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Effect of Root-Zone Warming and Air Heating on Snap Beans Plants Grown in Nutrient Film Technique (NFT)

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THE EXPERIMENT was carried out at El-Bosaily Protected Cultivation site, El-Behaira Governorate, during winter seasons of 2000/2001 and 2001/2002.The aim of the experiment is to improve yield quantity and quality of snap beans grown in winter using nutrient film technique (NFT) culture to study the effect of heating air or nutrient solution comparing with soil.

Nutrient solution temperature was adjusted to 25 °C day & night and air temperature was adjusted not to be less than 16 °C at night. The experiment contains six treatments as follows:

1- Soil grown plants under unheated plastic house (control).
2- Soil grown plants with air heating
3- Nutrient film technique without heating
4-Nutrient film technique with heated nutrient solution
5- Nutrient film technique with air heating
6- Nutrient film technique with heated both air and nutrient solution

The results of the experiment indicated that using the nutrient film technique as a method of growing snap beans at winter gave the highest yield and exportable yield of green pods in comparison with soil cultivation with or without air heating. Also, using air heating combined with nutrient solution heating or heating nutrient solution only gave the highest yield and quality.

Snap bean is an important crop in Egypt for local consumption as well as for exportation. This crop is grown in the open field in two main seasons, *i.e.* spring and autumn using bush type cultivars. The autumn crop ends by early January and the spring crop starts by early April. Therefore, a gap of three months, *i.e.* January, February and March without production of snap beans exists in Egypt and in several Mediterranean countries because of low temperature prevailing during this period of the year. For instance, temperature in Egypt falls to less than 7 °C at night in January and February. The main demand of the Egyptian snap beans for exportation is located in the winter season.

The optimum temperature for flowering and fruit setting of snap beans is about 25/15 °C-day/ night. As a result of high demand for snap beans during winter, research work is needed for producing high yield and quality pods during this time of the year (Saleh, 1996). Using NFT system provides an excellent means for avoiding the limitation of low temperature. Low temperatures in the root zone greatly restrict root growth, transpiration and ion uptake (Moorby & Graves, 1980; Graves & Hurd, 1983 and Mongeau & Stewart, 1984).

Thompson & Langhans (1998) observed that lettuce growth was maximized at high air temperatures when 24°C root temperature in hydroponic systems was applied.

Root temperature is thought to be one of the major factors which directly affect plant growth (Ikeda & Osawa, 1984) and correspondingly, increase yield (Moss, 1985).

Root zone warming is more specific to soilless cultivation methods and especially applicable to the nutrient film technique (NFT). In this system, warming only a moderate volume of nutrient solution significantly reduces the expenditure of energy (Moorby & Graves, 1980 and Moss, 1983).

It is well known that plant roots function is better at a temperature between the high tens to the mid twenties. Outside this range, roots will function poorly. Nutritional problems can be resulted from high root temperatures as well as low root temperature (Barry, 1996). Solution temperature affects water uptake. It may be influenced by the changes in root structure that take place when the recirculating solution is heated (Al-Harbi & Burrage,1992)

For these reasons, an investigation was performed to study the effect of warming the nutrient solution and / or air heating on the yield and fruit quality of winter crop snap beans.

Material and Methods

This experiment was carried at El-Bosaily Protected Cultivation site, Behaira Governorate during the winter seasons of 2000/2001 and 2001/2002. Seeds of snap bean (*phaseolus vulgaris*) cv. Serbo (round type) were obtained from the seed produced from Vegetable Research Institute, Agriculture Research Centre, Dokki, Cairo.

Plant material

Snap bean (*Phaseolus vulgaris*) cv. serbo was used in this experiment. Seedlings were prepared for NFT system as follows:

Three seeds of snap bean were sown in a perforated black bag 250 ml filled with washed Gerick pumice plus peat moss plus vermiculite (60%:20%:20% v: v: v) and placed in the nursery. After full emergence of all seedlings, bags were transferred to the NFT channels on 15^{th} of October in both seasons. For soil cultivation treatments, seeds were directly sown in the soil. For both growing systems, planting distance was 50 cm between plants.

Cultivation system

Plastic house with diminsion of 70 m lengths, 9 m wide and 3.25 m height was used to install the NFT system. The plastic house was divided into two parts; each part has five ridges (30m long * 1m wide) with a slope of 1% in direction from the door to the middle.

White and black polyethylene sheets of 200-micron thickness, 70 cm wide and 30 m long were used to form the gullies. The gullies were laid on top of the ridges. Two gullies were placed on each raised bed to construct channels.

Two catchments tanks with holding capacity of 1.5 m^3 each were dugged in the middle of the greenhouse.

