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PLANT PRODUCTION

Growth and Productivity of Tomato and Cucumber as Affected by Intermittent Flowing Solution in Nutrient Film Technique

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Abstract. The influence of intermittent flowing solution on the growth and yield of tomato *Lycopersicon esculentum* Mill, cv. Dombito and cucumber *Cucumis sativus* L, cv. Dina grown hydroponically in nutrient film technique (NFT) was studied. Seedlings of tomato and cucumber were transplanted at the fifth leaf stage to NFT gullies. The day and night temperatures of the greenhouse were 23°and 19° C, respectively. Two solution circulation treatments were tested, 10 minutes on, 5 minutes off (T1) and 10 minutes on , 10 minutes off (T2). Vegetative growth of the plants was measured three times during the experiment, 30, 82 and 152 days after transplanting for tomato and 21, 78 and 92 days after transplanting for cucumber. Circulation treatments did not affect the vegetative growth of tomato. Vegetative growth of cucumber was slightly higher for T1 plants in the first sample and for T2 plants in the other two samples, but the difference did not reach a significant level. Early and total yield of tomato, as fruit number and weight per plant, was not affected by the circulation of the nutrient solution. Circulation of the nutrient solution for 10 minutes on, 10 minutes off (T2) extended the harvesting period of cucumber for two weeks, which resulted in a significant higher total yield.

Introduction

The standard method of growing greenhouse vegetables throughout the world is in the soil. The greenhouse crops productivity decreases with the time. This reduction caused by several factors including the excessive build up pathogens and environmental and health restrictions in using soil fumigants [1]. The build up of salinity resulted from the heavy use of fertilizer and brackish irrigation water is another factor. These problems induced the change over to hydroponic culture. Van Os [2] reported that 95% of the fruit vegetables crops (tomato, cucumber, and pepper) in Netherlands have changed to hydroponic culture.

Nutrient Film Technique (NFT) is one of the most advance hydroponic systems. In NFT the plants are grown in a shallow stream of recirculating solution in which are dissolved all the nutrient required for growth. Since Cooper popularized the practical

guidelines for NFT in 1973, the commercial production of vegetables and flowers using NFT has been increased and the cultural practices has been improved.

Root environment is an important factor in plant production using NFT and intermittent flowing solution can be used to control the plant growth. The intermittent flow will repeatedly expose the root to air, which would result in better root aeration. When using this technique, the pump is off for much of the time with a saving in pump, solution and in electricity [3]. The intermittent flow also reduces the water consumption and increases the water use efficiency [4 , 5].

Tomato has been grown successfully in NFT and the intermittent flowing solution can be used to restrict the early vigorous vegetative growth [3 , 6]. El-Behairy *et al* [7] correlated the flowing of the nutrient solution with the accumulated radiation at different growth stages of cherry tomato. They found that intermittent flow has increased the early yield and reduced fresh and dry weight of the root but no significant effect was observed on total yield. Cucumber plants failed to produce enough yield in NFT. This was attributed to the root die back and aerobic condition [8]. Sharaf *et al* [5] grew cucumber plants in NFT gullies, supplied with continuous and intermittent flowing solution depends on accumulative radiation and they did not find a significant difference between the treatments on plant growth parameters. The objective of the present study was to evaluate the effect of two regimes of flowing solution on the growth and yield of tomato and cucumber grown in NFT.

Materials and Methods

Tomato (*Lycopersicon esculentum* Mill.) and cucumber (*Cucumis sativus* L.) plants were grown in a standard NFT set up in a greenhouse compartment at the Agricultural Research and Experimental Station, College of Agriculture, King Saud University. Seeds of tomato, cv. Dombito and cucumber, cv. Dina were sown on 6 Nov. 1995 in a jiffy-7 blocks. Seedlings were transferred to NFT gullies, after being selected for uniformity, on 10 Dec., 1995 for tomato and on 28 Nov., 1995 for cucumber. The NFT gullies were made of black and white polyethylene strip laid upon 8 m long benches. The plants were spaced on 50 cm apart resulting in a plant density of 2 plants m^{-2}. Tomato plants were terminated on 15 June, 1996 and cucumber plants on 25 March, 1996.

