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SHADING AND PERIODIC REPLACEMENT OF NUTRIENT SOLUTION IMPROVE PRODUCTION OF HYDROPONICALLY-GROWN WATERCRESS

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Abstract: Watercress was grown in uncovered tanks (30 cm deep) of non-circulating nutrient solution with an EC of 1.0 to 1.8 mS in a polyethylene-covered rainshelter at an elevation of 1300 m. Additional nutrient solution was added to replace evaporation and transpiration, but no other adjustments or amendments were made. Shading with 57 and 71% saran shade significantly reduced moderately severe tipburn that occurred on non-shaded plants even though these plants experienced light reduction of 15% from the rainshelter roof. Monthly harvests were taken. The highest yields were obtained when a complete nutrient solution change was made after completion of the second harvests. Yield increased 25% and 68% by changing the nutrient solution every 2 months as compared to changing nutrient solution every 4 months and 6 months, respectively. B, Mg, Na and pH increased and nitrate-N, P, Ca, Cu, Fe and Mn decreased as the time period between nutrient solution changes increased. This contributed to lower yields from watercress harvested 4 and 6 months after changing the nutrient solution. The optimum hydroponically-grown watercress treatment (where the nutrient solution was changed every 2 months) required only about 0.1% as much water as watercress grown in continuously flowing water.

Keywords: shading, nutrient solution, non-circulating hydroponics, watercress, tipburn, nitrate-N, water requirement

Introduction

Watercress (*Nasturtium officinale* R.Br.) is "an herb found creeping on damp earth or in streams or springs" (5). In Hawaii, open field watercress is grown in shallow ponds or beds with 0.6 to 8 cm of water flowing continuously at a rate of 36 to 72 m per minute (3). Over 9 million liters/hectare/day of clean, continuously flowing water are needed to produce optimum yields of watercress. Production and quality decrease during warm summer months (22-33C) as compared to cooler winter months (18-27C) even though the temperature of the flowing water remains in a 20-25C range during both cool and warm seasons (4).

Phytotoxic substances accumulate in the nutrient solution of hydroponically-grown tomatoes (11) . Growers are advised to renew recirculated nutrient solutions twice monthly for fully grown tomatoes and cucumbers (6,7). For cucumber and tomato bag culture some nutrient solution is commonly allowed to leach from the bottom of the bags (8,9). Shading reduced maximum air temperatures and resulted in yield increases of semi-head lettuce, head lettuce and head cabbage (10). Anthuriums are routinely shaded to prevent fading and burning (2).

The objective of this study was to develop a simple, non-circulating hydroponic method for growing watercress and to determine the effects of shading and nutrient solution replacement on the yield and quality of watercress.

Methods and Materials

Trials were conducted in a polyethylene-covered rainshelter at a 1300 m elevation on the Island of Hawaii. Uncovered plywood tanks (0.3 m wide x 0.3 m high x 2.4 m long) were lined with 0.15 mm black polyethylene and filled with nutrient solution ranging in EC from 1.0 to 1.8 mS. There was a 0.7 m distance between tanks. Relatively deep tanks insured less temperature variation of the nutrient solution. The nutrient solution consisted of a ratio of 1:1:0.6 of Hydro-Gardens Chem-Gro Tomato Formula (4-8-32-0.2-0.05-0.4-0.2-0.01-0.05 % N-P-K-B-Cu-Fe-Mn-Mo-Zn, respectively) :calcium nitrate:magnesium sulfate added to rainwater. The initial planting of 'Pepeekeo' watercress consisted of adding 40 stems (30 cm long) into each tank. At harvest time, watercress stems were cut at a point 5 cm above the nutrient solution level and fresh weights of the foliage were recorded. Successive crops emerged from the root mass of the previous crops. Over 95% of the daily low air temperatures ranged from 10-15C and daily high temperatures ranged from 15-25 C in the rainshelter throughout the year at the growing level.

Effects of shading. Plastic saran shade (60 cm wide) was suspended 1 m above the tanks. Treatments consisted of no saran shade, 57% and 71% shade. The plastic rainshelter roof caused 15% shade in the no saran shade treatment. There were 3 replications arranged in a randomized complete block design. Eleven yields were taken during a one year period. Total yield and tipburn rating data were collected.

