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Growth, Yield and Quality of Three Greenhouse Cucumber Cultivars in Relation Two Types of Water Applied at Different Growth Stages

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Abstract. Two levels of salinity of irrigation water (I: well water with EC 2.61 ds.m^{-1}, II: desalinized water with EC 0.39 ds.m^{-1}) were applied to three greenhouse cucumber cultivars; Alasil, Alia and Copra; at various stages of growth and for different time durations, to study the effect of irrigation water salinity on growth, quantity and quality of cucumber production. Five irrigation treatments (IT) were applied; (IT1) irrigation with desalinized water for the whole experimental period; which was 105 days, (IT2) irrigation with desalinized water from the beginning of experiment until the beginning of flowering stage (30 days) then irrigation with well water, (IT3) irrigation with desalinized water until the beginning of fruit setting stage (35 days) then irrigation with well water, (IT4) irrigation with local well water (35 days) then irrigation with desalinized water until the end of the experiment, and (IT5) irrigation with well water for the whole experimental period. Vegetative growth traits recorded were: plant height, leaf number, leaf area, leaf fresh and dry weight. Fruit growth traits were; length, diameter, firmness, number, fresh and dry weight. Early and total yield were also recorded. Salinity during the entire growing period and (IT5) significantly reduced early and total yield by 46.8% and 28.3% respectively. Also, it reflected higher negative results in all traits, except fruit dry weight. The negative effect of salinity on most traits was less severe when IT4 was applied. No significant differences were found between IT2 and IT3, since they resulted in intermediate negative effect in all studied traits; except for early yield. Significant differences among cultivars were found in fruit growth traits especially yield and its components. Highest values for fruit weight, early and total yield were recorded in Copra followed by Alia and Alasil, respectively. Considering that all traits were less severely affected by IT4 and that total yield was only reduced by 7.2% as compared to IT1, it can be concluded that the use of salinized irrigation water until fruit setting stage followed by desalinized water for greenhouse cucumber production is recommended to save the high cost of water desalinization.

Keywords: Cucumber, Saline irrigation water, Water quality, Cultivars, Yields response, Growth stages.

Introduction

Cucumber (*Cucumis sativus* L.) is one of the main greenhouse vegetable crops widely grown in Saudi Arabia. The total greenhouse area for cucumber production increased

from 1112 hectares in 1997 up to 2182 hectares in 2003 [1], its production increased from 67044 tons in 1997 up to 168112 tons. Among all vegetable crops produced in greenhouse, cucumber production area increased from 20.8% to 45.1%. One major factor influencing growth and yield of cucumber is water quality. Cucumber is moderately sensitive to salinity [2-4]. Increasing salinity affects growth mainly by reducing plants ability to absorb water [5] and through a reduction in photosynthesis and photosynthesing area [6].

In arid and semi-arid climates, most of water requirements for crops are supplied through irrigation, and water normally contains large amounts of dissolved salts. Therefore, salinity control is considered frequently a major objective of irrigation management [4]. Beside affecting crop yield and soil physical condition, irrigation water quality can affect soil fertility and irrigation system performance. Therefore, knowledge of irrigation water quality is critical to understanding the necessary management changes for long-term productivity [7]. In many areas of Saudi Arabia, good water quality (low salinity) is not often available for irrigation, consequently saline water is available.

Many investigators recorded negative effects of irrigation with saline water on cucumber growth and yield. According to [8] plant water uptake, growth and yield decreased with salinity. [9] reported that increasing salinity levels progressively decreased all growth traits for cucumber plants. Increasing salinity (4000 mg NaCl/liter) reduced and delayed germination [10]. Growth of cucumber seedlings was generally reduced by increasing salinity. Shoot and root dry weight increased with decreased Na:Ca ratio at 4.0 mg/cm [11]. [12] reported that plant height, unit leaf area and leaf area index were linearly affected by water salinity. Fruit growth, fruit number and seed yield per plant decreased with increasing salinity. Plant height, total leaf area, plant dry weight, fruit yield, number of fruits per plant and fruit weight were decreased with increasing salinity, particularly above 1.2 mmohs/cm [13]. Increasing the salinity over 10 mm NaCl significantly reduced the fruit yield and number of fruits per plant [6]. Increasing water salinity from 50 to 120 mm NaCl had higher effects on cucumber fruits (chloride, sodium and soluble solids contents, and hence had more flavor than control). This could increase prices, and was not regarded as an adequate compensation for yield losses [14]. Salt injury symptoms (e.g. chlorosis, burn leaf margins and necrosis) developed at Electrical Conductivity (EC) more than 2.7 mmohs/cm and were more severe at higher water salinity [13].

