria* (PI 491365), Gourd 6: *Lagenaria siceraria* (PI 554556) X *Lagenaria siceraria* (PI 534556), in addition to the interspecific hybrid Winter squash 1 : *Cucurbita maxima* × *Cucurbita moschata*. Seeds of local genotypes were obtained from the local source, while all other genotypes seeds were kindly provided by Stacey Estrada, Gene Bank, ARS, Geneva, NY., USA.

Grafting process was carried out under greenhouse conditions, Bader Centre, Behira Governorate. The compatibility between 13 rootstocks (6 genotypes and 7 F_1 hybrids rootstocks) and the commercial greenhouse cucumber cv. Hesham was tested in first half of March. Thereafter, the seeds of these 13 rootstocks were sown on 20th march 2020 in foam seedling-trays (84 cells). Seeds of the commercial varity were sown 7 days after the sowing of rootstock seeds.

Hand grafting process was carried out during first week of April, slant cut grafting method was applied at one true-leaf stage. Then the grafted plants were kept under 90-95% RH and 45% shading conditions at temperature between 30 to 32 °C for healing in a professional greenhouse for adaptation. Survival grafted cucumber plants and non-grafted cucumber were sowing on 10th and 15th May of 2020 and 2021 seasons, respectively, in the shade net house (at El-Anwar Farm, Kilo 75 Cairo-Alexandria Desert Road. Wadi El Natrun, El-Beheira Governorate, Egypt) in rows at a distance of 50 cm between plants within the rows. A completely randomized block design with 3 replicates was used. The area of experimental plot was 5 m^2 (5 x 1m^2). Each plot contained 20 plants. Plants were subjected to the common agricultural practices.

2.3.Determination of plant growth characters:

After 60 days of transplanting five plants of each treatment were randomly labeled to determine plant growth parameters such as plant height, number of leaves /plant, inter-node length, chlorophyll content using a SPAD meter (SPAD 502 Minolta Co, Osaka, Japan), and leaf area (the 6th leaf from meristem tip) was measured by portable leaf area meter (Biovis Leaf Av., Expert Vision Labs Pvt. Ltd., India), Photosynthesis rate, stomatal conductance, transpiration rate were measured between 10:30 am and 11:00 am using Li-1600 Steady State Porometer, LI-COR,USA.

2.4.Determination of fruit yield and fruit quality traits:

Total yield (kg/m^2) was estimated as total weight of fruits all over the harvesting season. Fruit quality traits for 10 fruits were recorded at the fifth harvest to determine the fruit characters such as weight, length, diameter, TSS% using Zeiss laboratory refractometer).

2.5.Determination of biochemical components concentrations:

Totalcarbohydrates of cucumber leaves, 60 days after transplanting, weredeterminedin ethanol extract according to Cheshire and Mundie (1966), Proline in cucumber leaves, 60 days after transplanting, was determined in dry plant material according to Bates et al., (1973). Macro (N, P, K, Ca and Mg) and micro (Na, Fe and Zn) nutrients of cucumber leaves were measured, 60 days after transplanting. Nitrogen was measured by the modified “Micro Kjeldahl” apparatus of Parnas and Wagner as described by Pregl (1945). Phosphorus was determined

spectrophotometrically by using stannous chloride method according to AOAC (1975). Potassium was determined by flame photometer according to the method described by Brown and Lilliland (1964). Calcium (Ca), magnesium (Mg), sodium (Na), iron (Fe) and zinc (Zn) contents were measured by Atomic Absorption Spectrophotometer (PyeUnicam, model SP-1900, Cambridge, UK) with air-acetylene fuel according to Helrich (1990).

2.6.Statistical Analysis:

The statistical analysis of the experimental data was carried out using ANOVA procedures with CoStat software. The treatment means were compared by least significant difference (L.S.D.) test as given by Snedecor and Cochran (1976) by used MSTAT-C v. 2.1 (Michigan State University, Michigan, USA).

