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Effect of Minimum Root-zone Temperature on the Growth and Production of Greenhouse Sweet Pepper

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Abstract: A greenhouse experiment was conducted to investigate the effect of minimum root-zone temperature on the growth and production of sweet pepper plants grown under un-heated greenhouse conditions. Sweet pepper plants cv. Godeon were grown in NFT system in a plastic-house. Treatments were heated nutrient solution with minimum temperature 18°C and unheated nutrient solution (control). Results showed that raising minimum root-zone temperature was effective until mid-spring and no-longer needed afterward. Plant water use, plant height, leaf area increased by heating treatment however, number of leaves was not affected. Data of yield showed that both number and weight of harvested fruits were higher and average fruit weight increased by heating treatment while dry matter content of the fruits was not affected. Dry matter production was also improved by heating treatment. Data are further discussed in relation to the interaction between greenhouse climate and root-zone conditions.

Keywords: Root-zone temperature, C*apsicum annuum*, sweet pepper, NFT, plant water use, yield.

INTRODUCTION

Introduction of alternative substrates for greenhouse crops and the Nutrient Film Technique (NFT) raised the interest for the role of root temperature on plant growth due to the ability to control the root-zone layer more directly. There is evidence that nutrient/water uptake are affected by nutrient solution temperature [1-3]. One option for the grower to improve plant growth is to manipulate it. In practice, potential transpiration increases suddenly at sunrise [4] while water uptake may be delayed because of the low nutrient solution temperature since water uptake was reported to be improved by warming up the nutrient solution [1-2,5-6]. However, those latter researchers have used 24 hours/day heated nutrient solution. In countries like Egypt or regions like the Mediterranean, daytime temperature is high enough that there is no need to heat the nutrient solution during the day. On the other hand, during night-time, nutrient solution temperature may drop as a result of a drop of greenhouse air temperature (commonly unheated plastic-house). Therefore, heating the nutrient solution during night-time may be enough.

The aim of this study is to investigate the effect of raising minimum root-zone temperature rather than a constant 24-hours temperature.

MATERIALS AND METHODS

The experiment was carried out in an arched type, non heated, North-South oriented greenhouse located in Arid Land Agricultural Research Unit (ALARU), Dept. Horticulture, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.

Nutrient Film Technique (NFT) was used for the experiment. The growing channels were constructed using black-white polyethylene sheets 650-700 mm wide. This was folded to form a triangular structure to give 250-300 mm wide at the base. Ten channels were designed with a slop of 1:100 cm. The two boarder channels in addition to the neighbouring two were fed from a 2 m^3 unheated ground tank located in the side of the greenhouse while the other 6 channels were fed from 6 small ground tanks each is 120 litres located in the end of each channel. Nutrient solution was pumped by an electrical submersible pump to the beginning of each channel. EC of the nutrient solution was monitored on daily basis as well as pH and were kept in the range of 2.5 – 3.0 mS cm^{-1} and 5.5-6.0 respectively. Nutrient solution composition was as described by El-Behairy[7].

Treatments: Sweet pepper seedlings (*Capsicum annuum* Mill) cv. Godeon were transplanted on December 5th in

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the greenhouse in a density of 2.5 plant m^{-2}. Treatments started one week after transplanting to ensure homogeneity in root distribution. Treatments were heated and unheated nutrient solution using small electrical heaters. Heaters were set to work at minimum temperature of 18°C. Temperature of nutrient solution was monitored using floating temperature sensor.

Greenhouse climate and crop measurements: The greenhouse was not heated and natural ventilation was carried out when required by rolling up the plastic cover in the two sides of the greenhouse. This also insured new air going into the greenhouse so preventing CO_2 concentration from falling down due to photosynthesis. The rolled up openings were covered with screens for plant protection from insects.

Plant height, number of leaves and total leaf area per plant (m^2), using digital leaf area meter (LiCor, model 3100 Area meter), were recorded in each destructed sample. Fruits were harvested in mature green stage. Weight and number of fruits of the total yield were recorded. Total fresh and dry weights of the plants were measured in destructed samples which was carried out once a month. The experimental design was complete randomized block with three replicates.

RESULTS AND DISCUSSIONS

Daily average of nutrient solution temperature was positively affected by heating treatment (fig. 1). Heating treatments increased the daily average temperature of the nutrient solution by 5°C than that of non heated nutrient solution. The temperature of the nutrient solution in the two treatments started to increase as the experiment progressed. It can be seen that by mid spring there was no need for heating treatment.

Plant water use was clearly affected by warming up the nutrient solution (fig. 2). Cumulative water use by plants increased by 15% in heated nutrient solution compared to non-heated nutrient solution.