The objectives of this study is to investigate the effect of water salinity applied at different growth stages on yield and quality of cucumber, and to determine the optimum irrigation treatment with well and desalinized water for the best growth and yield characteristics.

Material and Methods

This study was conducted during the spring and early summer seasons of 2004 at the Agricultural Research and Experiment Station in Dirab near Riyadh. Seeds of three

greenhouse cucumber cultivars; namely Alasil, Alia and Copra were sown on 20 January 2004 in Jiffy 7 pots in the fiberglass greenhouse; and transplanted into soil on 10 February 2004. Two salinity levels (Electrical Conductivity, EC) in the irrigation water were utilized (I: well water with EC = 2.61 mmhos/cm, II: desalinized water with EC 0.39 mmhos/cm). The chemical analysis of both irrigation water is shown in Table 1.

Table 1. Chemical analysis of the two kinds of irrigation water

Characters	Well water	Desalinized water
EC ($ds.m^{-1}$)	2.61	0.39
pH	7.1	6.47
Ca^{++} $meq1^{-1}$	11.0	0.73
Mg^{++} $meq1^{-1}$	10.5	0.16
Na^{+} $meq1^{-1}$	14.65	3.5
K^{+} $meq1^{-1}$	0.56	0.1
HCO_3^{--} $meq1^{-1}$	4.7	0.325
Cl^{-} $meq1^{-1}$	12.9	1.85
$No3^{-}$ ppm	5.2	2.69
SO_4^{--} $meq1^{-1}$	14.61	0.9
SAR	4.66	5.11

Five irrigation treatments (IT) were applied at various stages of plant growth and for different time durations; (IT1) irrigation with desalinized water for the whole experimental period (105 days from transplanting) which represented the control treatment, (IT2) irrigation with desalinized water from the beginning of experiment until the beginning of flowering stage (30 days) then irrigation with well water, (IT3) irrigation with desalinized water until the beginning of fruiting stage (35 days) then irrigation with well water. (IT4) irrigation with well water for 35 days then irrigation with desalinized water until the end of the experiment, (IT5) irrigation with well water for the whole experimental period. Irrigation treatments using drip irrigation system started 7 days after transplanting. The experimental soil texture was sandy and the mechanical soil analysis was: 84% sand, 8% silt and 8% clay with pH 7.65 and EC 5.35 mmhos/cm. Temperature and R.H. were averaged about 20 & 24 °C and 75 & 80% during vegetative growth and fruiting stages, respectively. Fertilization and other cultural practices, such as pest control, cultivation and pruning were applied as commonly recommended in commercial production of greenhouse cucumber [15].

The experimental units consisted of 15 treatments (five irrigation treatments and three cultivars). The experimental layout was split-plot in randomized complete blocks design with four replications. Irrigation treatments were randomly allocated to the main plots, whereas cultivars were arranged in the sub-plots. Plot area was 5 m^2 and included 15 plants. Planting distance was 50 cm and 70 cm between plants and rows, respectively.

Two plants were randomly selected from each sub-plot, six weeks after starting the irrigation treatments (at the flowering stage), plant height, leaf number, leaf area, leaf fresh weight and leaf dry weight percentage were recorded. A random representative sample consisting of 10 fruits was taken from each experimental unit for the 10th harvest. The following fruit characteristics were determined: average fruits length, average fruit diameter, average fruit weight, fruit dry weight (DW) percentage and fruit firmness. Harvesting time started on 20 March 2004 and continued two times a week until 29 May 2004 (total of 20 harvests). Average early yield, represented as the number and weight of fruits per plant and per square meter, was counted from the first seven harvests, whereas total yield included the entire harvest period.

Data was statistically analyzed using SAS [16] software, and treatment means were compared by using L.S.D. test at 0.05 level according to [17].

Results and Discussion

Effect of irrigation treatments

Irrigation treatments did not have any significant effect on plant height, leaf number and leaf dry weight (Fig. 1 A, B and D). However, irrigation with IT5 caused a significant reduction in leaf fresh weight and leaf area (12.2% and 28.1% respectively, compared with control treatment IT1 (Fig. 1 C and E). These results clearly indicated that the decrease in leaf dry weight by salinity was not caused by a reduction in leaf number, but by a reduction in leaf area. This observation is in agreement with the data reported by [18] on tomato. [19] found a 46% reduction in dry weight of cucumber plants when the salinity level increased from 3 to 8 mmhos/cm. No significant differences were found between IT2, IT3 and the control irrigation treatment, since saline water was applied at the flowering and fruiting stages in IT2 and IT3 treatments, respectively. In addition, IT4 did not reflect any negative effect on leaf area and leaf fresh weight.