3. RESULTS

3.1.Plant growth of cucumber plants:

The study examined the response of cucumber plants to grafting into different rootstocks, under salinity stress conditions in both seasons. As shown in Table 3 vegetative growth characteristics were statistically influenced by all rootstocks in comparison to the control plants in both seasons.

Table 3. Effect of grafting onto some genotypes and F1 hybrids of cucurbit rootstocks on cucumber growth parameters (plant height, number of leaves, internode length and leaf area) at 60 DAT, during 2020 and 2021 seasons

Rootstocks	Plant height (g)		No. of leaves		Internode length (cm)		Leaves area (cm^2)	
	2020	2021	2020	2021	2020	2021	2020	2021
Control	172.70	179.70	38.00	40.00	7.83	8.67	26.85	28.16
C. maxima X C. moschata	212.30	217.70	41.67	48.33	7.73	8.17	33.65	35.35
L. s. PI 534556 X L. s. PI 491365	198.70	202.70	40.00	48.00	7.83	8.07	39.84	41.23
Kalabsha X L. s. PI 491365	202.00	206.00	40.00	45.67	7.17	7.83	38.06	39.30
L. s. PI 534556 X L. s. PI 554556	197.00	206.70	38.67	40.33	7.93	8.33	34.36	36.76
Kalabsha X L. s. PI 534556	183.00	195.70	40.33	47.00	8.60	9.03	38.73	39.31
L. s. PI 554556 X L. s. PI 491365	193.00	210.70	42.67	45.67	8.67	9.00	40.87	45.45
L. s. PI 554556 X L. s. PI 534556	196.00	207.30	43.33	43.33	7.83	8.17	43.49	45.08
L. s. PI 534556	202.00	206.70	48.67	49.00	8.23	8.83	38.07	39.75
L. s. PI 491365	192.00	196.70	41.33	42.33	8.17	8.67	37.04	39.27
Kalabsha	202.00	209.30	49.00	50.33	8.77	8.87	40.64	44.87
L. s. PI 554556	192.30	196.70	39.00	40.33	8.77	9.00	37.58	39.31
C. maxima	208.00	214.70	44.67	50.67	8.90	9.03	41.53	45.53
C. moschata	201.70	209.00	47.00	48.67	7.70	8.90	42.37	46.12
LSD 0.05	4.08	4.26	1.60	2.11	0.44	0.43	2.29	2.41

In this regard, grafted plants onto all rootstocks significantly improved plant height and leaves area of cucumber in both seasons, as compared with non-grafted cucumber. The highest plant height were recorded when cucumber grafted onto the rootstock resulted from hybridization between *Cucurbita maxima* x *Cucurbita moschata*, whereas the highest leaves area were observed with the rootstock of *Lagenaria siceraria* PI554556 x *Lagenaria siceraria* PI534556 in the first season and with *C. moschata* rootstock in the second season. On the other hand, except grafting onto the hybrid rootstock of *Lagenaria siceraria* PI 534556 x *Lagenaria siceraria* PI 554556 and *Lagenaria siceraria* PI 554556 rootstock, all rootstocks exhibited a significant increase in cucumber number of leaves in both seasons, as compared with non-grafted plants. Grafting cucumber onto Kalabsha, *Lagenaria siceraria* PI 554556, *C. maxima*, *C. moschata*, Kalabsha x PI 534556 and *Lagenaria siceraria* PI 554556 x *Lagenaria siceraria* PI 491365 rootstocks had larger internode length than non-grafted plants in the first season, while those rootstocks as well as grafting onto PI 534556 and PI 491365 rootstocks in the second season did not show any significant differences with compared to control as result to increase the internode length of control plants. In contrast, grafting cucumber onto Kalabsha x PI 491365 rootstock in the first season as well as grafting onto *C. maxima* x *C. moschata*, PI 534556 x PI 491365, Kalabsha x PI 491365 and PI 554556 x PI 534556 rootstocks in the second season significantly decreased internode length as compared to control plants.