Two Submersible pumps (0.33 HP.), one for each tank were used to deliver the nutrient solution in the polyethylene pipe (25 mm) to the top of gullies.

Heating

Characters of air heater

Warming was performed with air heaters with 8000-kilo calories/hour, using kerosene as an energy source and electricity for the fan to force the heated air around the heater into the perforated tubes. Kerosene consumption was determined and was found to be 7.5 L/hr. Warming treatments was adjusted at 16 °C during day and night.

The duration of the heater working hours was recorded in order to evaluate kerosene consumption.

Heating of the nutrient solution

Stainless steel coil was used for heating of the nutrient solution. The coil was sited in the catchments tank and controlled by a thermostat. The temperature of the nutrient solution was adjusted at 25 °C day and night.

The experimental treatments

Six treatments were used as follows:

1- Soil cultivation in plastic house (control)
2- Soil cultivation with air heating
3- Nutrient film technique without heating
4- Nutrient film technique with heated nutrient solution
5- Nutrient film technique with air heating
6- Nutrient film technique with both air and solution heating

The nutrient solution used was adapted from Cooper solution (Cooper, 1979) depending on the analysis of the local water (El-Behairy, 1994).

Measurements

Pod length

The average length of the pod was measured in cm by Venire caliper.

Pod diameter or width

The average pod diameter was measured in cm by Venire caliper.

The average fresh weight of the pod was determined in g.

Total soluble solids (TSS)

Total soluble solids were determined in green pods with ABBE refracto meter (A.O.A.C, 1984).

Pod dry matter percentage

Known weight of each sample was separately oven dried at 70 °C till constant weight was reached. Dry matter percentage was calculated.

Total protein

Total protein was determined as g/100 g dry weight using Micro- Kjeldahle method according to Piper (1947).

Fibers

Fibers were determined as g/100 g dry weight according to A.O.A.C (1984).

Total carbohydrate

Total carbohydrate was determined as g/100 g dry weight according to Mgnetski *et al.* (1959).

Total yield

Total yield, included all the green pods was determined as kg/m^2.

Exportable green pod yield

Exportable green pod yield, determined as normal pods (good formed and not curved), as kg/m^2.

A complete randomized block designed with three replicates arranged the treatments.

Results and Discussion

The physical properties of pods

The effect of different heat treatments on pod length, pod diameter and average pod weight for two seasons are presented in Table 1.

TABLE 1. Effect of air and / or solution heating on physical properties of snap beans pods in the first and second seasons of 2000/2001 and 2001/2002.

Treatments		Pod length (cm)	Pod diameter (cm)	pod weight (gm)
First season				
Soil	No heat	10.13	1.07	6.43
	Air heat	11.97	1.15	7.52
NFT	No heat	10.03	1.08	6.6
	Solution heat	10.57	1.18	7.63
	Air heat	12.27	1.12	8.17
	Air+ solution heating	12.63	1.25	8.28
LSD at 5 %		0.46	0.09	0.29
Second season				
Soil	No heat	10.27	1.27	6.57
	Air heat	12	1.2	7.67
NFT	No heat	10.17	1.23	6.83
	Solution heat	10.6	1.22	7.7
	Air heat	12.38	1.27	8.1
	Air + solution heating	12.7	1.25	8.18
LSD at 5 %		0.5	N.S	0.24

Heat treatments increased pod length significantly. Air heating in soil treatment increased pod length significantly compared to unheated plants in soil treatment. Heating air and nutrient solution or heating air in NFT increased pod length significantly comparing with solution heating and no-solution heating treatments.

On the other hand, heating air and / or nutrient solution increased pod diameter significantly comparing with unheated treatments in NFT and soil. When air and nutrient solution was heated in NFT, pod diameter has increased significantly as compared with either air or solution heating. In the second season there were no significant differences in pod diameter among all heat treatments.

Average pod weight increased significantly by heat treatments. Air and nutrient solution heating together and air heating in NFT significantly increased pod weight in both seasons. The lowest average of pod weight was obtained when NFT and soil were unheated.

Improving pod characters probably due to the fact that the processes of cell division and / or cell elongation are faster at high temperature than at low temperature.

These results are in agreement with those obtained by Medany *et al.* (1990) on sweet pepper; Abou-Hadid *et al.* (1995) on snap beans; Saleh (1996) on snap beans and El-Behairy (2002) on cantaloupe

Chemical properties of pods

The results of chemical properties of pods obtained from the two seasons are illustrated in Table 2.

Heating air in all treatments reduced TSS significantly as compared with the other treatments. On the other hand, air-heating treatments showed no significant effect regarding total soluble solids (TSS) in pods. Similar trends were obtained in the second season. These results are in agreement with those of Medany *et al.* (1990) and El-Said *et al.* (1995) who found that heat treatments did not affect TSS of sweet pepper fruits.