Irrigation treatments IT2 and IT5 adversely affected fruit length, fruit diameter and fruit firmness (Fig. 2A, B and C). However, IT2 and IT3 did not have any negative effects on these traits compared with the control treatment (IT1). Irrigation treatment IT5 significantly increased fruit DW percentage (Fig. 2D) while other treatments reflected negative effects on this trait. The reason for this result could be attributed to the increase in the soluble solids contents [9]. These data are in accordance with the suggestion of [20, 21], who reported that dry matter (DM) accumulation of plants decreased as salinity increase, but DM of fruits increased. Increasing salinity reduces DM production and increased the proportion of total DW in the fruits at the expense of upper shoot. In the case of average fruit weight (Fig. 2E), no significant differences were observed among all irrigation treatments, except for IT5, which reflected the highest value. This finding could be attributed to the higher reduction in total yield than reduction in number of fruits when IT5 was applied.

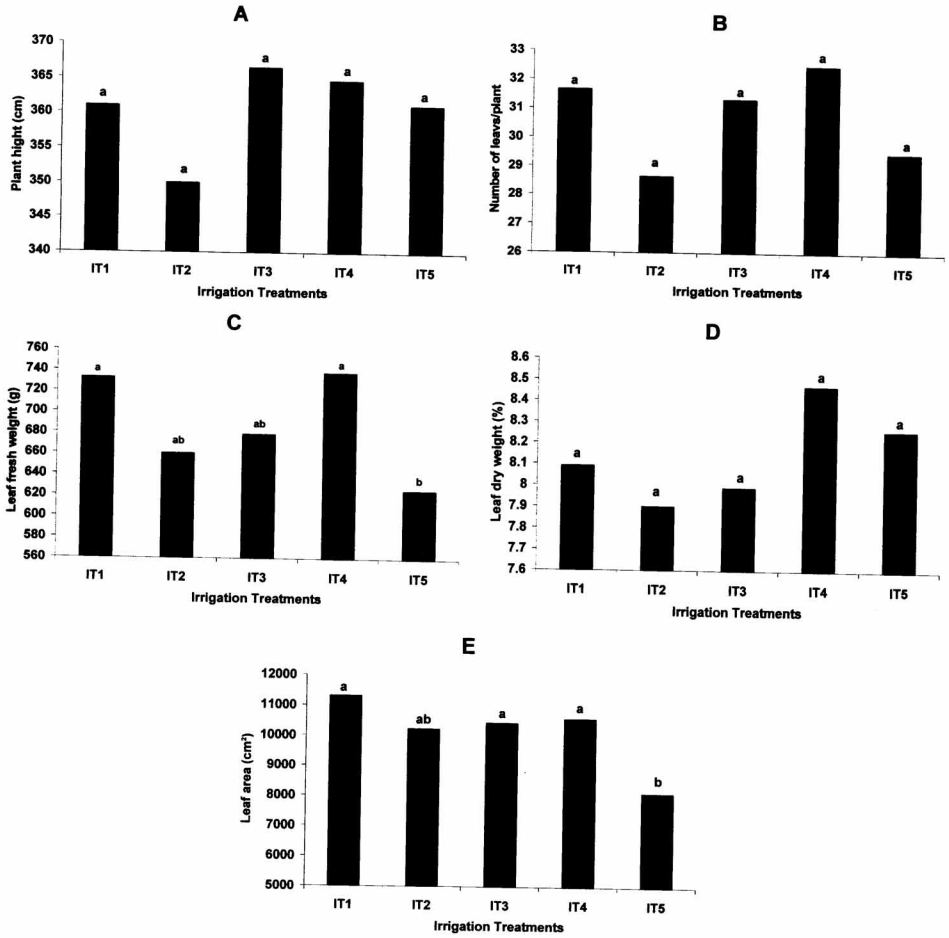

Fig. 1. Vegetative growth characteristics of cucumber plants as affected by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):
A. Plant height (cm) B. Number of leaves/plant
C. Leaf fresh weight (gm) D. Leaf dry weight (%) E. Leaf area (cm^2)
*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly different using the revised L.S.D. test at 0.05 level.**

With respect to early yield per plant (Fig. 3A), irrigation treatment IT5 caused a significant reduction by 46.8%, while the reduction caused by IT2 was not significant (13.6%). Intermediate negative effects of IT3 and IT4 were observed (they both reduced the early yield by 23.7% and 25.6% respectively). Number of fruits per plant for early yield was not affected by the irrigation treatments (Fig. 3B). Only the longest duration of salinity treatments (IT5) caused a significant reduction in this trait. Reduction in early yield accounted by salinity was partially similar and in agreement with those reported by [22, 23].

