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Influence of Salinity on the Growth and Nutrients Composition of Cucumber Plants (*Cucumis sativus*).

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Abstract. Cucumber plants (*Cucumis sativus*) were grown on NFT at four levels of salinity concentrations (2.5, 4.5, 6.5 and 8.5 mS cm^{-1}). Higher salinities were achieved by addition of NaCl. The effects of these treatments on plants growth and nutrient elements levels in roots and leaves were studied. Increasing salinity progressively reduced fresh and dry weights of roots and shoots. Results showed significant reduction on Ca and K% in the dry matter of the roots and leaves while Na% and Cl were increased with increasing nutrient solution salinity. The reduction of growth under saline conditions could be due to the interference of Na and Cl on the metabolism in leaves or on the uptake and transport of essential ions such as Ca and K. The plants were found to tolerate a salinity level of 4.5 mS cm^{-1} without any significant reduction on yield.

Introduction

Crop salt tolerance is usually related with the relative reduction in yield for a given level of salt concentration compared with the yield of plants grown under non-saline conditions. Salinity in general reduces plant growth. Salt stress consists of two influences: osmotic stress, caused by the increase in the external osmotic pressure of the soil solution due to high concentration of salts, and the nutritional effect of salinity which includes specific ion toxicity and ion imbalance due to the excess of some particular ions. Growth reduction of non halophytes grown in saline nutrient solution, is often due to the effect of ion imbalance rather than the osmotic potential [1].

Ion transport in the plants is affected by salinity. The ion uptake into the whole plant involves ion uptake into the root, its transport through various organs and finally their accumulation in the leaves.

Jones [2, pp. 271-292] reported that the salt tolerance of glycophytes and even halophytes to NaCl has been correlated with their ability to exclude Cl and/or Na from the shoot. These exclusion mechanisms are effective at low or moderate levels of salinity.

There are many factors which may affect the plant tolerance to high salinity, these include species, climate and growth stage. The cucumber plant (*Cucumis sativus*) has been classified as a moderate salt-sensitive crop [3]. Zayed [4] reported that plants could tolerate higher levels of salinity in nutrient solution culture than in soil. In NFT a constant level of salinity is maintained; whereas, in soil, the level of salinity fluctuates with irrigation and water uptake and hence the area of high salinity may occur close to the root system. This experirr ent was carried out to study the effects of salinity on growth and nutrient composition of cucumber plants, grown in nutrient solution.

Materials and Methods

Cucumber plants, *Cucumis sativus* L. cv. Farbiola, were grown using nutrient film technique (NFT). Seeds were germinated at a constant temperature of 27°C. The seedlings were selected and transplanted to the gullies at the second leaf stage. The treatments included four levels of nutrient solution salinity that were maintained at constant electrical conductivity (Ec) of 2.5 (control), 4.5, 6.5 and 8.5 millisiemens (mS cm^{-1}). The solution pH was maintained at 5.5-6.5, using 5% acid mixture of nitric acid and orthophosphoric acid (3:1). Wye solution, developed by Varley and Burrage [5], was used as a stock solution in this experiment. The basic nutrient solution conductivity was achieved by adding equal amount of stock solution A and B to give 2.5 mS cm^{-1}. High levels of salinity were obtained by adding sodium chloride (NaCl) to the basic nutrient solution. The experiment was carried out in randomized block design. Each treatment was replicated four times. Each replicate consist of five plants.

The nutrient solution Ec was maintained at the required level by adding equal amounts of solution A and B. When NaCl was used conductivity was corrected by adding NaCl to maintin the Cl concentration in the solution, then the solution Ec was corrected to maintain the original nutrient solution conductivity using stock solution A and B. The solution was changed on the second occasion the conductivity dropped below the required level. Intermittent solution recirculation was used. The flow of the solution was controlled by a time-clock, giving circulation for 45 min/h. The plants were trained to a single stem and supported with a string to an overhead wire. The normal cultural practices were followed.

The responses of the plant growth to the nutrient solution salinity were measured. Relative water content (RWC) was measured as described by Turner [6]. Plant water potential measurements were carried out on tendrils using a pressure bomb.

At the conclusion of the experiment, samples roots and mature leaves were taken from the different treatments. The samples were dried at 70°C until a constant weight was achieved. 0.2 gram of the dried samples were dry ashed for mineral elements determintion.

K, Ca and Na plant material content were determined, using a Corning Flame Photometer 410. P content was estimated by Pye Unican SP9 atomic absorption spectrophotometer with air-acetylene flame. Plant tissue chloride content was determined as described by Zayed [4]. Accumulative yield data for all treatments were determined.

