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Full Length Research Paper

Effect of regulated irrigation water temperature on hydroponics production of Spinach (*Spinacia oleracea* L)

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The effects of different temperature regimes of irrigation water on the growth rate of *Spinacia oleracea* L. were determined in the greenhouse for 8 weeks. The spinach seedlings were irrigated with water heated to various temperatures (24, 26 and 28°C) via pumps connected to 4 sets of water tanks each maintained at the experimental temperatures using Dolphin aquarium heaters. Unheated water from the tap supplied from the fourth tank served as control. All the plants were supplied with a mixture of Ocean HYDROGRO and Ocean HORTICAL nutrient solutions containing all essential elements. After 8 weeks of growth, results showed that leaf length (mm), leaf number and total fresh and dry weights (g per plant) was higher in plants grown at elevated temperatures compared with the control plants with optimum growth being recorded at 28°C. These results suggest that controlled production of spinach during winter seasons is possible by irrigation with heated water in a greenhouse.

Key words: Growth rate, root weights, shoots weights, leaf length, leaf number.

INTRODUCTION

Spinacea oleracea L (Chenopodiaceae) is an annual herb with deep tap root and shallow secondary root (Nonnecke, 1989). Commonly called spinach (English), the crop is mainly a winter vegetable crop which survives low temperatures (Nonnecke, 1989). The crop can however, be successfully grown under partial shade in summer provided there is sufficient moisture at the root zone (Klein, 2007). Spinach is considered to be a popular salad ingredient rich in iron content and a good source of folic acid (Roy and Chakrabarti, 2003). "Spinach salad" flavour is best when cooked compared with being eaten raw (Lavelle, 2005).

Spinach can be grown hydroponically in greenhouse production (Rosik- Dulewska and Grabda, 2002) even though greenhouse vegetable production is an intensive system mainly used in commercial farming (Larson et al., 1996). Its cultivation in greenhouses during winter can possibly be achieved by modifying irrigation water to optimum levels through increasing water temperatures.

Heating of water used in greenhouse production has shown success in other parts of the world in a variety of crops (Kozai, 2006; Moorby and Graves, 1980; Rivera, 2005; Sethi and Sharma, 2007).

In order to expand production during winter, heat is required to increase growth (Moorby and Graves, 1980; Sethi and Sharma, 2007). Root zone heating has been practiced elsewhere to increase plant growth (Chen and Katan, 1980; Moorby and Graves, 1980; Rovira, 2005). For instance, bottom heat applied on deciduous apple, pear and plum rootstocks have proved successful in increasing their rooting percentages (Bite and Lepsis, 2004). Conventional bottom heating or root zone heating also contribute to fuel savings compared with heating the complete propagating structures (Laubscher and Ndakidemi, 2008).

In addition to temperature, water is a necessary requirement for plants to complete their life cycle (He et al., 2002). Bubel (2007) recommended that different plants can thrive well under different temperature regimes. When water temperature drops below the optimum levels needed for crop growth, various modifications to the growth medium are essential to sustain the plant growth (Santarius, 2004). This can be achieved by installing a heating device that will supply heated water of the required temperature to the plant roots (Rosk-Dulewska and Grabda, 2002). In spinach, temperature below between 15 - 10°C is regarded as low (Yamori et

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al., 2006).

The high demand for fresh salad crops, including spinach throughout the season has increased. However, production levels during winter are much lower than in summer because of the lowered temperature experienced by commercial growers during winter (Olivier, 1974; Mills et al., 1990). This study was therefore designed to investigate the possibility of increasing production to meet optimum growth during the winter season through the determination of various water temperature levels required for maximum growth in a hydroponics system.

