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The Effect of Nutrient Solution Conductivity on the Growth of Cucumber Plants

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Abstract. Cucumber growth responses to nutrient solution conductivity (Ec) were evaluated. Four levels of nutrient solution Ec, ranging from 1.0 to 2.5 mS cm^{-1}, were used. Plant height, stem diameter, leaf area and fresh and dry weight of different plant parts were measured. The results showed that cucumber plants can be grown in a wide range of nutrient solution Ec without affecting the plant growth and productivity. Plant water uptake and relative water content (RWC) were significantly reduced with increasing nutrient solution Ec. Plant water potential, measured 40 days after imposing the treatments, was higher for 2.5 mS cm^{-1} than 1.0 mS cm^{-1} plants. There was no significant effect for the treatments on the transpiration rate and stomatal conductance. Photosynthetic rate measured 40 days after applying the treatment, significantly increased with increasing nutrient solution Ec.

Introduction

Most of the nutrient film technique (NFT), crops are grown in a solution of electrical conductivity (Ec) ranging from 2.0 to 3.0 millisiemens (mS cm^{-1}) [1]. Steiner [2] reported that over a wide range of nutrient ratios in the nutrient solution, the mutual ratio in which the plants take ions is not influenced by the mutual ratio of these ions within the solution.

Investigators have reported different values for the optimal solution conductivity for growing cucumbers. Graves and Hurd [3] reported that the highest yield of cucumber was obtained when the solution conductivity was between 2.5 and 4.0 mS cm^{-1}. Sonneveld [4], however, found a decline in the yield of cucumber grown in rockwool as the conductivity was increased from 1.0 to 4.0 mS cm^{-1}. An Ec range of 2.0 – 2.5 mS cm^{-1} was recommended by Voogt [5] for cucumbers grown on rockwool matting with a drip-fed nutrient solution. He found that at low values there were signs of deficiencies in N and K whereas at the higher levels no increase in the crop yield was found.

The experiment presented here was carried out to evaluate the response of cucumber plants to low levels of nutrient solution Ec and its effect on plant water relation and nutrient uptake.

Materials and Methods

Cucumber *(Cucmus sativus* Cultivar farbiola) seeds were germinated in an incubator at a constant temperature of 27°C. The seedlings were transplanted to the NFT channels at the 5 leaf stage. Tap water was circulated for the first two days to encourage development of the root. Initial measurements were taken for plant height and stem diameter to ensure the uniformity of the seedlings before starting the treatments. Four different levels of nutrient solutions Ec (1.0, 1.5, 2.0 and 2.5 mS cm^{-1}) were used in this experiment. Wye solution, developed by Varley and Burrage [6], was implemented as a stock solution. The solution levels in the catchment tanks were corrected daily by adding tap water and the solution conductivity was corected by adding equal amounts of solution A and B as required. The solution pH was maintained between 5.5 – 6.5. The experiment was carried out in randomized block design. Each treatment was replicated four times.

Changes in plant height, stem diameter and leaf area were measured nondestructively. Plant water potential was measured using a presure bomb and relative water content (RWC) was measured as described by Turner [7]. Gas exchanges were measured using a portable battery operated infra-red gas analyzer (LCA2).

Ca, K and Na were determined in the plant using Corning Flame photometer 410. P content was estimated by Pye Unicam SP6-500 spectrophotometer. Mg content was determined using Pye Unicam SP9 atomic absorption spectrophotometer with air-acetylene flame.

Results and Discussion

The results in this experiment showed that increasing nutrient solution Ec from 1.0 to 2.5 mS cm^{-1} had no significant effect on the plant growth and yield (Tables 1, 2 and 3). This result indicates that cucumber could be grown in a wide range of nutrient solution conductivity without affecting the plant growth and productivity.

Table 4 summarizes the average plant water uptake and the relative water content. The result shows a significant ($P=0.01$) reduction in plant water uptake and relative water content with increasing nutrient solution Ec. The negative correlation between water uptake and nutrient solution Ec supports the close relationship found between the nutrient solution osmotic potential and plant water uptake [8, 9].