Plant height was also positively affected by heated nutrient solution treatment (fig. 3A). The increment in plant height was about 7%. As the number of internodes is related to number of leaves, the increment in plant height seemed to be due to longer internodes. This is because there was no significant effect of the treatments on the number of leaves per plant (Fig. 3B). Apparently the difference in root temperature by the treatment in this experiment did not affect the number of leaves per plant.

In a similar response to that of plant height, leaf area index responded positively to the heated nutrient solution (fig. 4A). With the same number of leaves for the two treatments, this positive effect comes from the increment in the average leaf area per leaf. Higher average leaf area per leaf must be brought about by higher cell elongation as a response to root zone temperature. Higher leaf area index reflected on higher dry matter production under heating treatment (Fig. 4B).

The data show that there were significant differences among the treatments ($p < 0.05$) concerning number of fruits per square meter (fig. 5A). A fluctuation in the number of fruits was very clear in the data. It is very clear that total weight is a reflection of the total number of the fruits (fig. 5B). The differences among the treatments were also significant at ($P < 0.05$).

Differences in the cumulative number and weight of fruits (Table 1) were also significant where heating treatment increased the two parameters.

Heated nutrient solution improved the average weight of individual fruits (Table 1). The difference started to disappear by the end of the experimental period. On the other hand dry matter content was not significantly different between the two heating treatments and averaged 8.5% (Table 1).

The majority of results of the studies on heating root-zone [1-2,8-15] showed a positive effect on crop production but it appears that crop responses to root-zone temperature may also depend on above ground factors such as air temperature [1,16-17] and light level [18]. The results of the present experiment agreed with these previous studies. Apparently under Egyptian conditions, low air night temperature occurs for a short time in the early morning [19]. Since the nutrient solution tank was barred in the soil, the effect of air temperature on the nutrient solution was relatively small. As a result, nutrient solution temperature differed by only 5°C between the two heating treatments and for a short time. It follows that the positive effect measured under heated nutrient solution treatment must have occurred during the first few hours of the morning. It was noticed that water uptake increased very rapidly with sunrise [4]. In that case if the temperature of the nutrient solution was low, water uptake would also decrease due to higher viscosity and lower metabolic activity of the root tissue [12]. It follows that plants will not be able to meet their fast increasing transpiration demands and a temporarily physiological water deficit will occur. This will lead to either a reduction in the transpiring surface (leaf area) and/or stomatal conductance. Lower total leaf area as well as lower stomatal conductance were observed as a result of low temperature in the root zone [20]. A reduction in leaf area and stomatal conductance will also lead to a reduction in photosynthesis. The increment in plant height due to increasing root zone temperature was totally due to longer internodes in tomato [16, 21] and the same explanation can be used here.