Regarding pod dry weight, heating air and / or nutrient solution significantly reduced dry weight as compared with unheated treatments in both seasons. The reduction of dry matter content in fruits when air and nutrient solution were heated may be due to better water uptake as a result of warmer air combined with higher solution temperature. These results agree with those obtained by Medany *et al.*, 1990) on sweet pepper. Chil *et al.* (2001) found that percentage of dry matter of foliage was reduced at 20 and 25 °C of solution temperature.

El-Behairy (2002) found that the highest dry matter percentage for fruit was obtained when air and solution were heated.

Data of total carbohydrate percentage in the dry. pods indicated that heat treatments significantly decreased total carbohydrate comparing with control treatments in both season. Air and nutrient solution heating treatments decreased carbohydrate in all treatments significantly. There was no significant difference among air heating, nutrient solution heating in NFT and air heating in soil. This may be due to that low temperature prevents the transportation of carbohydrates from the leaves to the storage parts as mentioned earlier (Acock & Pasternak, 1986).

Air and / or solution heating, significantly reduced protein contents in the pods comparing with unheated treatments. No significant differences were found regarding protein contents in the pods among all heat treatments. The reduction in protein contents in the pods might be attributed to the increase in respiration rate under heat treatments.

Heating air and / or solution decreased fiber content in the pods produced in both seasons as compared with unheated treatments. Heating air and solution together significantly decreased fiber content in the pods as compared with the other heated and unheated treatments. There was no significant difference among all other treatments. These results may be due to the faster cell division, cell elongation and better water absorption with the warmer treatments. Also, these results may be attributed to that heating treatments reduced sugar contents which are considered as the building unit of fibers.

TABLE 2 . Effect of air and or solution heating on chemical properties of snap beans pods in first and second seasons (2000/2001) and (2001/2002).

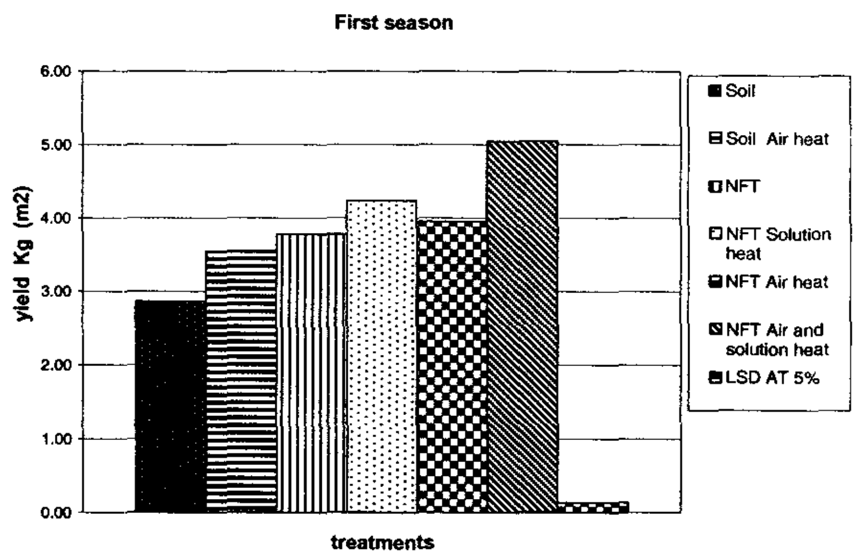
Treatment		Total soluble solids (TSS)	Dry weight of pods %	Total carbohydrate. %	Pod protein %	Fiber content%
First season						
Soil	No heat	5.3	10.32	19.3	16.42	13.39
	Air heat	4.78	7.97	18.47	13.57	11.17
NFT	No heat	5.4	10.78	20.5	15.78	12.1
	Solution heat	5.1	7.69	18.7	14.17	11.9
	Air heat	4.85	7.73	18.23	13.87	11.1
	Air +Solution heating	4.74	7.19	17.77	14.34	10.8
LSD at 5 %		0.12	1.51	0.6	1.63	0.43
Second season						
Soil	Non heat	5.41	10.9	19.75	16.35	13.2
	Air heat	4.8	7.85	18.89	13.85	11.2
NFT	Non heat	5.43	11.03	20.97	16.24	12.33
	Solution heat	5.13	7.88	19.13	14.33	12.2
	Air heat	4.95	7.91	18.65	14.01	11.23
	Solution +air heat	4.73	7.36	18.18	14.84	11.03
LSD at 5 %		0.23	1.5	0.484	0.994	0.407

Total yield

The effect of heat treatments on the total yield of snap beans is shown in Fig.1 for the two seasons.