MATERIALS AND METHODS

Site location and description

The experiment was conducted at the greenhouse of the Cape Peninsula University of Technology, Cape Town, South Africa. A steel table (2.5 x 1 m) used as a flat surface, fish tank, leca clay pebbles were supplied by the Horticultural Department of Cape Peninsula University of Technology (CPUT), Cape Town, South Africa. Four plastic gutters (2 x 0.6 m), 4 pumps, 20 ml black plastic pipe, cable ties and 3 Dolphin aquarium heaters were purchased from Builders Warehouse, spinach seedlings from St.Omer Farm Wholesale Nursery, and mixture of Ocean HYDROGRO and Ocean HORTICAL nutrient solution Hortical from Stark Ayres all in Cape Town, South Africa.

Experimental

The randomised complete block design experimentation was used (Steel and Torrie, 1980). Four white plastic gutters (2 x 0.6 m) filled with leca clay pebbles were placed on a steel table (2.5 x 1 m). Water was supplied to the leca pebbles through pumps projecting from 4 sets of fish tanks placed beneath the table. The water in each of the 3 tanks was heated and maintained at 24℃ (A), 26℃ (B) and 28℃ (C) respectively using Dolphin aquarium heaters. Spinach seedlings were planted in each gutter (20 seedlings per gutter) and supplied with nutrient solution prepared according to Ocean HYDROGRO (2009) and Ocean HORTICAL (2009) respectively. The nutrient solution was supplied to the seedlings immediately after transplantation. Nutrient solution supplied from the pumps was re-circulated to the fish tanks through a 20 ml black plastic pipe and the plants were left to grow for the period of 8 weeks. To prevent accumulation of salts in the clay pebbles due to evaporation of nutrient solution, water was drained from the gutters and refreshed after every 2 weeks.

Collection and analysis of data

After two weeks of transplantation, rate of spinach growth was determined by measurements of plant height and leaf length (mm) and enumeration of leaf numbers. And after 8 weeks each plant was harvested and the total fresh and dry root and shoot mass (g) was determined. Statistical analysis was carried out as one way analysis of variance (ANOVA) using the STASTICA Software Programme version 2009 (StatSoft Inc., Tulsa, OK, USA). Where F-value was found to be significant, Fisher's least significant difference (LSD) was used to compare the means at $P \leq 0.05$ level of significance (Steel and Torrie, 1980).

RESULTS

Table 1 shows the effect of four different temperature treatments in leaf numbers of spinach. Results showed that increasing the water temperature from 24 - 28℃ significantly ($P \leq 0.01$) increased the leaf number. Result also showed that all the three sets of plants supplied with heated water had significantly ($P \leq 0.01$) higher number of leaves than those of the control (unheated water) set. However, as the temperature was increased to 28℃ there was an insignificant reduction in the number of leaves of the plants.

The effect of temperature on leaf length is shown in Table 2. Results showed that leaf length of the plants increased significantly ($P \leq 0.01$) with increase in temperature with maximum leaf length (371 mm) recorded at 26℃. Results also showed that the leaf length of the control treatment did not increase significantly compared with the heat treatment from other plants.

Figures 1 and 2 shows the influence of various temperature treatments on fresh and dry weights of roots and shoots of spinach. Results showed that increasing water temperature to 28℃ did not significantly improve the fresh and dry root weight as compared with the control treatment. However, fresh and dry shoot weights were significantly ($P \leq 0.001$) increased at elevated water temperatures (24 - 28℃). Maximum fresh shoot (31.2 g) and dry shoot weights (3.22 g) were recorded at 28℃ compared with that of the control treatment and 24℃. Water temperatures of 26 and 28℃ were significantly superior in stimulating the fresh and dry shoot weights. Generally, in this study increasing temperature promoted the rooting of spinach. The total fresh and dry weights also showed significant improvement ($P \leq 0.001$) at water temperature of 28℃ compared with that of the unheated water (control).