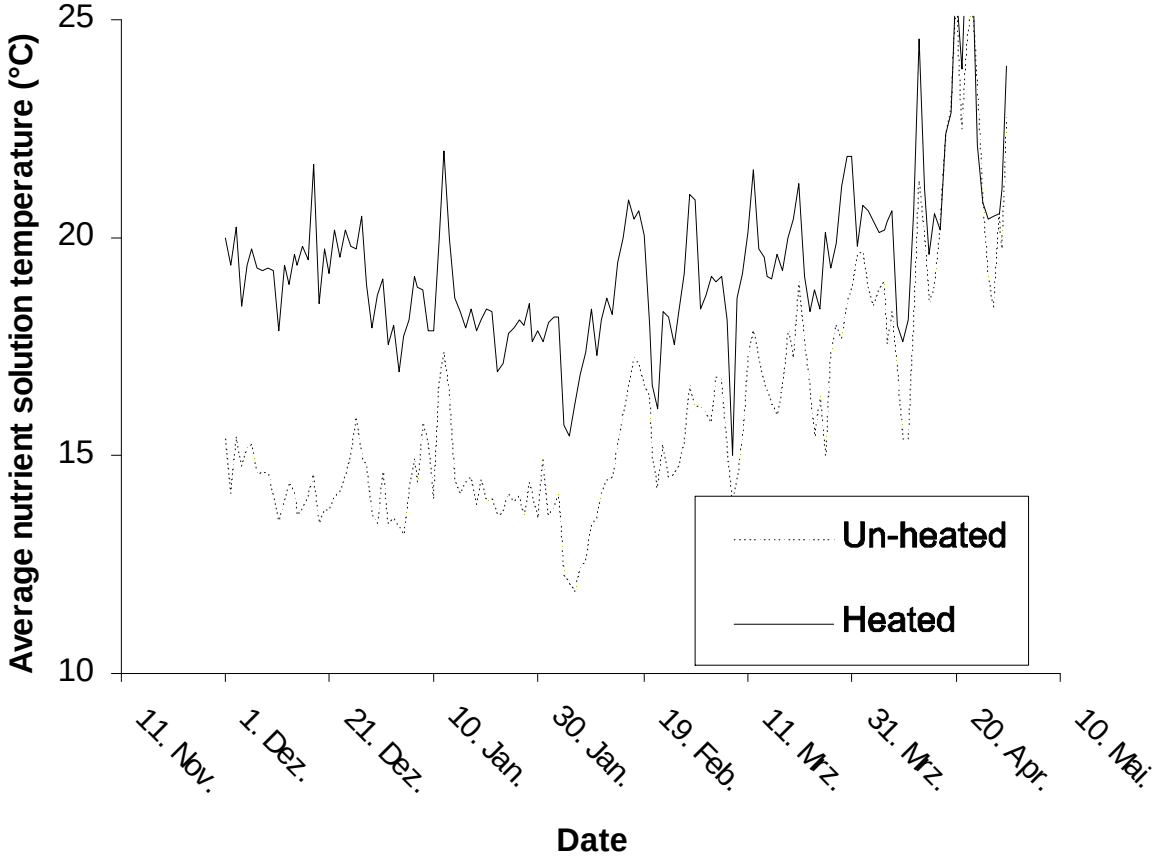

Figure 1: Average daily temperature of un-heated and heated nutrient solutions.

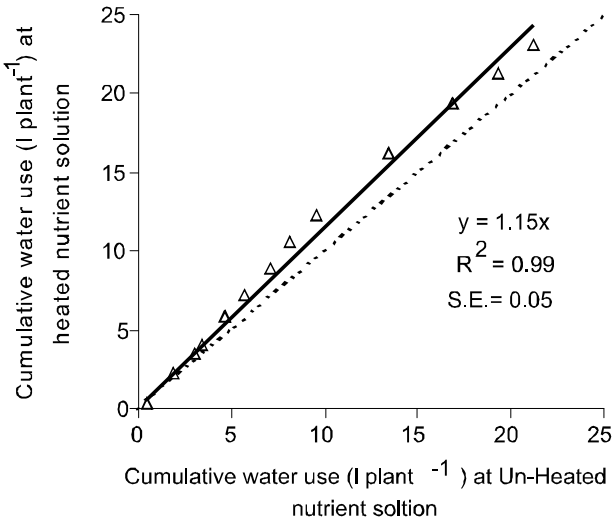

Figure 2: cumulative water use (l plant^{-1}) of sweet pepper plants grown in heated vs. non heated nutrient solution. Dotted line is 1:1 .

The positive effect of heating on yield production of pepper was reported earlier where 39% -76% increases in pepper yields were found from soil heating [22]. In this study, increasing yield production was due to an increase in both fruit number and average fruit weight. Gosselin and Trudel[16] did not find any effect of root zone temperature on the number of flowers per cluster in tomato. This indicates that the higher number of fruits that was observed in this experiment may come from a higher percentage of fruit set. The latter may be due to a higher assimilate production (function of leaf area and stomatal conductance) and/or a better plant water status under higher root zone temperature conditions. The two factors, more assimilates and better water status, may also be responsible for a higher average of individual fruit weight.

It can be concluded that under mild winter climate conditions, temperature of the root zone during the first few hours of the morning is the most critical parameter affecting plant water uptake. Hence setting the nutrient solution temperature to a minimum seems quite enough to improve plant growth and production.

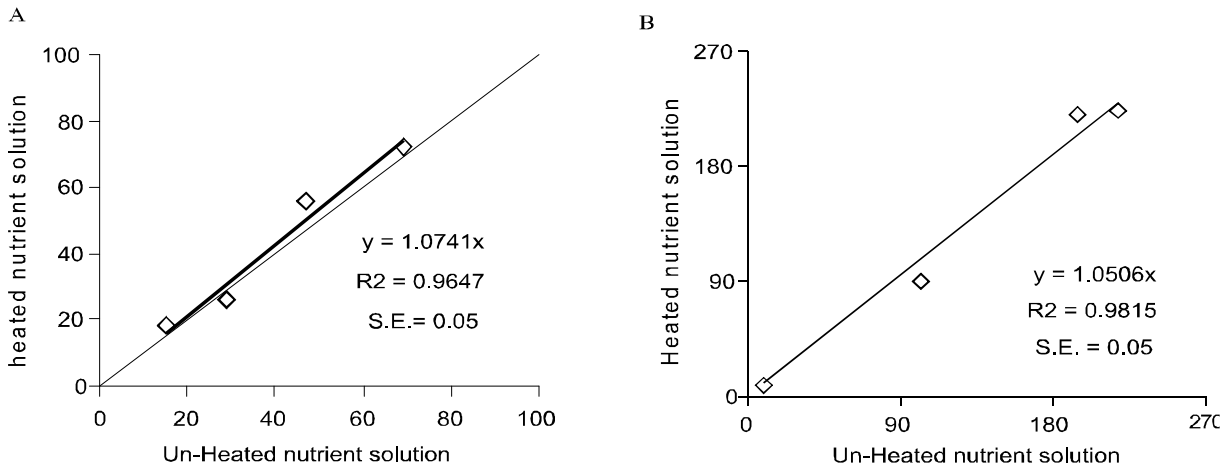

Figure 3: Plant height (cm) (A) and number of leaves (B) of sweet pepper plant grown in heated vs. unheated nutrient solution.

