Response of Lettuce to the Coupling Electrical Conductivity and Circulation Rate of the Nutrient Solution in Hydroponics

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Abstract: The coupling effect of nutrient solution EC (electrical conductivity) levels and CR (circulation rate) on the morphology and quality, in hydroponically grown lettuce was assessed. Lettuce was grown at 5 treatments from High EC & Low CR to Low EC & High CR. The environmental parameters were controlled in a 20 m² plant factory during the hydroponic cultivation with the following values: irradiated by blue and red light-emitting diode lighting with PPFD (photosynthetic photon flux density) value of 150 mol·m⁻²·s⁻¹ for 16 hours per day; Temperature was maintained at 22.0 °C during the photoperiod and 16.0 °C in dark cycle. The results demonstrate that growing lettuce can be adopted using nutrient solution with lower EC levels and higher CR. The results also indicate that the effect of bi-directional coupled EC and CR resulted in expansion of root length but reducing the root biomass. Nitrate content was significantly reduced.

Key words: LED lighting, lettuce, hydroponics, flow rate of nutrient solution, nutrition supply.

1. Introduction

Considering that there is increasing interest about maintaining agriculture within and around cities, controlled environment cultivation, especially hydroponic systems with artificial lighting have drawn much attention [1]. The demand of urban agriculture resulted in its growing importance as an agricultural production pattern and research issue towards food security and environmental concern [2, 3]. One of the most practical and effective ways to improve the yield and nutritional quality of vegetables is controlling the nutrient solution concentration [4]. Considerable research efforts have been devoted to ascertaining the effects of EC (electrical conductivity) of the nutrient solution on plant growth and morphology in hydroponics [5-7]. Improving the nutrition uptake and minimum the emission of the waste chemical solution

is also important [8]. Furthermore, optimal fertilizer concentration for leafy vegetables also depends on the other environmental conditions especially in the root area [9, 10]. Oxygen content around root area is an effective factor of plant growth, hypoxia stress of the root results in poor resistance to pathogenic microorganism [11]. Soluble oxygen of the nutrient solution consumes fast, and oxygen demand of root increases with the increasing of leaf area. Circulation of the nutrient solution is an effective way to enrich the oxygen content via consuming limited energy [12].

Based on these studies which described growth promotion, we investigated the effects on lettuce growth and morphology of patterns in which EC changes and total fertilizer is fixed of the nutrient solution. For this study, we considered that lettuce growth can be promoted by the circulation rate, while decreasing EC level could result in nutrition stress of the plant under artificial lighting. Therefore we coupled the circulation rate and EC level, to

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investigate the effects of soluble oxygen and nutrition stress on the lettuce growth.

2. Materials and Methods

Experiments were conducted in the experimental site of the NERCV (National Engineering Research Center of Vegetable), in Beijing, China, in May-July, 2014. Plants were grown in hydroponics using the NFT (nutrient film technique) under a 20 m² plant factory. Plants were irradiated with blue light and red light continuously for 16 h per day, at a PPFD (photosynthetic photon flux density) of 150 mol·m⁻²·s⁻¹. Temperature in the plant factory was maintained at 22.0 °C ± 1.5 °C during the day and 16.0 °C ± 1.5 °C at night.

Lettuce (*Lactuca sativa*, Jingyan Yinong (Beijing) Seed Sci-Tech Co., Ltd) seeds were sown on urethane-foam cube placed. One week after sowing, seedlings with an approximately 1 cm first true leaf were used for cultivation experiments. The cubes were placed in 20-mm holes in 25-mm thick polystyrene foam plates. A total of 75 seedlings were transplanted to the plate. Then the plate was floated in a 12-L plastic container. Plants were exposed to five treatments, as shown in Table 1, each treatment included 15 plants and it was repeated 4 times.

For all samples, above ground (lettuce heads) and below ground (lettuce roots) parts were harvested separately. At both harvest dates, eight plants per cultivar and treatment were weighed to obtain the mean head and root mass. Values are given in gram FM (fresh matter). Lettuce heads were cut in pieces. Some head fresh matter and the roots were dried in an oven at 75 °C for three days, to obtain dry matter content. Values for dry matter content are given in

milligram dry matter per gram fresh matter.

Content of vitamin C, chlorophyll and nitrate were determined by the method of Gahler et al. [13], Guadagnin et al. [14], and Cataldo et al. [15], respectively.

3. Results and Discussion

As shown in Table 2, the leaf length did not statistically differ in all treatments; In treatments T2, T3 and T4, leaf width and the number of leaves are larger than T1 and T5; root length of T5 was significantly larger than other treatments.