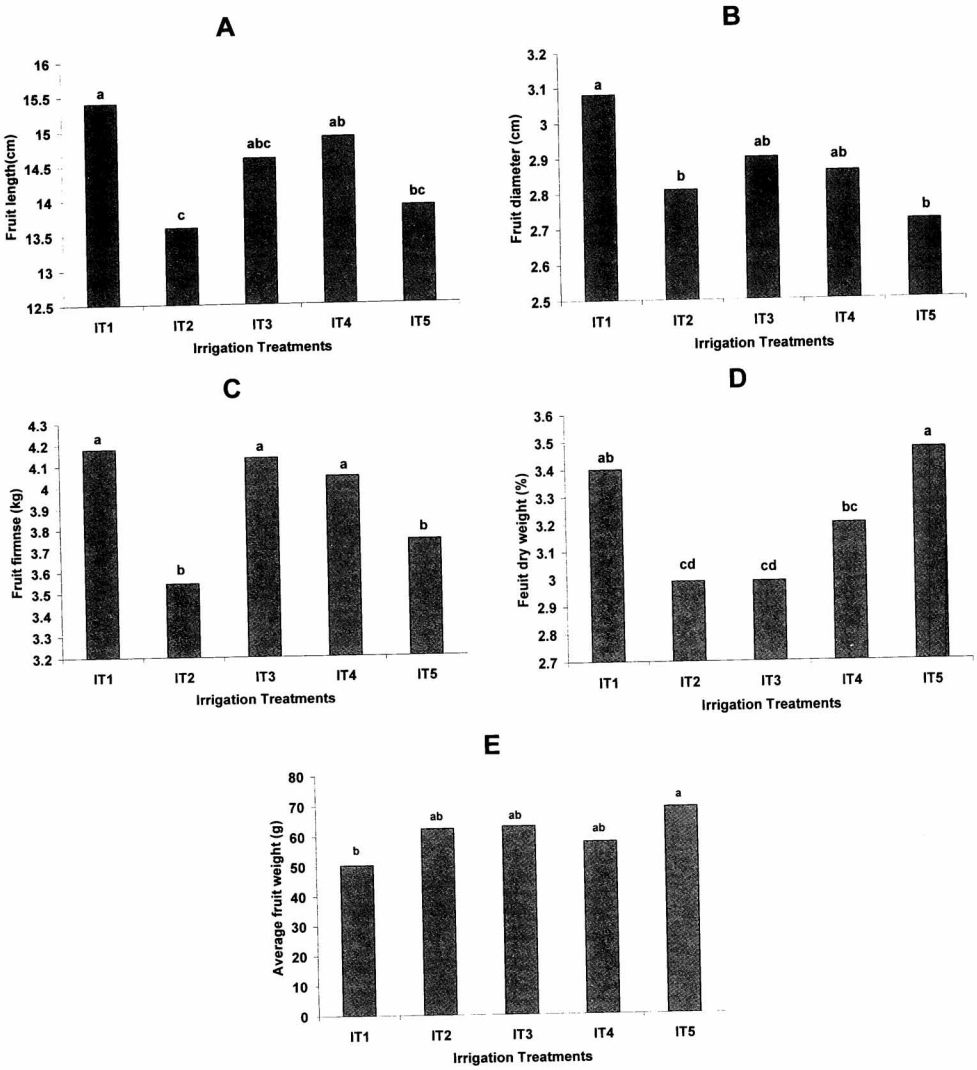

Fig. 2. Fruit characteristics of cucumber plants as affected by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):

A. Fruit length (cm) **B. Fruit diameter (cm)**

C. Fruit firmness **D. Fruit dry weight (%)**

E. Average fruit weight (gm)

*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly different using the revised L.S.D. test at 0.05 level.**

Irrigation treatment IT5 caused significant reduction in total yield per plant by 28.3%, (Fig. 3C), while the reduction caused by IT2 and IT3 was 15.5% and 14.6%, respectively. Irrigation treatment IT4 only reduced the total yield by 7.2%, as compared to control. This result indicated that the cucumber plants were more sensitive to salinity in irrigation water at fruiting stage than at vegetative growth stage. [24] reported that cucumber plants require a continuous supply of moisture during the growing season where the most critical need occurs at the time of fruiting. Moisture stress then can seriously reduce the yield of marketable fruits. The response of total number of fruits per plant (Fig. 3C) was similar to the trend of total yield as previously described. The reduction in yield even at relatively short duration of irrigation with saline water (i.e. IT4) supports the finding of [25] that even under normal growing conditions. The EC of the root solution is close to the threshold for yield reduction. When irrigation with fresh water and fertilization were done normally, the saturated soil extract varied between 1.6 and 3.1 mmohs/cm [26]. Some other investigators reported significant negative effects in cucumber yield as a result of irrigation with saline water [6, 8, 13, 22, 23, 27].