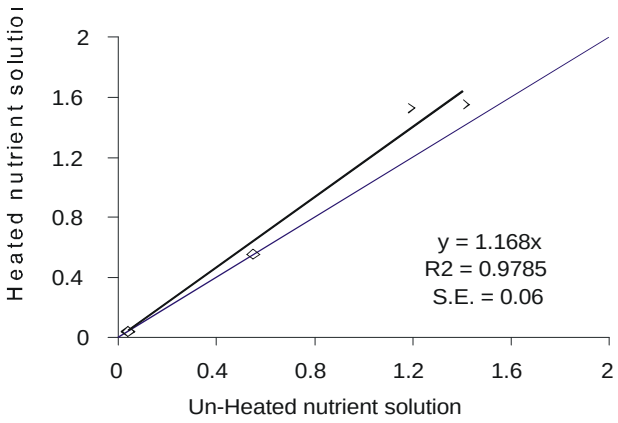

Figure 4: Leaf area index (LAI) of sweet pepper plants grown in heated vs. un-heated nutrient solution.

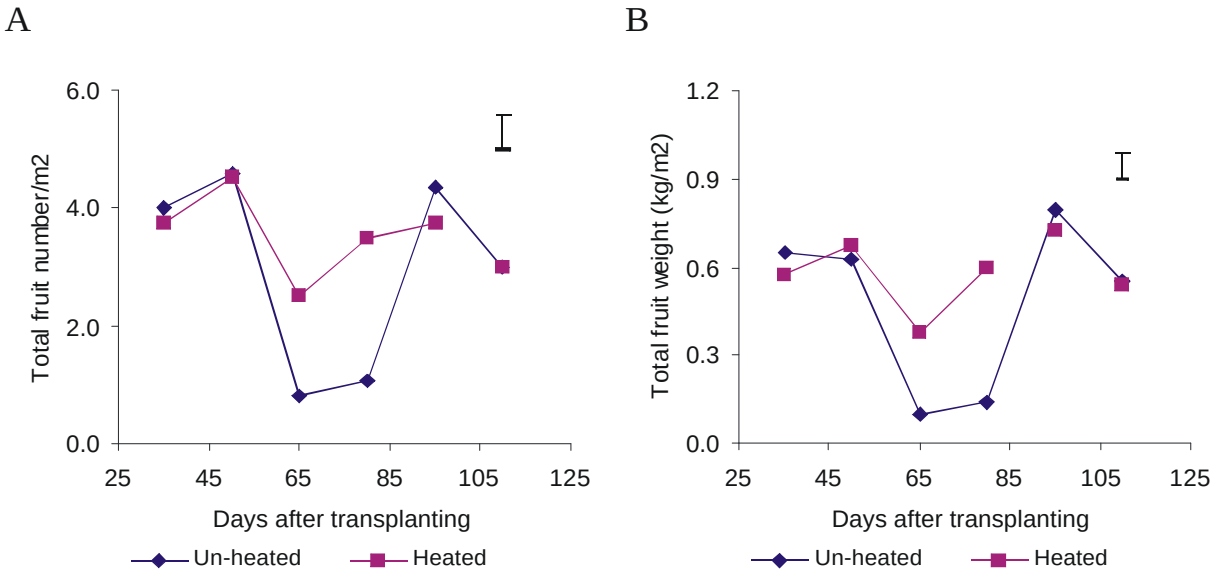

Figure 5: Total number (A) and weight (B) of fruit yield production under un-heated and heated nutrient solution treatments. Error bars are LSD 5%.

Table 1: Total number, weight of fruit yield and its quality (average individual fruit weight and fruit dry matter content) of sweet pepper plants grown in heated or unheated nutrient solutions. (N.S. not significant)

	Total number of fruits per m^2	Total weight of fruits (kg/m^2)	Average weight of individual fruit (g)	Fruit dry matter content (%)
Heated nutrient solution	21.02	3.49	163.2	8.4
Unheated nutrient solution	17.82	2.86	151.3	8.6
LSD 5%	02.93	0.56	008.9	N.S.

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