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Yield and Mineral Element Concentration of Beetroot in Response to Nutrient Source in Hydroponic Solution

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Purpose

Beginning small-scale, hydroponic growers often have limited access to the required reagents to formulate the appropriate nutrient solution. Consequently, these growers often utilize the most readily available complete fertilizer for hydroponic production. The purpose of this study was to evaluate the effect of a hydroponic and non-hydroponic fertilizer (*FERT*) on the yield, and tissue mineral element concentration of beetroot in a nutrient recirculating NFT hydroponic system. It examines the hypothesis that leaf elemental concentration and yield of beetroot in NFT hydroponic culture will vary with the composition of the nutrient solution source.

Experimental Procedure

Seedlings of beetroot 'Bull's blood' were transferred into NFT system in a controlled environment greenhouse at the first true-leaf stage, and harvested at 42 DAT. Mean ambient temperature during NFT culture was 22.4 ^{o}C, with day/night temperature and relative humidity of 31/17 ^{o}C; and 97/47%, respectively. Nutrient solutions were prepared from 1) a hydroponic fertilizer (All-Purpose Hydroponic Nutrient™: 9-4-15 [% N-P_2O_5-K_2O]), supplying N and Ca at 108 and 12 mg liter^{-1}, respectively (N_1Ca_1), and 2) a non-hydroponic fertilizer (Peters Excel-CAL-MAG™: 15-5-15 [% N-P_2O_5-K_2O]) at 200 mg N liter^{-1}, plus 66.7 mg Ca liter^{-1} (N_2Ca_2). The refill water source had pH = 7.0–7.2, and contained in mg liter^{-1}: 1.14 K, 6.57 Ca, 18.60 Mg, 0.008 Fe, 0.144 Cu, 0.002 Mn, 0.001 Mo, 0.027 Zn, and 8.34 Na. Nutrient solution pH was maintained within the range (6.0–7.0) for beetroot. Mean nutrient solution pH and EC during NFT culture were respectively, 6.42; 1.73 with N_1Ca_1, and 6.72; 1.67 with N_2Ca_2. At harvest, 72 single replicate plants from each of the two completely randomized *FERT* treatments (N_1Ca_1 and N_2Ca_2), were sampled for leaf and edible root yield (LFW and RFW), and 10 plants for leaf elemental analysis. Data from yield and leaf elemental concentration were examined for the main effect of *FERT* with Analysis of Variance (ANOVA), using the General Linear Model (GLM) procedure (SAS Ver. 9.1; SAS Inst. Inc., 2004, Cary, NC).

Results and Discussion

Yield and Leaf mineral nutrient concentration. Nutrient source had no detectable effect ($p=0.05$) on LFW, LDW or RDW; however, compared to N_1Ca_1, RFW was significantly ($p=0.0308$) increased with N_2Ca_2 (Table 1). Despite significantly higher leaf concentrations of Mg, Mn, Mo, and Al with N_2Ca_2 compared to N_1Ca_1 (Tables 2a and 2b), the mineral nutrients most related to differences in the yield of beetroot were Ca, B, and Na. Leaf Ca and B were both significantly higher with N_2Ca_2 than N_1Ca_1, and below the sufficiency range with N_1Ca_1. Xylem transport of Ca into organs of low transpiration rate like the tuberous storage organ of beetroot is usually very low. The limited translocation of Ca in the phloem also reduces its retranslocation from older to younger shoot tissue (Tisdale et al., 1993b; Kirkby and Pilbeam, 1984).

Table 1. Effect of mineral nutrient source on leaf and root yield of beetroot 'Bull's blood' in NFT hydroponic culture

Nutrient source	LFW[‡] (g/plant)	LDW (g/plant)	LDWR (%)	RFW (g/plant)	RDW (g/plant)	RDWR (%)	RDW/LDW (%)
N_1Ca_1	60.73 ± 3.25[z]	5.38 ± 0.27	9.24 ± 0.20	24.99 ± 1.62	2.76 ± 0.18	10.94 ± 0.22	51.08 ± 2.37
N_2Ca_2	64.05 ± 2.89	5.85 ± 0.26	9.24 ± 0.15	30.93 ± 2.18	3.04 ± 0.21	9.88 ± 0.19	51.37 ± 2.59
Prob > F	0.4479	0.2137	0.9915	0.0308	0.3100	0.0004	0.9328

[z] Data represents a mean of 72 plants from each of the 2 mineral nutrient sources ± SEM

[‡] LFW = Leaf fresh weight, LDW = Leaf dry weight; RFW = Root fresh weight; RDW = Root dry weight. LDWR = leaf dry weight ratio (LDW/LFW); RDWR = Root dry weight ratio (RDW/RFW).