3.2.Chlorophyll, photosynthesis, stomatal conductance, transpiration of cucumber plants:

The relative chlorophyll content SPAD and photosynthetic measurements such as photosynthesis rate, stomatal conductance and transpiration rate were estimated for all grafted and non-grafted plants in both seasons (Table 4). Cucumber plants grafted onto *C. maxima*, *C. moschata*, *C. maxima* x *C. moschata*, PI 534556 x PI 491365 and Kalabsha rootstocks in both seasons as well as PI 534556 rootstock only in the second season had a significant increment of chlorophyll SPAD readings when compared with the control plants. Moreover, all rootstocks significantly improved photosynthesis rate in the two seasons as compared with control plants. The highest values of photosynthesis rate were recorded when cucumber grafted onto *C. maxima* rootstock in the first season as well as PI 534556 x PI 491365 rootstock in the second season.On the other hand, except grafted cucumber onto Kalabsha x PI 534556 and PI 491365 rootstocks in the first season, all rootstocks significantly increased stomatal conductance of cucumber in both seasons, compared to non-grafted plants. The highest values of stomatal conductance were noticed in cucumber grafted onto *C. maxima* rootstock in the first season as well as PI 554556 x PI 534556 rootstock in the second season. Furthermore, using Kalabsha x PI 491365, PI 534556 x PI 554556 and PI 554556 x PI 534556 as rootstocks in both seasons as well as PI 554556 x PI 491365, PI 554556, *C. maxima* and *C. moschata* as a rootstocks only in the second season gave a significant increase in transpiration rate, compared to non-grafted cucumber. Generally the lowest transpiration rate was recorded when cucumber grafted onto Kalabsha rootstock in the first season as well as PI 534556 x PI 491365 rootstock in the second season.

3.3.Quality parameters of cucumber fruits:

Cucumber fruits quality traits were significantly impacted by grafting onto various rootstocks (Table 5). Fruit quality parameters, such as fruit weight, fruit length, fruit diameter and TSS percentage, displayed significant variation between the grafted cucumber and control plants in both seasons. Generally, all rootstocks caused a significant improvement of fruit weight, fruit length, fruit diameter, as compared to controlplant in both seasons. The maximum fruit weight (64.92 and 69.67 g), fruit length (15.07 and 15.63 cm) and fruit diameter (1.97 and 2.00 cm) were observed during grafting onto *C. maxima* rootstock in the two seasons, respectively. Contrariwise, the highest TSS percentage were observed in cucumber fruits that grafted onto *C. maxima* x *C. moschata* rootstock in both seasons as compared to non-grafted

Table 4. Effect of grafting onto some genotypes and F1 hybrids of cucurbit rootstocks on chlorophyll SPAD content, photosynthesis rate, stomatal conductance and transpiration rate of cucumber at 60 DAT, during 2020 and 2021 seasons.

Rootstocks	Chlorophyll SPAD content (%)		Photosynthesis rate (µmol CO2 m-2 S-1)		Stomatal conductance (mmol CO2 m-2 S-1)		Transpiration rate (mmol H2O m-2 S-1)	
	2020	2021	2020	2021	2020	2021	2020	2021
Control	44.87	47.20	353.70	374.00	6.830	7.500	1.748	1.711
C. maxima X C. moschata	50.23	51.03	431.30	469.00	9.197	10.240	1.822	1.769
L. s. PI 534556 X L. s. PI 491365	50.00	51.40	450.70	481.00	7.627	10.000	1.668	1.695
Kalabsha X L. s. PI 491365	45.27	48.17	448.70	469.00	7.493	8.527	2.044	1.993
L. s. PI 534556 X L. s. PI 554556	43.50	46.07	438.30	454.70	9.703	10.520	2.016	1.924
Kalabsha X L. s. PI 534556	45.17	48.30	443.30	476.70	6.890	8.693	1.757	1.871
L. s. PI 554556 X L. s. PI 491365	46.33	47.67	443.00	454.70	8.200	8.697	1.708	1.942
L. s. PI 554556 X L. s. PI 534556	44.50	47.03	438.00	458.30	9.500	10.670	2.113	1.990
L. s. PI 534556	47.23	52.67	440.30	468.00	8.097	9.670	1.872	1.903
L. s. PI 491365	43.77	49.83	436.70	452.30	7.243	8.597	1.853	1.922
Kalabsha	49.83	51.30	462.30	474.70	8.343	9.980	1.633	1.759
L. s. PI 554556	44.50	48.23	443.30	455.00	7.770	8.507	1.941	1.979
C. maxima	51.53	52.77	468.30	475.00	9.840	10.360	1.901	1.939
C. moschata	51.17	51.03	456.70	466.00	8.910	9.803	1.911	1.979
LSD 0.05	3.27	3.16	8.06	7.48	0.501	0.557	0.249	0.212