Table 1. Effect of the nutrient solution Ec on stem growth

Nutrient solution Ec (mS cm^{-1}	Stem diameter (cm)	Plant height (cm)	Fresh weight (g/plant)	Dry weight %
1.0	1.07	307	331	5.83
1.5	1.04	307	332	5.47
2.0	1.01	315	301	5.33
2.5	0.97	303	255	5.75
LSD 0.05	ns	ns	42.6	ns
LSD 0.01	ns	ns	61.2	ns

Table 2. Effect of the nutrient solution Ec on leaf growth

Nutrient solution Ec (mS cm^{-1})	Leaf fresh weight (g/plant)	Leaf dry weight (g/plant)
1.0	776	7.09
1.5	868	7.45
2.0	729	6.63
2.5	621	6.85
LSD 0.05	ns	ns
LSD 0.01	ns	ns

Table 3. The effect of nutrient solution Ec on fruit yield growth

Nutrient solution Ec (mS cm^{-1})	Fruit number/ plant	Total yield (g/plant)	Dry weight% in the fruit	TSS in the fruit
1.0	3.44	1356	2.94	2.53
1.5	3.19	1514	2.91	2.38
2.0	2.94	1287	2.84	2.88
2.5	2.88	1132	2.72	2.31
LSD 0.05	ns	ns	ns	ns
LSD 0.01	ns	ns	ns	ns

Table 4. Effect of nutrient solution Ec on plant water uptake and relative water content

Nutrient solution Ec (mS cm^{-1})	Average water uptake (ml/plant/day)	Relative water content %
1.0	747	93.7
1.5	664	93.8
2.0	611	91.2
2.5	576	87.5
LSD 0.05	64.9	4.21
LSD 0.01	93.3	6.04

Plant water potential was measured several times after starting the treatments (Fig. 1). The measurements were carried out between fourteenth and sixteenth hours. The result shows no consistent changes in the first five weeks. In the last measurement, the plant water potential was generally found to increase with increasing

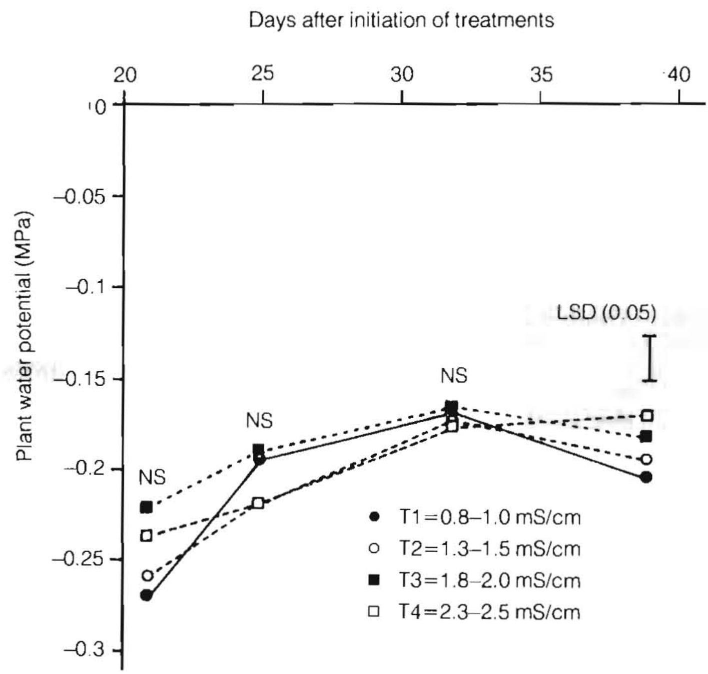

Fig. 1. Effect of the nutrient solution Ec on plant water potential.

solution conductivity. A lower water potential (–0.205 MPa) was recorded for plants grown in a solution at 1.0 mS cm^{-1} than for those grown at 2.5 mS cm^{-1} (–0.171 MPa). This result supports the findings of Burrage and Varley [10] who found that the water potential of lettuce plants grown in solutions at 1.1 mS cm^{-1} was reduced from –0.25 to –0.6 MPa between ninth and eleventh hours whereas the water potential of plants grown in a solution at 2.5 mS $cm^{-1}$was reduced from –0.25 to –0.35 MPa during the same period. They suggested that the high evaporative demand during the midday period created short term stress. The greater reduction at the 1.1 mS cm^{-1} suggested a greater sensitivity or response capability to this short term stress. Black [11] also found a transient decrease in leaf water potential when the evaporative demand was increased by a rapid reduction of relative humidity. This was subsequently accompanied by an increase in stomatal resistance.