Table 2a. Effect of mineral nutrient source on mean leaf macronutrient content of beetroot ‘Bull’s Blood’ in NFT hydroponic culture

Nutrient source (N–Ca level)	N (mg g^{-1})[z]	P (mg g^{-1})	K (mg g^{-1})	Ca (mg g^{-1})	Mg (mg g^{-1})	S (mg g^{-1})
N_1Ca_1	51.2 ± 2.0[y]	7.0 ± 0.4	52.7 ± 1.9	13.4 ± 1.3	17.6 ± 0.6	6.1 ± 0.2
N_2Ca_2	48.9 ± 2.3	6.9 ± 0.4	52.6 ± 2.1	23.7 ± 1.1	21.6 ± 0.8	5.6 ± 0.1
Prob > F	0.4501	0.8523	0.9632	<0.0001	0.0008	0.0576
Sufficiency range[x]						
Beta vulgaris L.	35–55	2.5–5.0	30–45	25–35	3.0–10.0	0.75–6.3[†]

Table 2b. Effect of mineral nutrient source on mean leaf micronutrient content of beetroot ‘Bull’s Blood’ in NFT hydroponic culture

Nutrient source (N–Ca level)	Fe (μg g^{-1})[z]	Mn (μg g^{-1})	Zn (μg g^{-1})	Cu (μg g^{-1})	B (μg g^{-1})	Mo (μg g^{-1})	Al (μg g^{-1})	Na (μg g^{-1})
N_1Ca_1	47.6 ± 2.6[y]	110.3 ± 4.2	200.5 ± 9.0	25.6 ± 1.6	22.3 ± 1.1	1.64 ± 0.0	17.1 ± 0.7	6163.3 ± 353.4
N_2Ca_2	44.2 ± 2.1	276.8 ± 16.1	124.4 ± 8.4	23.1 ± 1.3	50.8 ± 1.8	5.08 ± 0.2	21.5 ± 0.8	7175.3 ± 325.9
Prob > F	0.3230	<0.0001	<0.0001	0.2587	<0.0001	<0.0001	0.0007	0.0497
Sufficiency range[x]								
Beta vulgaris L.	50-200	50–250	15-200	5-15	30-85	0.15–0.6[‡]	—	—

[z] Macro- and micronutrient concentration per gram leaf dry weight.

[y] Data represents a mean of 10 plants per treatment (N = 10) ± SEM.

[x] Sufficiency range of mineral elements determined from mature leaf tissue of *Beta vulgaris* Crassa group (Mills and Jones, 1996).

[†] Source: Haneklaus S, Bloem E, Schnug E, de Kok LJ, and Stulen I. *Sulfur*. In: Handbook of Plant nutrition, Barker AV, and Pilbeam DJ (eds.), Boca Raton, Florida: Taylor Francis Publishing Group; 2007: 183–238.

[‡] Young mature leaves. *Source*: Russell, LH. *Molybdenum*. In: Handbook of Plant nutrition, Barker AV, and Pilbeam DJ (eds.), Boca Raton, Florida: Taylor Francis Publishing Group; 2007: 375–394.

Beetroot in hydroponic culture has been observed to require moderately high K and Ca, high B, and absorbs more chlorine (Cl) and Na than any other crop. In addition, beetroot responds positively to high levels of Mn, Cu and Mo, and tolerate EC as high as 5.0 mS/cm (Mason, 1990).

With N_1Ca_1 leaf B (22.3 µg g^{-1}; Table 2b) was substantially below the sufficiency range of 30–85 µg g^{-1} (Mills and Jones, 1996), or 31–200 µg g^{-1} (Hills and Ulrich, 1976) for *Beta species*, which are among the crops with high B requirement (Tisdale et al., 1993a; Gupta, 2007). The significant decrease in RFW at N_1Ca_1 (Table 1) is in part attributable to the lower B content (Table 2b). Growth retardation is among the symptoms of B deficiency in *Beta species* (Vlamis and Ulrich, 1971).

Leaf Na concentration was significantly higher ($p=0.0497$) with N_2Ca_2 than N_1Ca_1 (Table 2b). While the critical concentration of this beneficial element for beetroot is not defined, *Beta species* are among the crops that require higher quantities of Na for optimum growth. It is estimated that Na can replace 90% of K requirement in the edible portions of beetroot (Subbarao et al., 2000). As with other crop species, the application of Na is known to stimulate growth in beetroot, fodder beet, and sugar beet, especially when K is deficient (Montasir et el., 1966; Troug et al., 1953; Harmer and Benne, 1945).

Conclusions

Both elemental concentration and yield of beetroot varied in a complex manner with the composition of the nutrient solution source. Calcium and B deficiency contributed to the lower yield of beetroot at N_1Ca_1 compared with N_2Ca_2, which supplied higher N, and Ca; and enhanced higher B and Na absorption. Adequate supply of Ca and B in balance with K, Mg, and the other essential elements, plus Na is vital in nutrient source selection and management for NFT hydroponic culture of beetroot.

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