cucumber, whereas using PI 534556 x PI 491365, Kalabsha x PI 491365, PI 534556 x PI 554556, Kalabsha x PI 534556, PI 554556 x PI 491365, PI 534556 and PI 554556 in both seasons as well as *C. moschata* in the first season as a rootstocks caused a significant reduction of TSS percentage as compared to control plants.

3.4.Yield of cucumber plants:

The results in Table 5 clearly illustrate that cucumber plants grafted onto all rootstocks showed a significant increment of total yield per m^2 in the two seasons, compared to non-grafted cucumber. The maximum yield per m^2 were recorded with grafting cucumber onto Kalabsha rootstock in the first season (15.83 kg) and onto *C. maxima* rootstock in the second season (16.21 kg).

3.5.Mineral content in cucumber leaves:

The results in Table 6show that macronutrient concentrations, such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg), of grafted cucumber leaves significantly influenced according to the type of rootstock in both seasons, as compared to non-grafted cucumber. Except grafting onto Kalabsha x PI 534556 rootstock in the first season in the case of N% or grafting onto the same rootstock in both seasons in the case of K%, all rootstocks experienced a marked increase in N% and K% compared to the control plants. Generally, the highest N and K concentrations were observed in cucumber leaves that grafted onto PI 534556 x PI 491365 rootstocks in both seasons. On the other hand, all rootstocks, except *C. maxima* x *C.*

Table 5. Effect of grafting onto some genotypes and F1 hybrids of cucurbit rootstocks on cucumber yield and fruits quality (fruit weight, fruit length, fruit diameter and TSS %), at fifth harvest date, during 2020 and 2021 seasons.

Rootstocks	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		TSS (%)		Yield (kg/m2)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Control	45.69	47.35	10.47	11.20	1.23	1.30	3.97	3.87	5.53	5.87
C. maxima X C. moschata	57.20	59.21	13.10	13.73	1.67	1.77	4.07	4.03	12.18	13.35
L. s. PI 534556 X L. s. PI 491365	55.65	62.55	13.67	14.27	1.67	1.87	3.10	3.07	11.58	14.98
Kalabsha X L. s. PI 491365	50.80	60.07	13.00	14.60	1.63	1.80	3.27	3.33	11.26	13.11
L. s. PI 534556 X L. s. PI 554556	56.60	62.78	12.50	14.97	1.77	1.93	3.50	3.37	13.07	15.20
Kalabsha X L. s. PI 534556	51.55	67.76	11.73	15.10	1.60	1.83	3.37	3.43	11.90	15.74
L. s. PI 554556 X L. s. PI 491365	52.80	57.55	12.10	13.80	1.67	1.80	3.37	3.30	10.88	12.85
L. s. PI 554556 X L. s. PI 534556	53.61	60.80	11.87	13.40	1.60	1.80	4.00	3.97	12.27	14.25
L. s. PI 534556	54.83	60.24	12.40	14.23	1.63	1.83	3.60	3.50	11.90	14.85
L. s. PI 491365	52.28	56.33	11.73	13.90	1.63	1.77	3.93	3.90	11.38	12.38
Kalabsha	60.65	65.09	14.20	15.03	1.77	1.93	3.93	3.90	15.83	15.95
L. s. PI 554556	59.30	65.95	14.33	14.97	1.80	1.97	3.50	3.43	13.95	16.11
C. maxima	64.92	69.67	15.07	15.63	1.97	2.00	4.00	3.97	14.28	16.21
C. moschata	58.53	63.55	13.97	15.10	1.77	1.97	3.83	3.90	14.24	16.03
LSD 0.05	2.39	4.25	0.98	0.66	0.12	0.13	0.13	0.14	0.97	1.22