DISCUSSION

Results of this study showed that increasing the temperature of water supplied to spinach during winter improved growth and yield of the crop. It has been reported that in hydroponics, root temperature can be controlled by warming the nutrient solution and thus providing the heat energy requirements for optimum plant growth and development (Calatayud et al., 2008; Dielman et al., 1998; Moorby and Graves, 1980; Moss and Dalgleish, 1984). Improving temperature in the hydroponic culture might have induced water and nutrient uptakes, speeding metabolic processes and hence shoot growth (Dong et al., 2001; Moorby and Graves, 1980). It is also possible that the increased temperature facilitated solubility of mineral nutrient uptake since the rate of dissolving of solutes increases with increase in temperature (Moorby and Graves, 1980; Xu and Huang, 2006). Thus, it is well established that nutrient solution temperature

Table 1. Effects of variation in water temperatures on leaf number of *S. olearacea*. Values presented are means ± SE.

Treatment	Temperature (ºC)	Leaf numbers			
		Measurements taken 2 weeks after transplanting		Measurements taken 8 week after transplanting	
Control	10	4.5	±0.24a	4.9	±0.21c*
A	24	4.6	±0.34a	6.5	±0.24a
B	26	4.9	±0.23a	6.4	±0.34ab
C	28	4.6	±0.19a	5.7	±0.40bc
F Statistic		0.61 ns		5.91**	

** = significant at P ≤ 0.01.
*Means followed by the same letter are not significantly different from each other at P ≤ 0.05.

Table 2. Effects of variation in water temperatures on leaf length of *S. olearacea*. Values presented are means ± SE.

Treatment	Temperature (ºC)	Leaf length (mm)			
		Measurements taken 2 weeks after transplanting		Measurements taken 8 weeks after transplanting	
Control	10	68.3	±4.22a	280	±11.06b*
A	24	70.7	±3.23a	347	±11.2a
B	26	73.1	±3.29a	371	±9.2a
C	28	74.2	±2.64a	356	±10.7a
F Statistic		0.62 ns		14.7***	

*** = significant at P ≤ 0.001.
*Means followed by the same letter are not significantly different from each other at P ≤ 0.05.