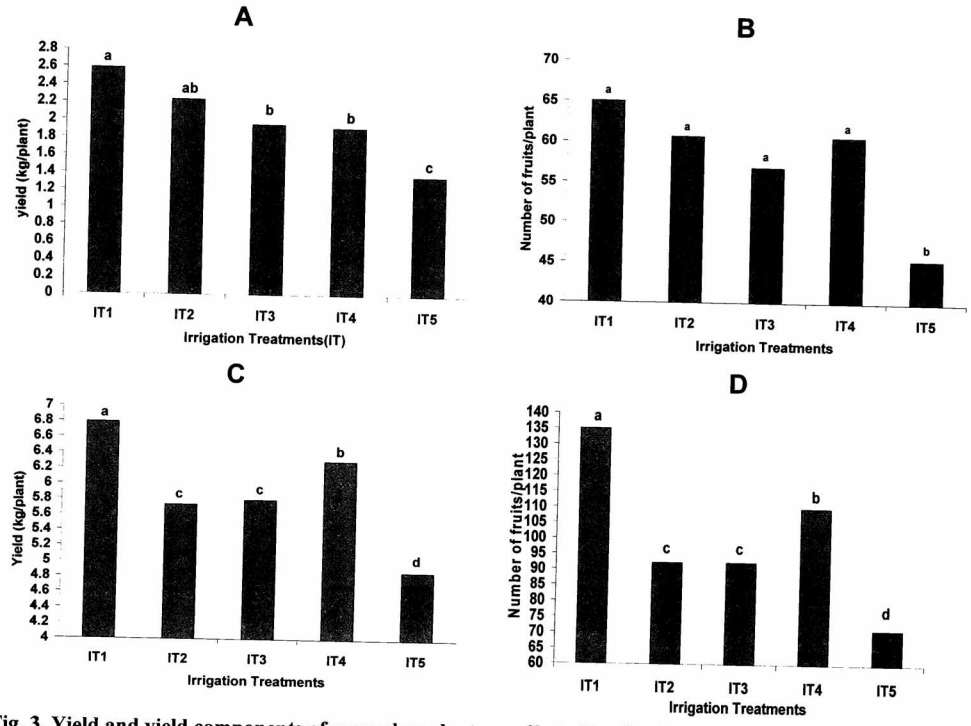

Fig. 3. Yield and yield components of cucumber plants as affected by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):

A. Early yield (kg/plant) **B. Number of early fruits/plant**

C. Total yield (kg/plant) **D. Total number of fruits/plant**

*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly different using the revised L.S.D. test at 0.05 level.**

Response of cultivars to irrigation treatments

Significant differences among cucumber cultivars were found in all vegetative growth traits; except for leaf dry weight (Fig. 4 A-E). The cultivar Copra gave significantly the highest values in all traits. However, no significant differences were found between Alia and Alasil, except in plant height which was higher in Alia.

No significant differences were observed among the three cultivars in fruit length, fruit dry weight and average fruit weight (Fig. 5). However, in the case of fruits firmness, the cultivar Copra reflected the highest values followed by Alasil and Alia, respectively. On the other hand, Alasil had the highest fruit diameters.

The cultivar Copra significantly had the highest values for early and total yield per plant, followed by Alia and Alasil, respectively (Fig. 6). With respect to the number of fruits per plant for early yield, Alia gave the highest value followed by Alasil and Copra respectively. No significant differences among cultivars were observed in total number of fruits per plant. Response of cucumber cultivars to irrigation treatments reported in this study are in partial accordance with those reported by [28] who studied the effect of two salinity levels of irrigation water (1.6 and 4.0 mmhos/cm) on yield and fruit quality of cucumber cultivars. They reported that water salinity significantly decreased fruit yield in 5 out of 6 cultivars, but had no effect on fruit quality.

Considering that all traits were less severely affected by IT4 and that total yield was only reduced by 7.2% , as compared to IT1, it can be concluded that the use of salinized irrigation water until fruit setting stage followed by desalinized water is recommended for greenhouse cucumber production to save the high cost of water desalinization.