The treatments consisted of two solution circulations; i.e., 10 minutes on, 5 minutes off and 10 minutes on, 10 minutes off. Number of plants per treatment was 248. The treatments were arranged in a complete randomized design (CRD) with four replicates and two gullies for each treatment. The greenhouse was divided into two sections for tomato and cucumber and the collected data was analyzed separately for each crop using SAS program. Least significant difference (LSD) was used to compare the treatment means. The plants were received a complete nutrient solution for which EC was 2.0 ± 0.5 dS m^{-2} and pH at 6.0 ± 0.5. Nutrient solution was monitored and automatically adjusted for EC and pH by controller injecting nutrient stock solution and acid into the

catchment tank. The pH was corrected using 5% acid mixture of nitric acid and phosphoric acid (2:1). Commercial nutrient solution, Hydrogarden*, was used as a stock solution. Main nutrients concentration of circulating solution (in pmm) was: 200 N, 60 P, 300 K, 170 Ca, 50 Mg, 3.4 Fe, 0.34 Mn, 0.29 Zn and 0.05 Cu and the nutrient solution was replaced every four weeks.

Greenhouse temperature was 23° C and 19° C during day and night respectively with approximately 70% relative humidity. The vegetative growth measurements of tomato and cucumber plants including plant height, leaf number, leaf area and fresh and dry weight were carried out at 30, 82 and 152 days after transplanting for tomato and 21, 78 and 92 days after transplanting for cucumber. Leaf area was not measured in the third sample. Growth analysis including relative growth rate (RGR), relative leaf area growth rate (RLAGR) and leaf area ratio (LAR) were calculated according to Hunt [9]. Tomato fruits were harvested at maturity and cucumber fruits at 15 cm in length and fruit picking was carried out twice or three times a week. Fruit harvest commenced 111 and 43 days after transplanting for tomato and cucumber, respectively and continued until the end of the experiment. The early yield for tomato and cucumber was calculated as the fruit production in the first two weeks (Approximately 25% of total yield).

Results and Discussion

Vegetative growth of tomato and cucumber plants was determined at different stages of growth. Results presented in Table 1 showed plant height, leaf number and area, fresh and dry weight of tomato plants 30, 82 and 152 days after transplanting. In the first and second samples, plant height was slightly higher for the T2 plants compared with T1 plants but the difference did not reach the significant level. Similar result was observed for the leaf area. Shoot fresh and dry weight was significantly higher for the T2 plants in the first sample. In the second and third samples, the fresh and dry weights of the T2 plants were higher but the difference was not significant. The same trend was observed for the root fresh and dry weight. Growth analysis measurement of tomato plants including RGR, RLAGR and LAR were presented in Table 2. RLAGR was significantly higher for the T1 plants but no significant difference was observed for the RGR and LAR parameters.

Different results were reported on the effect of the intermittent flow on the growth parameters of different crops. Abou-Hadi*et al* [4] did not find any significant effect on the dry weight and leaf number of butter head lettuce by the intermittent flow of the nutrient solution. While other reporters [3 ,6] indicated the possibility of restricting the vigorous vegetative growth of tomato plants grown in NFT by intermittent flowing solution.

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*Mention of trade name is for reader convenience and does not imply its approval to the exclusion of other product that may also be suitable.

Vegetative growth and growth analysis measurement of cucumber plants are presented in Tables 3 and 4. Cucumber vegetative growth was slightly restricted by increasing the intervals of solution flow. Plant height was significantly higher for the T1 plants in the first sample but the difference did not reach the significant level in the second and third samples.

Table 1. Growth characteristics of tomato as affected by the nutrient solution intermittent flow at different sampling dates

Solution circulation (minutes)	Plant height (cm)	Leaf number (leaf / plant)	Leaf area (cm^2)	Fresh wt. (g / plant)	Dry wt. (g / plant)
First sample (30 days after transplanting)					
(10 on /5 off)	45.3 a*	11.0 a	2694.5 a	152.0 b	9.01 b
(10 on /10 off)	49.5 a	10.9 a	3370.3 a	189.6 a	11.16 a
Second sample (82 days after transplanting)					
(10 on / 5 off)	155.5 a	27.8 a	25309 a	1343.8 a	103.7 a
(10 on / 10 off)	166.8 a	27.4 a	28878 a	1606.3 a	122.2 a
Third sample (152 days after transplanting)					
(10 on / 5 off)	319.0 a	23.6 a	___	894.0 a	83.9 a
(10 on / 10 off)	304.5 a	26.3 a	___	998.9 a	114.1 a

* Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) by LSD test.