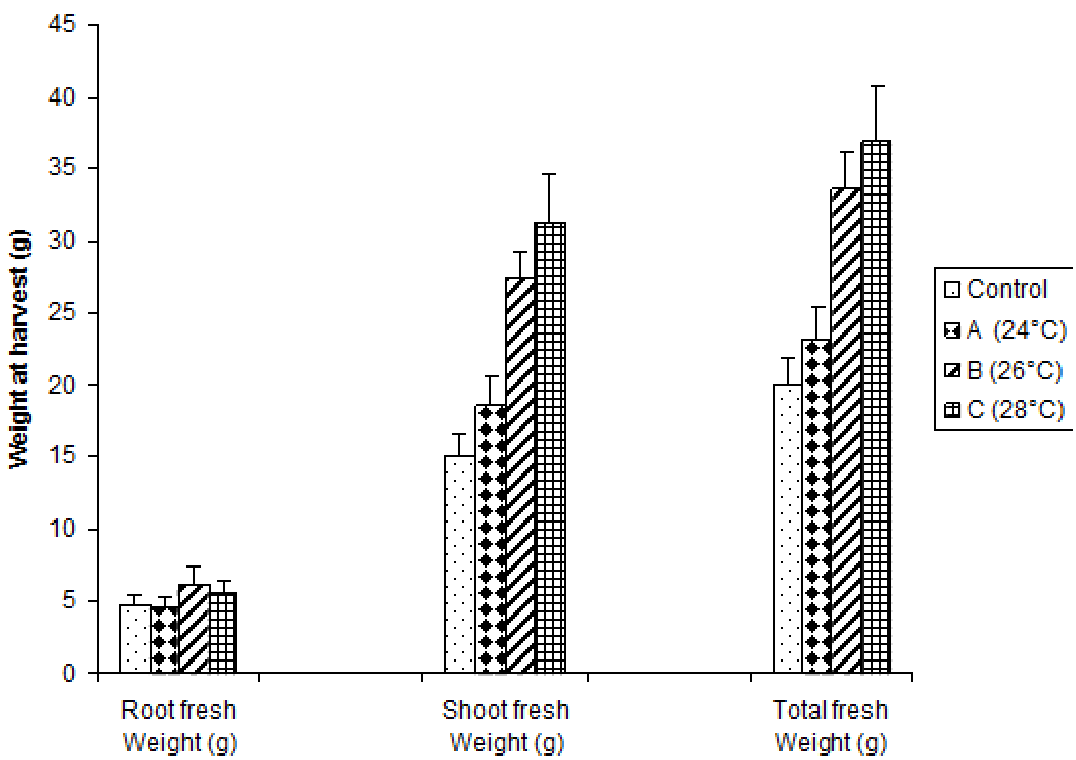

Figure 1. Effects of changing water temperature on fresh weight per plants (g) of *Spinacia olearacea.* (A = 24°C; B = 26°C; C = 28°C). Measurements were taken at 8 weeks after transplanting. *Means followed by the same letter are not significantly different from each other at P ≤ 0.05.

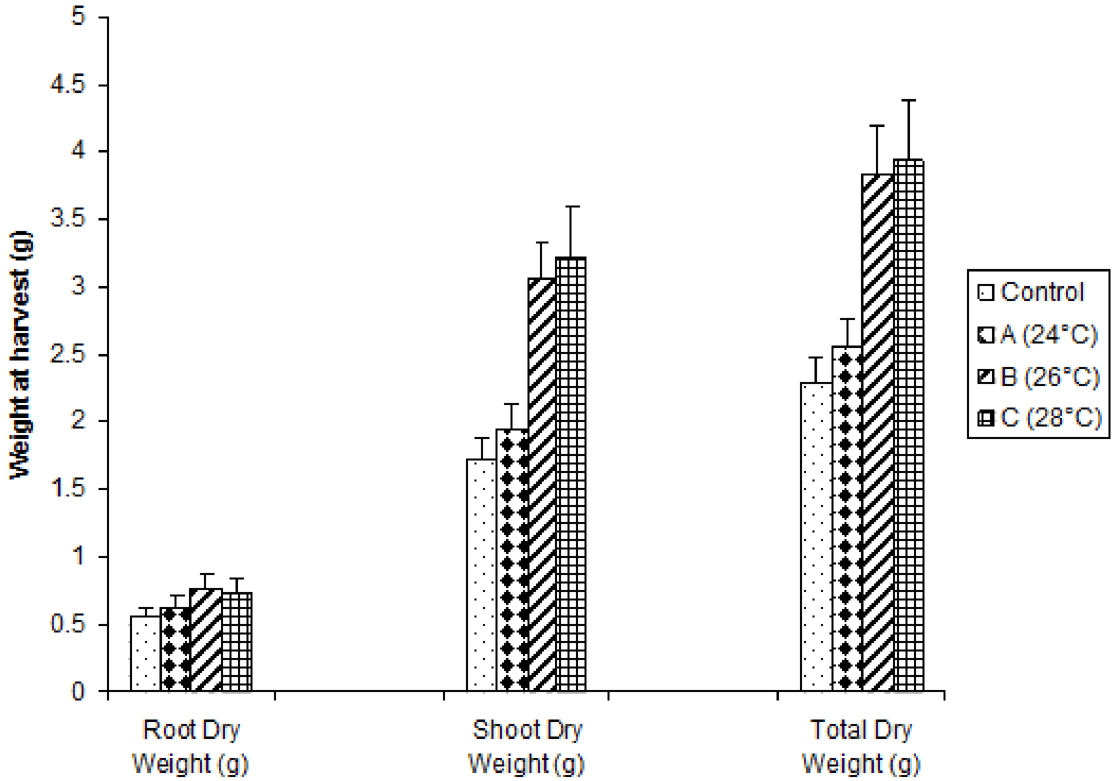

Figure 2. Effects of variation in water temperature on dry matter yield per plant (g) of *Spinacia oleracea*. (A = 24°C; B = 26°C; C = 28°C). Measurements were taken at 8 weeks after transplanting *Means followed by the same letter are not significantly different from each other at P ≤ 0.05.