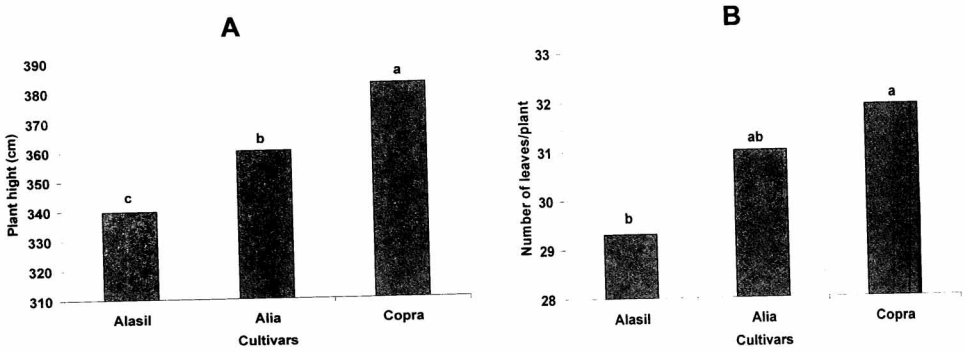

Fig. 4. Vegetative growth characteristics of three cucumber cultivars as influenced by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):
A. Plant height (cm) B. Number of leaves/plant
*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, ar not significantly differ using the revised L.S.D. test at 0.05 level.**

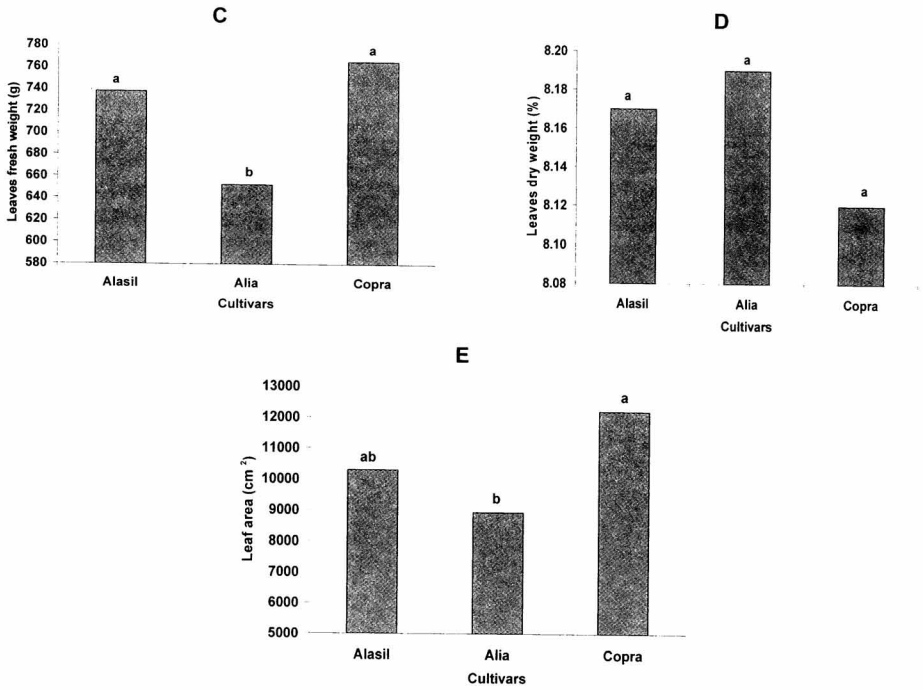

Fig. 4 (Contd.). Vegetative growth characteristics of three cucumber cultivars as influenced by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):

C. Leaf fresh weight (gm) D. Leaf dry weight (%)
E. Leaf area (cm^2)

*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly differ using the revised L.S.D. test at 0.05 level.**

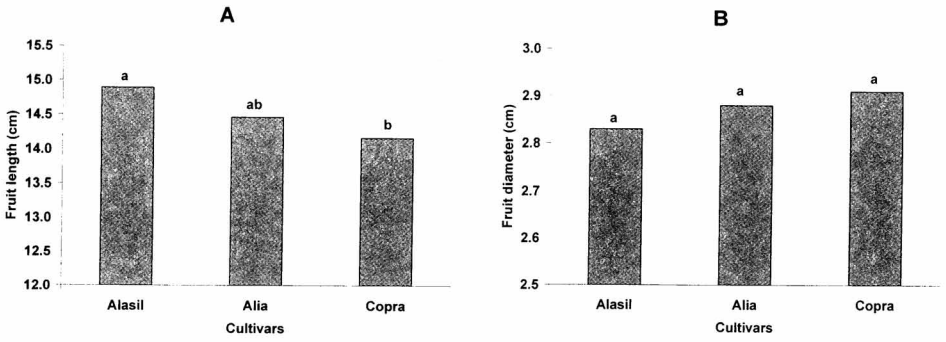

Fig. 5. Fruit characteristics of three cucumber cultivars as influenced by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):

A. Fruit length (cm) B. Fruit diameter (cm)

*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly differ using the revised L.S.D. test at 0.05 level.**