Table 2. Relative growth rate (RGR), relative leaf area growth rate (RLAGR), leaf area ratio (LAR), root fresh weight (fwt) and root dry weight (dwt) of tomato as influenced by the nutrient solution circulation

Solution circulation (minute)	RGR	RLAGR	LAR	Root fwt. (g / plant)	Root dwt. (g / plant)
(10 on / 5 off)	0.059 a*	0.0415 a	272.4 a	106 a	16.2 a
(10 on / 10 off)	0.044 a	0.0323 b	270.2 a	107 a	21.4 a

* Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) by LSD test.

Table 3. Growth characteristic of cucumber as affected by the nutrient solution intermittent flow at different sampling

Solution circulation (minutes)	Plant height (cm)	Leaf number (leaf / plant)	Leaf area (cm^2)	Fresh wt. (g / plant)	Dry wt. (g / plant)
First sample (21 days after transplanting)					
(10 on / 5 off)	62.6 a*	9.9 a	1405.8 a	58.7 a	2.92 a
(10 on / 10 off)	53.3 b	9.3 a	1225.2 a	53.5 a	2.63 a
Second sample (78 days after transplanting)					
(10 on / 5 off)	273.9 a	27.5 a	10897 a	522.3 a	35.4 a
(10 on / 10 off)	268.3 a	30.1 a	11229 a	586.4 a	39.74 a
Third sample (92 days after transplanting)					
(10 on / 5 off)	390 a	49.8 b	___	616.8 a	64.1 a
(10 on / 10 off)	385 a	80.3 a	___	855.1 a	79.1 a

* Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) by LSD test.

Table 4. Relative growth rate (RGR), relative leaf area growth rate (RLAGR) and leaf area ratio (LAR) of cucumber as influenced by the nutrient solution circulation

Solution circulation (minutes)	RGR	RLAGR	LAR
(10 on / 5 off)	0.0533 a*	0.1518 a	401.7 a
(10 on / 10 off)	0.0583 a	0.0468 a	382.6 a

* Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) by LSD test.

Leaf number and area, shoot fresh and dry weight were slightly higher for the T1 plants in the first sample, while in the second and third samples these parameters were slightly higher for T2 plants but the difference was not significant in the three samples. Similar result was reported by Sharaf *et al* [5]. They did not find any significant effect on the final vegetative growth of cucumber plant grown in NFT using the intermittent nutrient solution flow. The growth analysis measurements did not differ among the treatments.

Fruit harvest of tomato started 111 days after transplanting and continued for 8 weeks (Fig. 1a,b). Early and total yield of tomato plants were not affected by the treatments (Table 5). Lack of significant difference in tomato crop might be attributed to the short intervals between the solution circulation. This is also supported by the results of the vegetative growth measurments. Cucumber fruit harvest started 43 days after transplanting and continued for 9 weeks for T1 plants and 11 weeks for T2 plants (Fig. 2a,b). Switching off the circulation of the nutrient solution for 10 minute (T2) caused a significant reduction in the early yield in cucumber compared with 5 minute (T1) but it was extended the harvesting period for two weeks (Table 6). This might be a result of improvement aeration of the root system of T2 plants. At the end of the experiment the total yield in cucumber, as fruit number and weight, was significantly higher for the T2 plants. Higher early yield of T1 cucumber plants and total yield of T2 plants were associated with higher vegetative growth for T1 plants in the first sample and T2 plants in the third sample.

Table 5. Effect of intermittent flow of the nutrient solution on the early and total yield of tomato

Solution circulation (minutes)	Early yield		Total yield	
	Fruit number (f/p)	Fruit weight (kg/p)	Fruit number (f/p)	Fruit weight (kg/p)
(10 on / 5 off)	4.24 a*	0.476 a	34.38 a	3.94 a
(10 on / 10 off)	4.52 a	0.507 a	35.57 a	3.98 a

* Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) by LSD test.

Table 6. Effect of intermittent flow of the nutrient solution on the early and total yield of cucumber

Solution circulation (minutes)	Early yield		Total yield	
	Fruit number (f/p)	Fruit weight (kg/p)	Fruit number (f/p)	Fruit weight (kg/p)
(10 on / 5 off)	4.27 a*	0.44 a	29.53 b	2.058 b
(10 on / 10 off)	3.19 b	0.32 b	44.27 a	2.88 a

* Means within a column followed by the same letter are not significantly different ($p \leq 0.05$) by LSD test.