tends to determine the concentration of nutrients absorbed by the plant, as more nutrients are dissolved at higher temperatures and less at lower temperatures, consequently influencing the efficiency of the photosynthetic apparatus (Calatavud et al., 2004; Santarius, 2004 Yamori et al., 2006, 2008). This in turn exerts pronounced effects on shoot growth of a number of plant species (Bowen, 1991). Low temperatures such as those experienced by plants in the control treatment in this study were subjected to the lowering rate of several physiological processes and hence, the observed poor shoot growth (Calatavud et al., 2004).

Our results clearly showed the importance of increasing temperature in the solution, since the leaf number, leaf length and total fresh and dry weight per plant was higher in the plants grown in elevated temperatures in the solution as compared with the control. This is an indication that, increasing water temperature during cold season could potentially increase the yield of *oleraceae* L. The results from the experiment concur with other studies which reported that increasing water temperature to optimum levels, improved the growth rate of plants (Malauf and Breese, 1977). Other studies have also shown that, increasing water temperature during cold season produced good growth result in the production of vegetables (Bender, 1984; Rosik-Dulewska et al., 2002; Sethi and Sharma, 2007).

Conclusion

In this study the rate of growth of *S. oleracea* L. and biomass increased with increased water temperature, an indication for possible increase in yield when grown at higher temperatures during winter in controlled settings. Pilot studies for possible local cultivation in commercial green houses at controlled temperatures should be considered. In addition, nutrient, electrical conductivity (EC) and pH requirements in the hydroponic media on the growth of *S. oleraceae* L. need to be investigated.

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REFERENCES

Bender J (1984). An integrated system of Aquaculture vegetable production and solar heating in an urban environment, Aquacult. Eng.