All heating treatments significantly increased yield of the green pods over than unheated treatments in both seasons. The most effective treatment in inducing the highest yield was air and nutrient solution heating treatments followed by solution heating then by air heating and no-heat in NFT treatments. The total yields of heating treatments are increased as a result of increasing the vegetative growth that led to increase in the carbohydrates and protein levels.

These results were in the same line with Hurd & Graves (1985) who found solution temperature and air temperature at night influenced fruit production. Economaks & Krulj (2001) and El-Behairy (2002) found that the highest minimum solution temperature (25 °C) resulted in the highest total yield/plant.



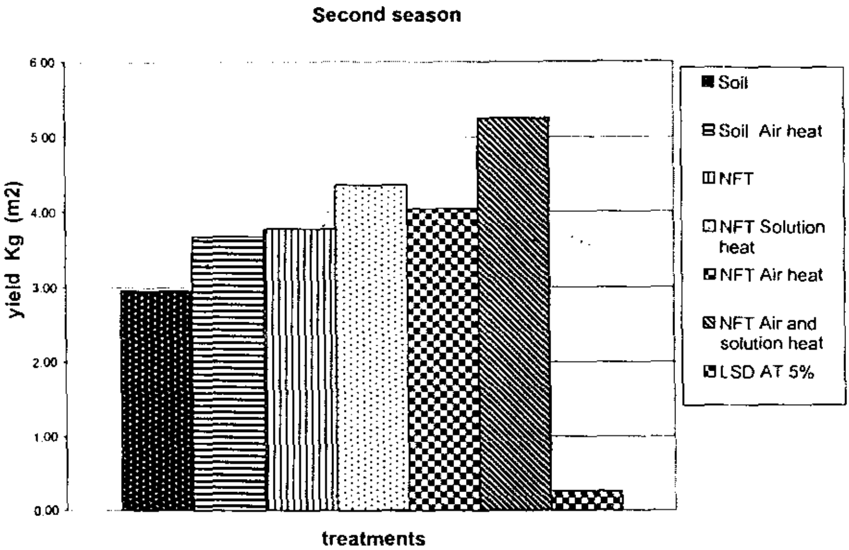


Fig 1. Effect of air and or solution heating on total yield (kg/m^2) in first and second seasons (2000/2001) and (2001/2002).

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تأثير تدفئه الجذور وتدفئه الهواء على نباتات الفاصوليا النامية فى نظام الفيلم المغذى.

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اجريت التجربة بمزرعة البوصيلى للزراعات المحمية بالبحيرة خلال موسمى الشتاء ٢٠٠٠-٢٠٠١ و ٢٠٠١-٢٠٠٢.

وكان الهدف من البحث تحسين انتاجية الفاصوليا النامية شتاء كماً وجودة باستخدام نظام الزراعة بالفيلم المغذى ودراسة تأثير تدفئة الهواء أو تدفئة المحلول المغذى مقارنه بالتربة.

تم ضبط درجة حرارة المحلول المغذى باستخدام سخان كهربى على درجه ٢٥ م° خلال ساعات الليل والنهار ودرجة حرارة الهواء باستخدام سخان يعمل بالسولار علىأ لا تقل درجه الحرارة عن ١٦ م° أثناء الليل.

وقد تضمنت التجربة ٦ معاملات كالتالى:

١- النباتات النامية فى التربة تحت الصوب الغير مدفأة (كنترول).
٢- النباتات النامية فى التربة مع تدفئة الهواء.
٣- الزراعة فى الفيلم المغذى بدون تدفئة.
٤- الزراعة فى الفيلم المغذى مع تدفئة المحلول.
٥- الزراعة فى الفيلم المغذى مع تدفئة الهواء.
٦- الزراعة فى الفيلم المغذى مع تدفئة كلا من الهواء والمحلول.

وقد أوضحت نتائج التجربة أنه باستخدام نظام الزراعة فى الفيلم المغذى لانتاج الفاصوليا الخضراء خلال الشتاء أعطى أعلى محصول وكذلك أعلى نسبه للقرون الخضراء الصالحة للتصدير مقارنه بالزراعة الأرضيه المدفأه هواء او الغيرمدفأ هواء. أيضا ظهر أن استخدام تدفئة الهواء مع تدفئة المحلول المغذى أو تدفئة المحلول المغذى فقط بدون تدفئة هواء أعطى أعلى محصول وجودة بينما ظهر أن استخدام تدفئة الهواء أو بدون تدفئة الهواء فى نظام الفيلم المغذى كان أفضل من الزراعه الارضيه المدفأ والغير مدفأ.