moschata, Kalabsha x PI 534556 and PI 554556 and PI 534556 rootstocks in both seasons as well as PI 534556 and PI 554556 or PI 534556 rootstocks in the first season, showed a significant improvement in P concentration of cucumber leaves compared to non-grafted plants. Additionally, all grafted cucumber, except that grafted onto Kalabsha x PI 534556 rootstock in the first season, had a significant increment of Ca% of leaves in both seasons as compare to non-grafted cucumber. On the contrary, only grafted cucumber onto PI 534556 x PI 491365 and Kalabsha x PI 491365 rootstocks in the first season as well as grafted cucumber onto all rootstocks, except PI 534556, Kalabsha and *C. moschata* rootstocks, in the second season exhibited a significant increase in Mg% of cucumber leaves as compared with control plants. Concerning the impact of rootstocks on the concentration of micronutrients in cucumber leaves (Table 7), there no significant differences were observed between grafted cucumber and non-grafted one of Na% in cucumber leaves in both seasons. Otherwise, grafting cucumber onto PI 534556 x PI 491365, PI 534556, Kalabsha, PI 554556 and *C. moschata* rootstocks in both seasons as well as grafting onto Kalabsha x PI 491365, PI 491365 and *C. maxima* rootstocks in the second season gave a significant increment of Fe concentration in cucumber leaves compared to non-grafted plants.

Table 6. Effect of grafting onto some genotypes and F1 hybrids of cucurbit rootstocks on macro-nutrients, N, P, K, Ca and Mg, percentages of cucumber leaves at 60 DAT during 2020 and 2021 seasons.

Rootstocks	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Control	3.31	3.34	0.25	0.25	3.15	3.15	2.14	2.15	0.57	0.54
C. maxima X C. moschata	3.63	3.72	0.28	0.29	3.26	3.31	2.44	2.51	0.60	0.62
L. s. PI 534556 X L. s. PI 491365	4.09	4.18	0.36	0.37	3.63	3.71	2.58	2.60	0.69	0.70
Kalabsha X L. s. PI 491365	3.77	3.84	0.34	0.34	3.59	3.61	2.52	2.58	0.66	0.68
L. s. PI 534556 X L. s. PI 554556	3.75	3.84	0.33	0.35	3.59	3.66	2.53	2.58	0.62	0.69
Kalabsha X L. s. PI 534556	3.36	3.47	0.30	0.31	3.15	3.23	2.17	2.28	0.59	0.62
L. s. PI 554556 X L. s. PI 491365	3.72	3.89	0.34	0.36	3.57	3.62	2.54	2.59	0.63	0.69
L. s. PI 554556 X L. s. PI 534556	3.54	3.65	0.31	0.34	3.57	3.61	2.49	2.57	0.59	0.63
L. s. PI 534556	3.67	3.77	0.32	0.35	3.60	3.63	2.42	2.60	0.60	0.61
L. s. PI 491365	3.70	3.80	0.34	0.35	3.47	3.67	2.54	2.56	0.61	0.63
Kalabsha	3.96	4.10	0.35	0.37	3.57	3.64	2.51	2.55	0.59	0.61
L. s. PI 554556	3.81	4.13	0.37	0.37	3.61	3.65	2.58	2.60	0.61	0.62
C. maxima	3.86	4.03	0.37	0.38	3.58	3.71	2.55	2.60	0.59	0.64
C. moschata	3.71	3.82	0.33	0.35	3.64	3.70	2.52	2.56	0.59	0.61
LSD 0.05	0.05	0.07	0.07	0.09	0.05	0.09	0.09	0.11	0.05	0.07

Likewise, grafting cucumber onto PI 534556 x PI 491365, Kalabsha x PI 491365, PI 534556 x PI 554556 and Kalabsha rootstocks in the first season as well as grafting onto all rootstocks in the second season, except grafting onto Kalabsha x PI 534556 rootstock, significantly improved Zn concentrations in cucumber leaves compared to control plants.