3:141-152.
Bowen GD (1991). Soil temperature, root growth, and plant function. In: Eshel A, Kafkafi U, Waisel Y (eds), Plant Roots, the Hidden Half, Marcel Dekker, New York pp. 309-330.
Bite A, Lepsis J (2004). The results of extended duration testing of apple rootstocks in Latvia. Acta Hort. 658:115-118.
Bubel N (2007). The new seed-starters. Handbook. Available online: http:www.green-seeds.com/seed_starters.pdf pp. 300. (Verified on 19/08/09).
Calatayud A, Gorbe E, Roca D, Martínez PF (2008). Effect of two nutrient solution temperatures on nitrate uptake, nitrate reductase activity, NH_4^+ concentration and chlorophyll *a* fluorescence in rose plants. Environ. Exper. Bot. 64:65-74.
Calatavud A, Iglesias DJ, Talón M, Barreno E (2004). Response of spinach leaves (*Spinacea oleracea* L.) to ozone measured by gas exchange, chlorophyll *a* fluorescence, antioxidant system, and lipid peroxidation, Photosynthetica 42: 23-29.
Chen Y, Katan J (1980). Effects of solar heating of soils by transparent polyethylene mulching on their chemical properties. Soil Sci. 130:271-277.
Dielman JA, Verstappen FWA, Kuiper D (1998). Root temperature effects on growth and bud break of *Rosa hybrida* in relation to cytokinin concentrations in xylem sap, Sci. Hort. 76:183-192.
Dong S, Scagel CF, Cheng L, Fuchigami LH, Rygiewicz P (2001). Soil temperature and plant growth stage influence nitrogen uptake and amino acid concentration of apple during early spring growth, Tree Physiol. 21:541-547.
He L, Nada K, Kasukabe Y Tachibana S (2002). Enhanced Susceptibility of Photosynthesis to low-Temperature Photo inhibition due to Interruption of Chill-Induced Increase of S-Adenosyl-methionine Decarboxyllase Activity in leaves of Spinach (*Spinach oleraceae* L.). Plant Cell Physiol. 43:196-206.
Klein C (2007). Grow your own vegetable. Octobus publishing group (Royal Horticultural Society), United Kingdom. pp. 224.
Kozai T (2006). Closed systems for high quality transplants using minimum Resources. Plant Tiss. Cult. Eng. 6:275-312.
Larson A, Ching A, Walk S (1996). Economics of greenhouse tomato production in the rural north central U.S. Acta Hort. 429:75-80.
Laubscher CP, Ndakidemi PA (2008). Rooting success using IBA auxin on endangered *Leucadendron laxum* (PROTEACEAE) in different rooting mediums. Afr. J. Biotechnol. 7:3437-3442.
Lavelle C (2005), Grow your own organic fruit and vegetables. Published by Southwater, London. pp.128.
Malauf RE, Breese WP (1977). Seasonal change in the effect of temperature and water flow rate on the growth of Juvenile Pacific oysters, *Crassostrea gigas* (Thunberg), Aquaculture 12:1-13.
Mills PJW, Smith IE, Marais G (1990). A Greenhouse design for a cool subtropical climate with mild winters based on microclimatic measurements of protected environments. Acta Hort. 281:83-94.
Moorby J, Graves CJ (1980). Root and air temperature effects on growth and yield of tomatoes and lettuce. Acta Hort. 98:29-44.
Moss GI, Dalgleish R (1984). Increasing returns from roses with root-zone warning, J. Am. Soc. Hortic. Sci. 109:893-898.
Nonnecke IL (1989). Vegetable production, Van Nostrand Reinhond, New York, pp. 476-485.
Ocean HYDROGRO (2009). Water Soluble Hydroponic Fertilizer Mix. Available online http//www.oceanag.co.za. (Verified On 12/11/2009).
Ocean HORTICAL (2009). Calcium Nitrate. Available online http//www.oceanag.co.za. (Verified On 12/11/2009).
Olivier OJ (1974). All-year-round vegetable production without protection and future prospects in South Africa. Acta Hort. 42:353-362.
Rosik-Dulewska CZ, Grabda M (2002). Development and yield of vegetables cultivated on substrate heated by geothermal waters part 1: Bell pepper, slicing cucumber, tomato. J. Veg. Crop Prod. 8:133-144.
Rovira AD (2005). Root excretions in relation to the rhizosphere effect IV. Influence of plant species, age of plant, light, temperature, and calcium nutrition on exudation. Plant Soil. 11:53-64.
Roy SK, Chakrabarti AK (2003). Vegetables of temperate climates: commercial and dietary importance. Encyclopaedia of Food Science Nutrition 5925-5932.
Santarius KA (2004). The protective effect of sugars on chloroplast membranes during temperature and water stress and its relationship to frost, desiccation and heat resistance. Planta. 113:97-191.
Sethi VP, Sharma SK (2007), Greenhouse heating and cooling using aquifer water. Energy 32:1414-1421.
Steel RGD, Torrie JH (1980). Principles and procedures of statistics: A biometrical approach, Second Edition. McGraw Hill, New York. p. 454.
Xu Q, Huang B (2006). Seasonal changes in root metabolic activity and nitrogen uptake for two cultivars of creeping bentgrass. Hort. Sci. 41:822-826.
Yamori W, Noguchi K, Kashino Y, Terashima I (2008). The role of electron transport in determining the temperature dependence of the photosynthetic rate in Spinach leaves grown at contrasting temperatures. Plant Cell Physiol. 49:583 -591.
Yamori W, Noguchi K, Hanba TK, Terashima I (2006). Effects of internal conductance on the temperature dependence of the photosynthetic rate in Spinach leaves from contrasting growth temperatures. Plant Cell Physiol. 47:1069-1080.