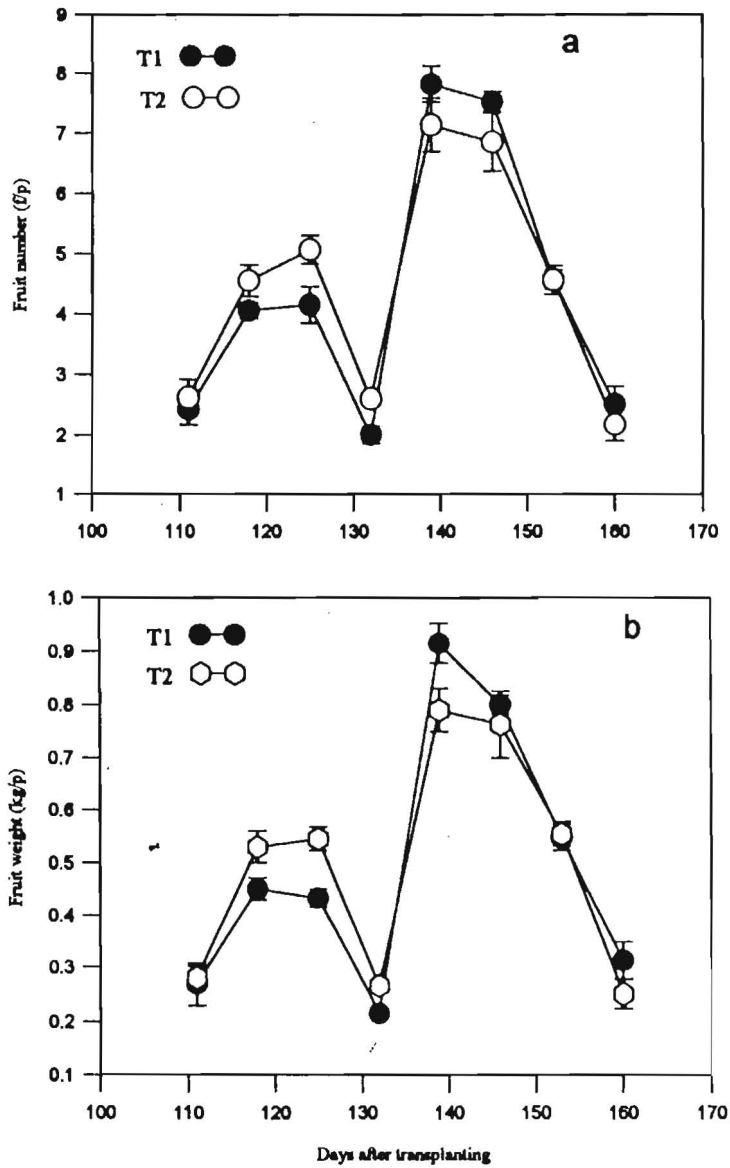

Fig. 1. Tomato fruits number (a) and weight (b) per plant as influenced by nutrient solution circultion (T1 10 min. on, 5 min. off and T2 10 min on, 10 min off). Vertical bars represent the SE of the means.