Effects of complete change of nutrient solution. A saran shade cloth was placed over the entire growing area. Six harvests were taken during a 189 day growing period. A complete change of nutrient solution was made at 2 and 4 months after planting. During a subsequent trial, 12 harvests were taken during Dec. 1, 1999 to Dec. 22, 2000. The nutrient solution was completely changed every 1, 2, 4 or 6 months. There were 3 replications arranged in a randomized complete block design.

Results and Discussion

Hydroponically-grown watercress developed significantly less tipburn when the plots were shaded with saran shade (Table 1). This is not surprising since tipburn is encouraged by water stress and shading causes reduced evaporation which translates into reduced water stress (10). Roots are exposed to lower oxygen levels in a non-circulating water culture method as compared to field culture with constantly flowing water. Lower oxygen levels reduce root functioning ability and thus, restrict their ability to absorb water. It was surprising that yields were significantly similar amongst all 3 shading treatments and this may be due to a very low light saturation requirement for watercress.

Watercress is a ratoon-type crop where harvests are taken about every month. Growers using this non-circulating hydroponic method would prefer to only replace nutrient solution which is lost by evaporation and transpiration rather than change the entire nutrient solution. It was, thus, disappointing to learn that the cumulative yield of 6 watercress harvests was 33% lower when the nutrient solution was not changed during this period as compared to changing the nutrient solution every 2 months (Table 2).

Furthermore, it was interesting to learn that watercress yield from the treatment without a nutrient solution change decreased only 19% during the fourth month after planting as compared to changing the nutrient solution every 2 months (Table 3). However, this escalated into a 51% yield decline by the sixth month after planting! Apparently, unfavorable growing conditions develop with increasing time between changes of the nutrient solution.

In a trial with 12 harvests over a 386 day period, again the cumulative watercress yield was greater when the nutrient solution was changed every 2 months. Yields in the second months after changing the nutrient solution were 24% greater than in the first months after changing the nutrient solution during the months of February, April, June, August, October and December (Table 4).

There was a 25% yield increase from changing the nutrient solution every 2 months as compared to changing nutrient solution every 4 months during the months of April, August and December (Table 4). In addition, there was a 68% yield increase from changing the nutrient solution every 2 months as compared to changing every 6 months during June and December.

An analysis of the nutrient solution is presented in Table 5. It is notable that the pH, Mg, Na and B increased with time. However, nitrate-N, P, Ca, Cu, Fe and Mn decreased as the time period between nutrient solution changes increased. Severely decreased yields in the sixth month after changing nutrient solution may have been caused by decreased levels of these elements in the nutrient solution. Nitrate and Mn levels were depleted rapidly after the first month and this is consistent with Bugbee's observations (1) with other crops. The accumulation of Mg contributed to the increased pH in the later harvests. Since this nutrient solution was not specifically designed for watercress, it is likely that some of the nutrient levels are not optimum for watercress. Based upon the results of these trials, an educated guess would direct the grower to increase the N, P, Ca, Cu, Fe and Mn levels for the third and successive harvests produced after changing the nutrient solution. The high pH problem could also be ameliorated by the addition of ammonium sulfate which would tend to lower the nutrient solution pH as the ammonium becomes absorbed by the plant. However, no attempt was made to correct the nutritional or pH levels of the nutrient solution in these experiments.

Experiments were not conducted to rule out the possibility that phytotoxic substances accumulate in the nutrient solution, but this should be investigated in future experiments. For example, the B level increased with time and B toxicity has been observed with various other crops.

The total water requirement to grow watercress by this hydroponic method at the 1300 m elevation location was 120.2, 63.4, 51.5 and 43.8 liters of water per kg of watercress where the nutrient solution was changed every 1, 2, 4 and 6 months, respectively (Table 6). This includes evaporation from the tanks, transpiration from the crop and water supplied to replace the nutrient solution at the above intervals. Approximately, 58,000 liters of water are needed to produce 1 kg of watercress in a shallow pond with continuously flowing water (3). Thus, the optimum hydroponically-grown watercress treatment (where the nutrient solution was changed every 2 months) required only about 0.1% as much water as watercress grown in continuously flowing water.

Growing watercress in tanks of non-circulating nutrient solution is conducive to high mosquito populations. Fortunately, mosquitoes are not a serious problem at the Volcano Experiment Station which is located at an elevation of 1300 m where a majority of the daily low temperatures range from 10-15C. However, mosquitoes are a serious pest at lower elevations and should be controlled with pesticides, fish or *B.thuringiensis* israelensis.