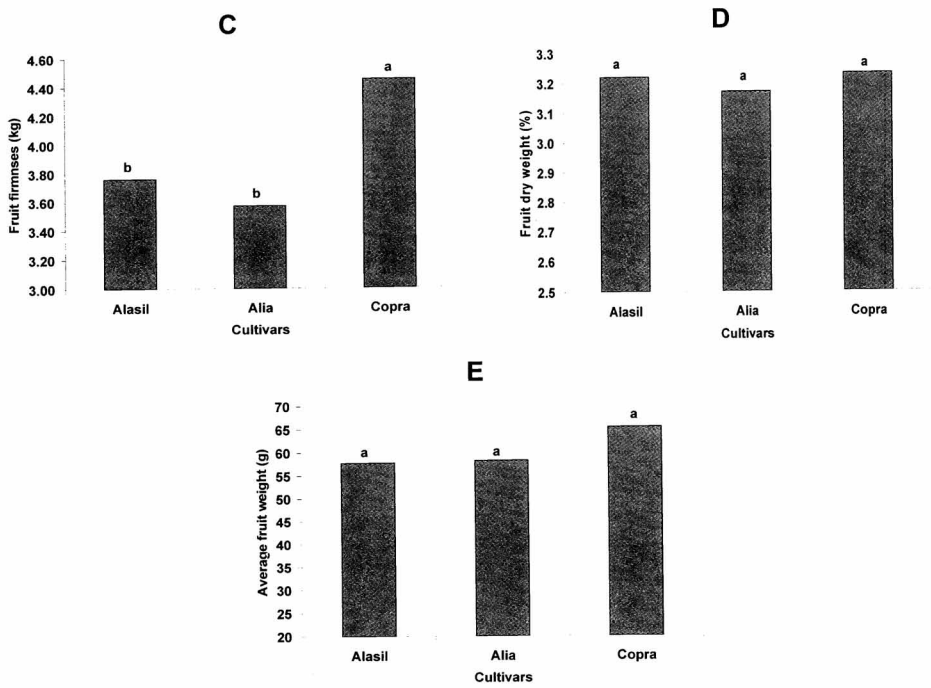

Fig. 5 (Contd.). Fruit characteristics of three cucumber cultivars as influenced by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):
C. Fruit firmness D. Fruit dry weight (%)
E. Average fruit weight (gm)
*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly differ using the revised L.S.D. test at 0.05 level.**

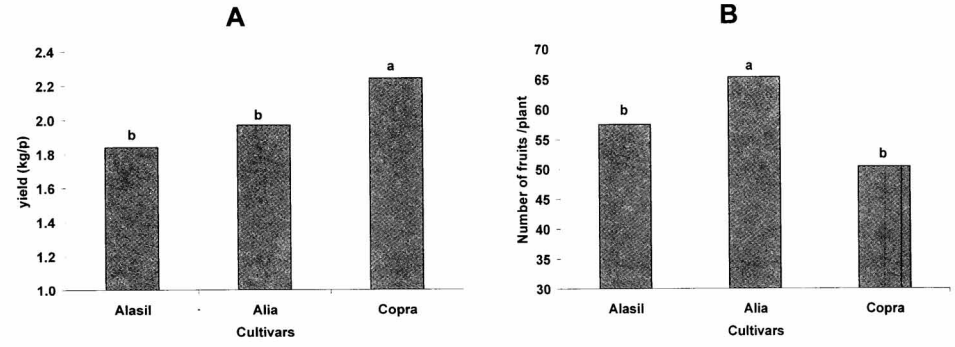

Fig. 6. Yield and yield components of three cucumber cultivars as influenced by five irrigatior treatments (two levels of salinity in the irrigation water applied at various stages of growth):
A. Early yield (kg/plant) B. Number of early fruits/plant)
*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters are not significantly differ using the revised L.S.D. test at 0.05 level.**