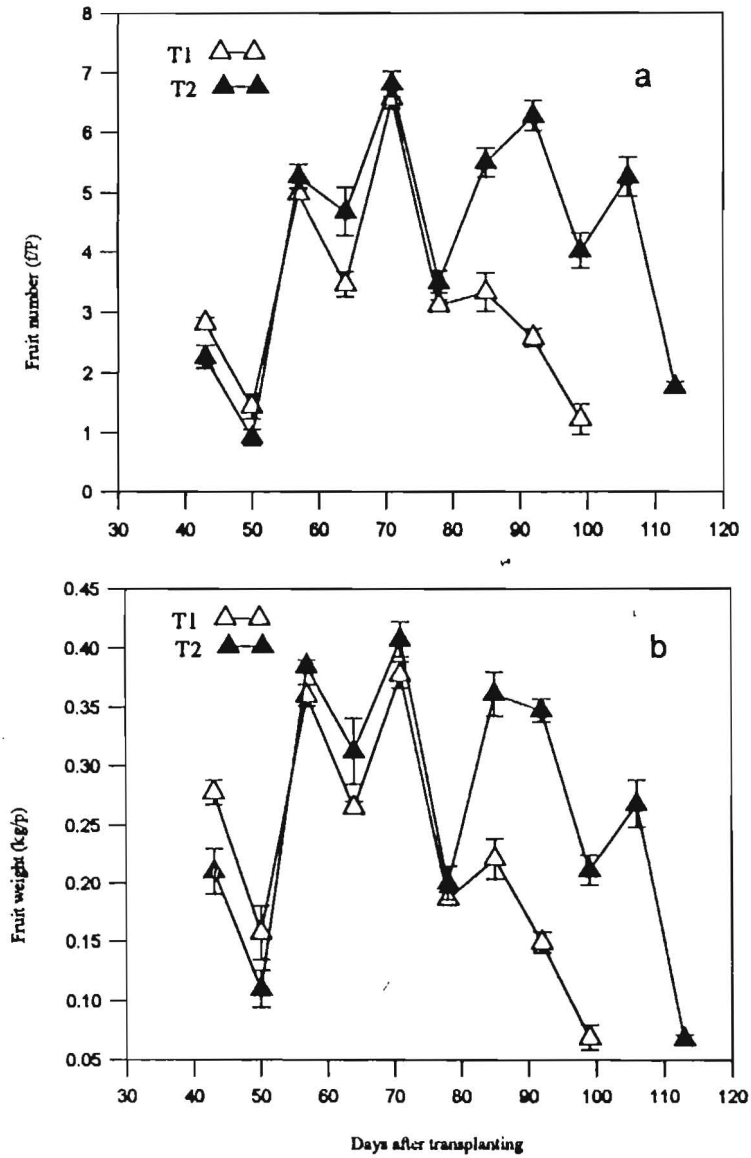

Fig. 2. Cucumber fruits number (a) and weight (b) per plant as influenced by nutrient solution circultion (T1 10 min. on, 5 min. off and T2 10 min on, 10 min off). Vertical bars represent the SE of the means.

Intermitting flow of the nutrient solution reported to increase the early yield of tomato crop but did not affect the total yield [6 ,7]. While Economakis [10] reported a marginal decrease in flower production by interrupted the nutrient solution flow and higher yield was produced by the combination of solution heating and intermittent solution flow. During the period of switching off the solution circulation, the plants might be subjected to a short term of water stress, especially at the time of high evaporative demand during the midday. This effect might restricte the early plant growth. The effect of short term stress was more pronounce on cucumber plants than on tomatoes. This could be due to the higher sensitivity of cucumber to this short-term stress compared with tomato plants

In conclusion, result of this study indicated that intermittent flow of the nutrient solution, with a short interval, could be used without a significant reduction in tomato yield in NFT. Cucumber growth and yield improved under this technique as a result of better root aeration.

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تأثير سريان المحلول المتقطع على نمو وإنتاجية الطماطم والخيار المزروعة باستخدام تقنية الغشاء المغذى

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ملخص البحث. أجريت دراسة لتحديد تأثير سريان المحلول المتقطع على نمو وإنتاجية الطماطم والخيار باستخدام تقنية الغشاء المغذى (NFT). حيث تم نقل بادرات الطماطم (صنف ديمبيتو) والخيار (صنف دينا) إلي قنوات الزراعة بعد وصولها لمرحلة الورقة الحقيقية الخامسة. تم ضبط درجة الحرارة داخل البيت المحمى على ٢٣°م نهارا و١٩°م ليلا. تمت دراسة معاملتين من سريان المحلول المتقطع، في الأولى يتم التشغيل لمدة عشر دقائق ثم إيقاف لمدة خمس دقائق وفى الثانية تم مضاعفة فترة الإيقاف بحيث تكون فترة التشغيل عشر دقائق ثم إيقاف سريان المحلول المغذى لمدة عشر دقائق.

تم خلال التجربة تقييم للنمو الخضري للطماطم والخيار على ثلاث مراحل. حيث تم قياسه للطماطم بعد ٣٠ ، ٨٢ و ١٥٢ يوما من الزراعة وللخيار بعد ٢١ ، ٧٨ و ٩٢ يوما من الزراعة. أظهرت النتائج زيادة طفيفة في النمو الخضري لنباتات الخيار في المعاملة الأولى في المرحلة الأولى وللمعاملة الثانية في المرحلة الثانية والثالثة ولكن هذه الفروق لم تصل إلي درجة المعنوية. لم يظهر للمعاملات المستخدمة تأثير على المحصول المبكر والمحصول الكلى للطماطم بينما أظهرت النتائج أن المحصول المبكر لنباتات الخيار كان أعلى في المعاملة الأولى مقارنة بالمعاملة الثانية. أدت زيادة فترة الإيقاف (١٠ دقائق تشغيل و ١٠ دقائق إيقاف) إلى زيادة فترة الحصاد لمدة أسبوعين في الخيار مقارنة بالمعاملة الأولى، مما نتج عنة زيادة معنوية في المحصول الكلى لنباتات المعاملة الثانية. كما أدت المعاملة الثانية إلى زيادة فترة الحصاد في نباتات الخيار لمدة أسبوعين مما نتج عنة زيادة معنوية في المحصول الكلى.