Generally, the highest concentrations of Fe (205.00 and 205.30 ppm) and Zn (62.41 and 65.66 ppm) were obtained from cucumber leaves that grafted onto PI 534556 x PI 491365 rootstock compared to control in both seasons.

3.6. Carbohydrates and proline concentrations of cucumber leaves:

Table 7 illustrates the effects of rootstocks on carbohydrates concentration of cucumber leaves and proline content of cucumber leaves. In this respect, all rootstocks in both seasons, except PI 491365 and *C. moschata* rootstocks in the second season, significantly enhanced the accumulation of carbohydrates in cucumber leaves compared to control plants. The maximum values of carbohydrates concentration of cucumber leaves were observed with grafted cucumber onto *C. maxima* x *C. moschata* rootstock in both seasons, whereas grafted cucumber onto PI 491365 and *C.*

Table 7. Effect of grafting onto some genotypes and F1 hybrids of cucurbit rootstocks on micro-nutrients (Na, Fe and Zn) concentrations, carbohydrates and proline concentrations at 60 DAT of cucumber leaves during 2020 and 2021 seasons.

Rootstocks	Na (%)		Fe (ppm)		Zn (ppm)		Carbohydrates concentration (mg/g)		Proline concentration (mmoles/g)	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Control	0.10	0.09	188.80	191.60	52.51	50.79	10.91	11.42	0.36	0.33
C. maxima X C. moschata	0.12	0.12	191.00	194.70	53.98	56.58	20.28	18.99	0.58	0.65
L. s. PI 534556 X L. s. PI 491365	0.10	0.11	205.00	205.30	62.41	65.66	12.83	16.43	0.31	0.38
Kalabsha X L. s. PI 491365	0.10	0.11	194.40	199.30	58.62	60.62	12.45	9.50	1.05	0.84
L. s. PI 534556 X L. s. PI 554556	0.09	0.11	192.60	194.00	58.42	62.88	13.99	16.04	0.82	1.01
Kalabsha X L. s. PI 534556	0.12	0.10	185.80	189.90	52.04	52.62	18.61	12.83	1.07	1.02
L. s. PI 554556 X L. s. PI 491365	0.09	0.10	189.20	190.50	56.33	60.40	13.48	16.81	0.81	0.64
L. s. PI 554556 X L. s. PI 534556	0.11	0.10	186.30	190.70	55.61	56.93	12.83	13.09	0.94	0.77
L. s. PI 534556	0.11	0.11	196.40	202.30	54.57	60.82	13.86	11.81	0.59	0.56
L. s. PI 491365	0.10	0.12	191.90	199.00	55.98	63.24	12.19	10.52	0.17	0.24
Kalabsha	0.11	0.10	194.60	197.70	58.29	62.43	11.17	15.91	1.97	1.15
L. s. PI 554556	0.10	0.10	194.80	198.50	52.96	59.87	11.94	13.22	1.32	0.80
C. maxima	0.12	0.12	194.20	197.10	56.88	60.71	14.50	15.14	0.58	0.53
C. moschata	0.11	0.12	199.30	200.50	54.33	61.87	11.16	10.01	0.22	0.20
LSD 0.05	N.S.	N.S.	5.67	3.44	4.18	2.74	0.15	0.12	0.07	0.07

moschata rootstocks in the second season showed a significant decrease of carbohydrates concentration in cucumber leaves compared to non-grafted cucumber. Furthermore, all rootstocks, except PI 534556 x PI 491365 in both seasons as well as PI 491365 and *C. moschata* rootstocks in the first season, exhibited significant excess of proline concentration compared to control. The highest proline concentration was estimated in cucumber leaves that grafted onto kalabsha rootstock in both seasons, whereas grafted cucumber onto PI 491365 and *C. moschata* rootstocks in the first season showed significant reduction in proline concentration of cucumber leaves compared to control plants.