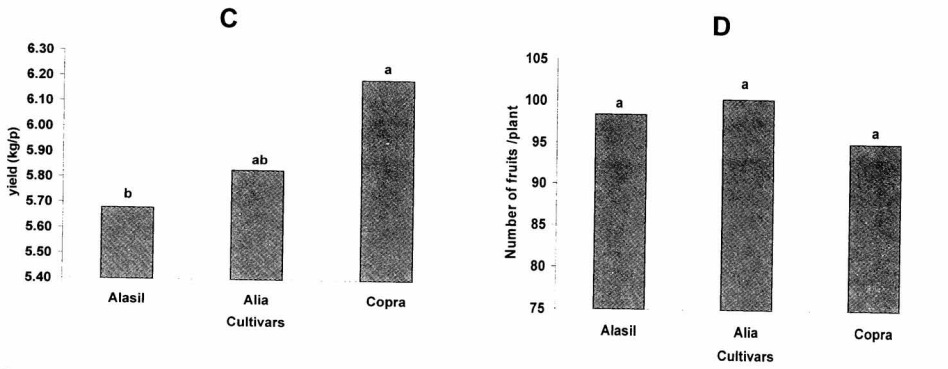

Fig. 6 (Contd.). Yield and yield components of three cucumber cultivars as influenced by five irrigation treatments (two levels of salinity in the irrigation water applied at various stages of growth):
C. Total yield (kg/plant) D. Total number of fruits/plant)
*** Bars in each graph sharing the same letter(s), within a particular group of means in each characters, are not significantly differ using the revised L.S.D. test at 0.05 level.**

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تأثير إضافة نوعين من مياه الري خلال مراحل النمو المختلفة في نمو وإنتاجية وجودة ثلاثة أصناف من الخيار تحت نظام الزراعة المحمية

عبد الله بن عبد الرحمن السعدون، و محمود عبادي وهب الله، و صفوت عثمان خليل

قسم الإنتاج النباتي، كلية علوم الأغذية والزراعة، جامعة الملك سعود،

ص. ب ٢٤٦٠ ، الرياض ١١٤٥١ ، المملكة العربية السعودية

(قدم للنشر في ١٤٢٦/٣/١٧هـ ؛ وقبل للنشر في ١٤٢٦/١٠/١٨هـ)

كلمات مفتاحية: خيار، ماء مالح، جودة المياه، أصناف، المحصول، مراحل النمو.

ملخص البحث. تم دراسة تأثير مستويين من ملوحة مياه الري (ماء البئر العادي ذو معامل التوصيل ٢,٦١ ملموز/سم، وماء البئر المحلى ذو معامل التوصيل ٠,٣٩ ملموز/سم) خلال مراحل النمو المختلفة في نمو وإنتاجية وجودة ثلاثة أصناف من خيار البيوت المحمية وهي عليا والأصيل وكوبرا. وقد نفذت خمس معاملات ري: (الأولى) الري بماء البئر المحلى طوال حياة النبات (١٠٥ أيام)، (الثانية) الري بماء البئر العادي طوال حياة النبات، (الثالثة) الري بالماء المحلى منذ الزراعة حتى بدء مرحلة الإزهار (٣٠ يوما) ثم الري بالماء العادي لنهاية التجربة، (الرابعة) الري بالماء المحلى حتى بدء مرحلة الإثمار (٣٥ يوما) ثم الري بالماء العادي لنهاية التجربة، (الخامسة) الري بالماء العادي حتى بدء مرحلة الإثمار (٣٥ يوما) ثم الري بالماء المحلى لنهاية التجربة. وقد سجلت بيانات النمو الخضري وهي طول النبات، عدد الأوراق، المساحة الورقية، الوزن الطازج والجاف، للأوراق، عدد الأيام للإزهار و للإثمار. وسجلت صفات الثمار وهي الطول والقطر والصلابة والعدد والوزن الطازج والجاف كما تم تقدير المحصول المبكر والكلي. وأدى استخدام ماء البئر العادي طوال حياة النبات إلى خفض معنوي للمحصول المبكر والكلي بنسبة ٤٦,٨ و ٢٨,٣ ٪ على الترتيب. كما أثر سلبا على الصفات المدروسة باستثناء الوزن الجاف للثمار. كان التأثير السلبي أقل وضوحا في جميع الصفات (باستثناء صفة المحصول المبكر) عند الري بالماء العادي حتى الإثمار ثم الري بالماء المحلى أقل وضوحا. لم تسجل اختلافات معنوية بين المعاملتين الثالثة والرابعة وكان تأثيرهما متوسطا على جميع الصفات باستثناء صفة المحصول المبكر. اختلفت الأصناف معنويا فيما بينهما في معظم الصفات وبخاصة صفات المحصول ومكوناته، حيث أعطى الصنف كوبرا أعلى قيم للمحصول المبكر والكلي وكذلك متوسط وزن الثمرة، تلاه الصنف عليا ثم الأصيل على الترتيب. على اعتبار أن صفات النمو الخضري

والثمري لم تتأثر كثيرا بمعاملة الري الخامسة وأن المحصول الكلي نقص بنسبة ٧,٢٪ فقط مقارنة مع المعاملة الأولى، لذا يمكن التوصية باستخدام ماء البئر العادي في الري حتى فترة عقد الثمار ثم الري بالماء المحلى مما يساهم في خفض التكلفة العالية لتحلية المياه.