Watercress grows well in non-circulating tanks of nutrient solution. Ideally, the crop should be grown in a cool climate. Tanks should be fairly deep (about 30 cm) to encourage uniform and cool nutrient solution temperatures. Nutrient solution temperatures did not exceed 18C in the middle of summer in these trials. Tipburn of watercress was prevented by shading with a 57 per cent saran shade cloth. With our present state of knowledge, it is recommended that the nutrient solution be changed after every second crop. However, future experimentation is needed to determine the presence of phytotoxic substance accumulation and to develop an optimum nutrient solution for watercress along with procedures for adjusting and amending the nutrient solution.

Table 1. The effects of shade on tipburn and yield of hydroponic watercress during 11 continuous harvests from January 31, 1995 to January 31, 1996.

Shade over plots %	Total Yield kg/linear m of row[y]	Tipburn rating[z]
15[w]	12.27 ns	2.81 a[x]

57[v]	11.03 ns	0.17 b
71[v]	10.97 ns	0.17 b

[z]0 = no tipburn; 2.5 = half salable; 5 = totally unsalable
[y]Hydroponic tanks are 30 cm wide.
[x]Mean separation by Duncan's Multiple Range Test, P=0.05.
[w]Caused by plastic rainshelter roof.
[v]Caused by plastic rainshelter roof plus plastic saran shade.

Table 2. The effects of a complete change of nutrient solution at 2 and 4 months after planting on the cumulative yield of 6 watercress harvests during March 25, 1999 to Sept. 30, 1999.

Change nutrient solution	Total yield kg/linear m of row[z]
Every 2 months	8.81 a[y]
4 months after planting	7.48 ab
No change	5.90 b

[z]Hydroponic tanks are 30 cm wide.
[y]Mean separation by Duncan's Multiple Range Test, P=0.05.

Table 3. Comparisons of a complete change of nutrient solution every 2 months vs. no change on watercress yield during 4th and 6th months after planting.

Change nutrient solution	Yield for one harvest kg/linear m of row[z]	
	4th month[y]	6th month[x]
Every 2 months	1.50 a[w]	1.77 a
No change	1.21 b	0.87 b

[z]Hydroponic tanks are 30 cm wide.
[y]Harvested July 27, 1999; Planted March 25, 1999
[x]Harvested September 30, 1999
[w]Mean separation by Duncan's Multiple Range Test, P=0.05.

Table 4. Beneficial effects on watercress yield from changing nutrient solution every 2 months vs. changing nutrient solution every month, every 4 months or every 6 months during 12 monthly harvests taken Dec. 1, 1999 to Dec. 22, 2000.

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Comparing Change nutrient solution	Relative Yield	Months Compared
Every second month vs.	1.24 a[z]	{Feb., Apr., June
Every month	1.00 b	Aug., Oct., Dec.}
Second months vs.	1.25 a	Apr., Aug., Dec.
Every fourth month	1.00 b	
Second months vs.	1.68 a	June, Dec.
Every sixth month	1.00 b	

[z]Mean separation by Duncan's Multiple Range Test, P=0.05.

Table 5. Electrical conductivity, pH and nutrient levels in the nutrient solution at 0 to 5 months after planting.

Months after Planting	EC (mS)	pH	Nitrate-N	P	K	Ca	Mg
			ppm				
0	1.57a[z]	5.8c	121a	33a	201a	96a	33b
1	1.33b	7.2b	65b	27b	169b	93a	42b
3	1.41b	7.8a	8c	25bc	223a	67b	56a
5	1.35b	7.8a	7c	22c	207a	69b	60a

Months after Planting	Na	B	Cu	Fe	Mn	Zn
	ppm					
0	4b	0.23c	0.13a	1.18a	0.72a	0.18b
1	4b	0.36c	0.14a	0.67b	0.08b	0.29b
3	6a	0.87b	0.12a	0.46c	0.06b	0.56a
5	6a	1.02a	0.04b	0.45c	0.05b	0.24b

[z]Mean separation by Duncan's Multiple Range Test, P=0.05

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Table 6. Total water required (evaporation, transpiration and replacement water) for hydroponically-grown watercress where the nutrient solution is replaced every 1, 2, 4 or 6 months during 12 monthly harvests taken Dec. 1, 1999 to Dec. 22, 2000.

Nutrient solution replaced every month(s)	Water required liters/kg of watercress
1	120.2a[z]
2	63.4b
4	51.5b
6	43.8b

[z]Mean separation by Duncan's Multiple Range Test, P=0.05

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