4. DISCUSSION

The dramatic global obstacle all over the world that threaten agricultural production and expansion is salinity and salination. The effect of salinity on plant growth found in dual edges; osmotically which short-term effect and ionic, nutritional imbalance effect, in which later the long termed effect. The negative impacts of salinity on the productivity and quality of plants due to increasing sodium and chloride ions uptake which causes cytotoxicity and nutritional

imbalance (Isayenkov and Maathuis, 2019). Based on our observations, grafting onto various rootstocks have the potential to enhance the tolerance of salinity stress in plants. As a result, this study was conducted to examine whether the hybrids of rootstocks were more successful than the individual effects of each in terms of increasing salinity tolerance and productivity in cucumber plants. In the current study, we observed that the growth parameters of cucumber plants are significantly decreased under salinity stress. These findings are agreement with those reported by Chartzoulakis, 1992 and Khan et al., 2013. However, grafted cucumber onto all rootstocks significantly raised the growth characteristics of plants in both seasons. These increases in plant growth parameters have been linked to improve macro and micronutrient uptake (Tables 6 and 7). Furthermore, these results also may be attributed to the increasing of photosynthetic activity and membrane stability or increased plant hormones (Elsheery et al. 2020). In contradiction, the reduction of internode length when cucumber grafted onto PI 534556 x PI 491365 rootstock may be due to decreasing of proline concentration of cucumber leaves (Table 7).

The findings also illustrated that grafting process tended to increase chlorophyll concentration, photosynthesis rate and stomatal conductance of cucumber leaves. These results attributed to the ability of rootstocks to increase the macro and micronutrients uptake, especially Mg and Zn, that play an essential role in chlorophyll formation and also Synthesis of amino acid tryptophan that involved of hormones formation. Similar results were observed by El-Shraiy and Mostafa (2016); Elsheery et al. (2020); Farajimanesh and Haghighi (2020).In contrast, grafted cucumber showed a reduction in transpiration rate as compared with control plants. These results are compatible with those found by Farajimanesh and Haghighi (2020).

According to the results, yield and fruit quality traits are changed due to salinity stress. However, harvested cucumber fruits from all grafted plants showed a high values of total yield, fruit weight, fruit length and fruit diameter in both seasons compared to the un-grafted cucumber (Table 5). In contradiction, grafted cucumber onto *C. maxima* x *C. moschata* rootstock had the highest TSS percentage in both seasons as compared to non-grafted cucumber, whereas grafting cucumber onto the rootstocks of PI 534556 x PI 491365, Kalabsha x PI 491365, PI 534556 x PI 554556, Kalabsha x PI 534556, PI 554556 x PI 491365, PI 534556 and PI 554556 in both seasons as well as *C. moschata* in the first season caused a significant reduction of TSS percentage as compared to control plants. These results illustrated due to the increase of leaf area in grafted cucumber under saline conditions that participated in increasing of photosynthesis rate and may be also return to increasing the absorption of micro – and macro elements by the vigor roots of rootstocks. Similar results were obtained by Soubeih et al. (2018); Elsheery et al. (2020); Farajimanesh and Haghighi (2020). On the other hand, the results of Bayoumi et al. (2021) showed that fruits quality of grafted cucumber did not have changes compared with the non-grafted plants.

Under salinity stress, the un-grafted plants displayed the lowest content of nutrients including N, P, K, Ca, Mg, Na, Fe and Zn in both seasons (Tables 6 and 7). In contrast, the results obtained from grafted cucumber showed better absorption of minerals under saline conditions in both seasons. These results are agreement with those recorded by El-Aidy et al. (1996).Also, in this respect, some rootstocks did not effect on the accumulation of minerals in the leaves of plans like in the case of N, K and Ca% when cucumber grafted onto Kalabsha x PI 534556 rootstock as well as when cucumber grafted onto PI 534556, Kalabsha and *C. moschata* rootstocks in the case of Mg%. Also, no significant differences were observed between grafted and non-grafted cucumber on Na% in leaves in the two seasons. These results are in agreement with those reported by Bayoumi et al. (2021).