Results and Discussion

Increasing nutrient solution salinity caused a progressive reduction in plant growth. Total fresh and dry weight of the shoot and root were significantly reduced with increasing salinity. leaf area was reduced by 10.7, 29.6 and 48.8% compared to the control when the solution salinity was increased to 4.5, 6.5 and 8.5 mS cm^{-1} respectively (Table 1). The reduction of the leaf area has been considered as the major cause of growth reduction by reducing the photosynthetic area [7] and [8].

Schwarz [9] concluded that the inhibiting effect of salinity on plant growth could generally be attributed to the osmotic effect and associated reduction on plant water uptake. The reduction in leaf growth might be attributed to water deficient induced by high salinity in the root media [10].

Delane *et al.* [11] and Munns *et al.* [12] attributed the growth reduction of barley plant, grown at high external NaCl, to salinity induced water deficit in the growing tissues. The rapidity, with which the growth inhibition occurs, reflects the sensitivity of leaf elongation of the changes in water potential. A slight decrease in water potential was reported to reduce leaf growth [13].

The results show a gradual reduction in the water uptake with increasing solution salinity (Table 2). Such a reduction seems to be attributed to the reduction in the root permeability (expressed as hydraulic conductivity of the root system) under salt stress. The plant water potential of the salt-stressed plants appeared more negative

Table 1. The effect of nutrient solution salinity on total fresh and dry weight, and leaf area

Nutrient solution salinity (mS cm^{-1})	Total shoot fresh weight (g/p)	Total shoot dry weight (g/p)	Leaf area (cm^2)
2.5	1152.25	87.608	914
4.5	972.74	75.16	816
6.5	712.66	58.3	643
8.5	510.0	42.25	468
LSD 0.05	88.23	8.23	96.81
LSD 0.01	126.75	11.83	139.1

Table 2. Effect of solution salinity on total water uptake and relative water content

Nutrient solution salinity (mS cm^{-1})	Total water uptake (ml/P/day)	Relative water content (RWC)%	
		20 days	40 days
2.5	592.6	72.51	96.03
4.5	556.8	70.44	95.95
6.5	382.5	64.04	93.43
8.5	270.4	60.24	88.65
LSD 0.05	42.07	2.1	3.8
LSD 0.01	60.45	3.0	5.5

than those of the control (see the Figure), as a result of decreasing the osmotic potiential of the nutrient solution.

The hypothesis that leaf water deficit limited leaf growth was ruled out by Termaat *et al.* [14] in their studies to manipulate the leaf turgor. Munns and Termaat [15] and Munns *et al.* [16] concluded that leaf growth is influenced by a hormone produced in the old leaves; or in root whereas NaCl exerts its effect, influencing indirectly leaf growth. Although they considered that to be the main effect, it is still possible that the reduction of leaf growth was a result of decreasing leaf turgor, induced by decreased water potential. Flowers and Yeo [17] suggested that growth reduction in the leaf turgor, caused by a rapid ion accumulation in the leaf apoplast. They concluded that whether leaf growth reduction was due to changes in hormone levels or turgidity, the consequences were a reduction in leaf photosynthesis and transpiration, which reduced growth and ion import.

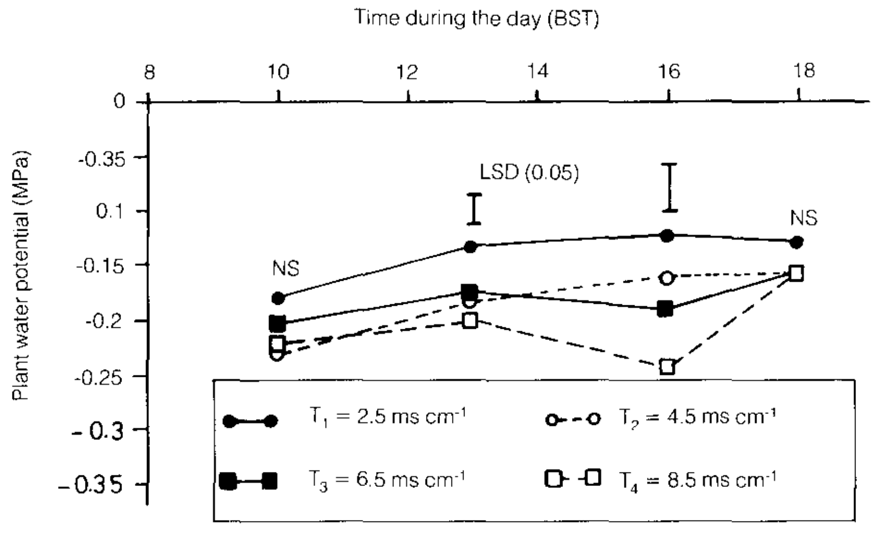

Fig. 1. Diurnal variation in plant water potential as influenced by nutried solution salinity.

In this experiment, cucumber plants of cv Farbiola were able to tolerate a salinity level of 4.5 mS cm^{-1} in the nutrient solution without a significant reduction in yield. Increasing salinity further to 6.5 and 8.5 mS cm^{-1} resulted in significant reductions in fruit yield (Table 3). Although cucumber fruit quality was improved by increasing solution salinity, this desirable result was offset by the large reduction in yield.