The gas exchange measurement shows a significant increase in the photosynthetic rate with increasing solution conductivity (Table 5). This increase in the photosynthetic rate was accompanied by a slight increase in the stomatal conductance. It seems likely that high radiation level at the time of measureemnt (397.2 W m^{-1}) subjected the plants to a short term stress. This caused a rapid increase in the evaporative demand by changing the humidity gradient between the leaf and the air which may have caused stomatal closure and depression in the photosynthetic rate. The 1.0 mS cm^{-1} plants show more sensitivity to this short term stress than the 2.5 mS cm^{-1} plants. This was also suggested by the water potential data (Fig. 1). Hall and Kaufmann [12] found that with increasing humidity gradient between leaf and air, leaf resistance was increased while the mesophyll resistance remained relatively constant. They suggested that the changes in the leaf resistance were caused by stomatal aperture

Table 5. Effect of nutrient solution Ec on the transpiration rate (mmol/m^2/s), stomatal conductance (mmol/m^2/s), and hotosynthetic rate (mmol/m^2/s)

Nutrient solution Ec (mS cm^{-1})	Transpiration rate		Stomatal conductance		Photosynthetic rate	
	5 days	40 days	5 days	40 days	5 days	40 days
1.0	10.95	9.02	696	693	3.55	3.27
1.5	11.10	9.05	704	712	4.81	4.28
2.0	11.74	9.66	849	743	5.68	6.68
2.5	10.40	9.77	634	752	6.62	7.32
LSD 0.05	ns	ns	ns	ns	ns	1.365
LSD 0.01	ns	ns	ns	ns	ns	1.96

and that non-stomatal aspects of photosynthesis and respiration were not influenced by variation in the humidity gradient.

The effect of the treatments on ion concentration in the root and the leaves is presented in Tables 6 and 7. Ca and K levels in the root were significantly increased with increasing nutrient solution Ec from 1.0 to 1.5 mS cm^{-1}. K level in the leaves was gradually increased with increasing nutrient solution Ec. There were no consistent changes in P and Mg levels in the root and in the leaves with increasing nutrient solution Ec.

Table 6. The effect of Ec of the nutrient solution on ion levels (%dry weight) in the root

Nutrient solution Ec	Ca	P	Na	K	Mg
1.0	0.220	1.02	0.285	2.31	0.121
1.5	0.401	1.08	0.440	6.65	0.184
2.0	0.363	1.35	0.367	3.89	0.149
2.5	0.381	1.23	0.386	4.50	0.149
LSD 0.05	0.0814	ns	0.098	0.706	ns
LSD 0.01	0.117	ns	ns	1.014	ns

Table 7. The effect of Ec on the nutrient solution on ion levels (%dry weight) in the leaves

Nutrient solution Ec	Ca	P	Na	K	Mg
1.0	5.31	0.488	0.206	3.6	0.417
1.5	5.35	0.606	0.312	5.07	0.463
2.0	4.17	0.741	0.309	5.98	0.403
2.5	5.64	0.553	0.302	6.05	0.487
LSD 0.05	0.961	ns	0.055	1.14	0.056
LSD 0.01	ns	ns	0.079	1.64	ns

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تأثير التوصيل الكهربي للمحلول المغذي على نمو نباتات الخيار

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ملخص البحث. تم دراسة استجابة نمو نباتات الخيار *Cucumis sativs* L للتوصيل الكهربي للمحلول المغذي، وذلك باستخدام أربعة مستويات تراوحت من ١ إلى ٢,٥ ملليموز/سم. تم دراسة تأثير هذه المعاملات على طول النبات وقطر الساق ومساحة الورقة، وكذلك على الوزن الجاف والرطب لمختلف أجزاء النبات.

أظهرت نتائج الدراسة أن نباتات الخيار يمكن أن تنمو في مدى واسع من خاصية التوصيل بالنسبة لمحلول التغذية بدون أي تأثير معنوي على نمو وإنتاجية النبات. كما أظهرت نتائج الدراسة أن كمية المياه الممتصة بواسطة النبات، وكذلك المحتوى المائي النسبي Relative water content قد تناقصت معنويًا مع زيادة التوصيل الكهربي للمحلول المغذي. لم يكن هناك تأثير معنوي للمعاملات على النتح أو على خاصية الاتصال الثغري Stomatal conductance . بعد ٤٠ يومًا من بدء المعاملات تم قياس الجهد المائي للنبات وكذلك البناء الضوئي. وقد أظهرت النتائج زيادة في الجهد المائي والبناء الضوئي للنبات مع زيادة التوصيل الكهربي للمحلول المغذي.