Moreover, all rootstocks enhanced the accumulation of carbohydrates in cucumber leaves compared to un-grafted plants. Grafted cucumber onto *C. maxima* x *C. moschata* rootstock has the highest value of carbohydrates concentration of cucumber fruits, whereas grafted cucumber onto PI 491365 and *C. moschata*

rootstocks in the second season showed a significant decrease of carbohydrates concentration. These results are agreement with those recorded by Farajimanesh and Haghighi (2020); Bayoumi et al. (2021) who reported that grafting cucumber onto the all rootstocks enhanced the carbohydrate concentration of cucumber leaves.

Moreover, except grafting cucumber onto PI 534556 x PI 491365 in both seasons as well as PI 491365 and *C. moschata* rootstocks in the first season, all rootstocks exhibited significant excess of proline concentration compared to un-grafted cucumber. In this regard, El-Shraiy and Mostafa (2016) found that grafted cucumber increased proline concentration, as compared with un-grafted plants under salt stress conditions. These results were in agreement also with those found by Elsheery et al. (2020).

5. CONCLUSION

Under salinity stress, the grafted cucumber plants onto different rootstocks was confirmed as an acceptable method to increase yield, especially in shade house conditions. Generally, the rootstocks that gave a high yield under salinity stress showed high concentrations of proline, macro- and microelements, high values of leaf area and photosynthesis rate, whereas they exhibited low values stomatal conductance and transpiration.

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الملخص العربي

تحسين تحمل نباتات الخيار المنزرع تحت ظروف صوب التظليل للملوحة بالتطعيم على بعض اصول التراكيب الوراثية وهجن الجيل الاول للقرعيات

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أصبحت الشتلات المطعومة ممارسة زراعية مهمة في أنحاء كثيرة من العالم لإنتاج وحماية محاصيل القرعيات من الإجهادات الحيوية وغير الحيوية. وتعتبر الملوحة أحد أهم الاجهادات الغير حيوية التي تسبب انخفاض في نمو وإنتاجية الخيار في مصر. تهدف هذه الدراسة إلى دراسة أداء هجين خيار الصوب التجاري (هشام) المطعم على أصول بعض التراكيب الوراثية بالاضافة الى بعض الأصول الهجينة F1 تحت ظروف الإجهاد الملحي (بلغت ملوحة التربة موضع الدراسة ومياه الري حوالي ٧٠,٩ و ٢,٧٧ ديسيسيمنز / م على التوالي) في مزرعة الأنور، طريق القاهرة الإسكندرية الصحراوي. خلال صيف موسمي ٢٠٢٠ و ٢٠٢١ تحت ظروف الصوبة الشبكية. نفذت هذه التجربة بتصميم القطاعات الكاملة العشوائية في ثلاث مكررات. تضمنت التجربة أربعة عشر معاملة للتطعيم (التطعيم على ستة تراكيب وراثية بالإضافة إلى التطعيم على ٧ أصول هجينة F1 مقارنة مع معاملة الكنترول الغيرمطعومة). أشارت النتائج إلى أن تطعيم الخيار على جميع الأصول أدى إلى تحسن معنوي في ارتفاع النبات ومساحة الأوراق ووزن وطول وقطر الثمرة والمحصول الكلي ومعدل التمثيل الضوئي في كلا الموسمين بالمقارنة مع الخيار غير المطعوم، بينما كان طول السلاميات في الخيار المطعوم على أصول كل من كلابشة، Lagenaria siceraria PI 554556 C.maxima, C. moschata Kalabsha x PI 534556 و Lagenaria siceraria PI 554556 x Lagenaria siceraria PI 491365 أكبر مقارنة بالنباتات غير المطعومة في الموسم الأول. لوحظ أعلى قيم لمحتوى ثمار الخيار من الكربوهيدرات عند التطعيم على أصل C.maxima x C. moschata في كلا الموسمين، بينما لوحظ أعلى محتوى من البرولين في أوراق الخيار عند التطعيم على أصل كلابشة في كلا الموسمين.