Table 3. The effect of nutrient solution salinity on fruit yield production

Solution Ec	Fruit number/p	Fruit weight (g)	Total yield (g/p)	Dry weight %	TSS	TA
2.5	5.82	516	2546	2.97	2.88	0.54
4.5	5.37	485	2341	3.03	2.81	0.58
6.5	3.04	301	1170	3.93	3.56	0.63
8.5	2.20	266	731	3.81	3.67	0.63
LSD 0.05	1.018	71.027	350.4	0.451	0.28	ns
LSD 0.01	1.463	102.05	503.4	0.648	0.41	ns

According to an FAO [3] report, cucumber yield was reduced by 25% at 4.4 mS cm^{-1} soil salinity. The differences between the results of FAO report and those of the present study may be due to the different growing media used. Plants could tolerate higher levels of salinity in the nutrient culture than in the soil [4].

The increases of dry weight % and TSS in fruits, with increasing nutrient solution salinity, might resulted from the reduced water uptake by the plants [18,4,10].

The results of the nutrient levels in the roots and leaves are presented in Tables 4 and 5. Increasing salinity in the nutrient solution led to substantial increment in Na and Cl in both roots and leaves, suggesting a general trend of excessive uptake, of these ions into plants under saline conditions. The Cl level in the leaves appeared higher than Na. Yang *et al.* [19] concluded that leaves appeared to be more discriminatory against the Na than Cl.

Table 4. The effect of salinity on ion levels in roots (% dry weight)

Solution Ec (mS cm^{-1})	Ca	P	K	Mg	Ma	Cl
2.5	0.7	1.46	5.51	0.095	0.22	1.12
4.5	0.69	1.48	3.87	0.088	2.72	3.78
6.5	0.61	1.36	3.88	0.093	3.92	5.92
8.5	0.64	1.37	4.34	0.109	5.11	8.52
LSD 0.05	0.066	0.101	0.56	0.014	0.335	0.99
LSD 0.01	ns	ns	0.81	ns	0.483	1.42

Table 5. The effect of salinity on ion levels in leaves (% dry weight)

Solution Ec (mS cm^{-1})	Ca	P	K	Mg	Ma	Cl
2.5	5.67	0.457	4.7	0.439	0.15	0.606
4.5	6.23	0.380	3.76	0.403	1.06	1.738
6.5	4.21	0.512	3.55	0.454	1.93	3.248
8.5	2.89	0.527	2.89	0.493	2.774	5.254
LSD 0.05	1.25	0.088	0.823	0.0534	0.327	0.352
LSD 0.01	1.8	ns	1.183	ns	0.470	0.506

The reduction in plant growth, under saline conditions, could result from the interference of Na and Cl on the metabolism in the leaves, or on the uptake and transport of essential nutrient ions; such as Ca and K. The reduction of Ca may be due to the substitution of Na for Ca in the root membrane [20]. Also, to the reduction in the transfer of Ca into the plant as a result of the decrease in water uptake. The reduction of K may be to high Na in the external solution, which was reported to increase K afflux from the salt stressed root [19]. This, also, could be related to the displacement of Ca from the root membrane by Na, since Ca has an imnportant role on permeability to K of plasma membrane and prevents the leakage of K from the root cell [21]. No consistent changes were found in the P and Mg % in the roots and leaves.

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تأثير الملوحة على النمو ومستويات العناصر الغذائية في نباتات الخيار

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ملخص البحث. زرعت نباتات الخيار *Cucumis sativus L.* بطريقة الزراعة المائية (NFT) على أربعة مستويات من الملوحة، تراوحت من ٢,٥ إلى ٨,٥ ملليموز /سم) تم زيادة ملوحة المحلول المغذي الأساسي (٢,٥ ملليموز/سم) بإضافة كلوريد الصوديوم (NaCl) . درس تأثير هذه المعاملات على نمو النباتات وعلى تركيزات بعض العناصر الغذائية في الجذور والأوراق. أظهرت نتائج الدراسة انخفاضًا في الـوزن الطازج والجاف للجذور والمجموع الخضري بزيادة ملوحة المحلول المغذي. كما بينت الدراسة انخفاضًا معنويًا في محتوى الجذور والأوراق من الكالسيوم والبوتاسيوم مع زيادة في تركيز الصوديوم والكلور عند زيادة ملوحة المحلول المغذي. انخفاض نمو النباتات عند الزراعة في البيئات الملحية قد يكون ناتجًا عن زيادة تركيز كل من الكلور والصوديوم في الأوراق أو عن تأثير الملوحة على امتصاص ونقل بعض العناصر الغذائية المهمة مثل الكالسيوم والبوتاسيوم.