In lettuce, fresh mass of leaf is directly related to yield and treatment T2 resulted in the highest yield but not significantly higher than T3 and T4. Low FR & high EC (T1) and high FR & low EC (T5) resulted in lower fresh and dry weight of shoot and root than other treatments.

It is noticed that Tables 2 and 3, the root length was increasing with increasing of FR and decreasing EC, but root weight (both in fresh and dry) showed negative correlation to root length.

Vitamin C content of T1 is significantly larger than other treatments, but no significant difference existed among T2-T5. Content of chlorophyll was highest with treatment of the highest EC and lowest CR, it was reported, that chlorophyll content was positively correlated with yield in soil cultivation condition [16], but in present study, the correlation did not exist. As shown in Table 4 Nitrate content decreased with reduction of the nutrient concentration from 2,482.42 mg/kg to 1,086.65 mg/kg, it was clear that the nutrient solution used in the current experiment reduced the load of tissues with N and improved the postharvest quality characteristics.

Table 1 Treatments of the experiment.

Treatments of the NS	Nitrogen concentration (mg/L)	Circulation rate (L/min)
T1	23.6	1.0
T2	11.8	2.0
T3	7.9	3.0
T4	5.9	4.0
T5	4.7	5.0

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Table 2 Effect of coupling decreasing EC and increasing CR of the nutrient solution in hydroponics on leaf length, width, number, and root length of lettuce.

Treatments	Leaf length (cm)	Leaf width (cm)	Number of leaves	Root length (cm)
T1	17.07 ± 0.81 a	12.43 ± 0.31 b	28.00 ± 1.00 ab	28.70 ± 0.20 d
T2	18.07 ± 0.50 a	13.57 ± 0.64 a	29.67 ± 1.15 a	34.07 ± 1.58 c
T3	18.23 ± 0.06 a	13.80 ± 0.26 a	29.67 ± 0.58 a	40.20 ± 0.61 b
T4	18.40 ± 1.21 a	13.60 ± 0.79 a	29.33 ± 0.58 a	40.50 ± 1.67 b
T5	17.40 ± 0.26 a	11.20 ± 0.61 c	27.00 ± 1.00 b	45.20 ± 1.77 a

Values followed by different letters in the same column differ significantly at 5% level by the LSD (Least Significant Difference) test.

Table 3 Biomass of lettuce under different levels of EC and CR of nutrient solution.

Treatments	Fresh weight (g/plant)			Dry weight (g/plant)		
	Shoot	Root	Total	Shoot	Root	Total
T1	33.05 ± 2.31 b	6.92 ± 0.25 ab	39.97 ± 2.56 b	2.14 ± 0.15 b	0.45 ± 0.02 a	2.59 ± 0.16 bc
T2	46.11 ± 4.13 a	7.16 ± 0.05 a	53.28 ± 4.18 a	2.95 ± 0.36 a	0.44 ± 0.05 a	3.38 ± 0.41 a
T3	43.81 ± 2.13 a	6.39 ± 0.70 ab	50.20 ± 2.83 a	2.66 ± 0.24 a	0.36 ± 0.01 b	3.01 ± 0.24 ab
T4	44.00 ± 1.16 a	6.18 ± 0.58 b	50.18 ± 1.73 a	2.83 ± 0.17 a	0.36 ± 0.02 b	3.19 ± 0.15 a
T5	27.52 ± 1.79 c	5.05 ± 0.41 c	32.57 ± 2.20 c	1.84 ± 0.25 b	0.28 ± 0.03 c	2.12 ± 0.27 c

Values followed by different letters in the same column differ significantly at 5% level by the LSD test.

Table 4 Effect of coupling decreasing EC and increasing flow rate of the nutrient solution in hydroponics on vitamin C, chlorophyll, and nitrate content of lettuce leaf.

Treatments	Vitamin C (mg/kg)	Chlorophyll (mg/kg)	Nitrate (mg/kg)
T1	215.25 ± 22.63 a	0.31 ± 0.05 b	2,482.42 ± 65.17 a
T2	183.04 ± 12.19 b	0.25 ± 0.01 c	1,940.62 ± 150.85 b
T3	187.35 ± 6.88 b	0.36 ± 0.00 a	1,696.74 ± 66.36 c
T4	172.25 ± 4.87 b	0.25 ± 0.00 c	1,480.38 ± 36.32 d
T5	189.19 ± 7.38 b	0.23 ± 0.03 c	1,086.65 ± 25.46 e

Values followed by different letters in the same column differ significantly at 5% level by the LSD test.

4. Conclusion

The results demonstrate that growing lettuce can be adopted using nutrient solution with lower conductivity levels and larger circulation rate. The results also indicate that the effect of bi-directional coupled EC and CR resulted in expansion of root length but deducing the root biomass. Nitrate content was significantly reduced.

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