Influence of Sodium Bicarbonate on Mineral Composition of Red Garden Beets

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The bicarbonate ion is one of the principal components in many of the irrigation waters applied on sugar beet fields in the western states. Wadleigh and Brown (2)[2] have reviewed the effect of an accumulation of sodium bicarbonate in the soil solution upon plants, and presented experimental data as to the effect of the bicarbonate ion in the substrate on chemical composition and growth response of bean plants. Since beans are remarkable in their capacity to exclude the sodium ion, it appeared expedient to study the effect of sodium bicarbonate on a species which was outstanding in its capacity to accumulate the sodium ion. Accordingly, beets were selected as the experimental plant, and since red garden beets are more convenient to work with in greenhouse experiments, they were used as the test plants. With proper qualifications, the results obtained from red garden beets are applicable to sugar beets.

Experimental Procedure

Selected seedlings of the Crosby Egyptian variety of red garden beets were grown in automatically irrigated sand culture equipment (1) in which the control nutrient solution was composed as shown in Table 1. Seeds were planted February 27, 1948, and treatments were initiated April 9, 1948, when the plants were 4 to 5 inches high. Each treatment was replicated three times and consisted of the addition of 0, 8, 16, and 32 m.e./liter $NaHCO_3$ to the control nutrient solution.

Table 1.—Composition of Control Nutrient Solution.

$Ca(NO_3)_2$	5.0 m.e./liter	K_2SO_4	2.0 m.e./liter
$MgSO_4$	3.0 m.e./liter	$MnSO_4$	0.5 ppm
KH_2PO_4	0.5 m.e./liter	H_3BO_3	0.5 ppm
K_2HPO_4	0.5 m.e./liter	FeCitrate	0.5 ppm
KNO_3	2.0 m.e./liter		

The pH of the control was adjusted daily to 8.0 with NaOH, and the solutions were changed completely at least once a week. Solutions with added $NaHCO_3$ had an initial pH of about 8.0. When the pH of these solutions reached 8.3 they were replaced with freshly prepared solution. Thus, pH was essentially eliminated as a variant in this experiment.

The plants were harvested on April 30. After determining fresh weights of tops and roots, samples of tissue were dried in a forced-draft oven. The methods of analysis followed were those previously reported (2).

Observations

The growth response of the beets on the various experimental treatments is shown *in* Table 2. All plants made excellent growth. There was no difference in response between plants receiving 0 and 8 m.e./liter of

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[2] Numbers in parentheses refer to literature cited.

added $NaHCO_3$; but the higher levels of added $NaHCO_3$ were associated with appreciably smaller tops; and the highest level of treatment was characterized by definitely the smallest roots. Accordingly, there was a tendency for the top-root ratio to increase with increasing concentration of bicarbonate in the growing medium. Even though beets were remarkably tolerant of the bicarbonate ion, the data suggested that any adverse effect is more serious to the development of the tap, or storage, roots than to vegetative growth of the tops.

The cationic content of leaf blades and storage roots of the experimental plants is showri in Table 3. The accumulation of sodium in the blades with increasing levels of $NaHCO_3$ in the growing medium is the outstanding feature of this table. It is to be noted that the level of sodium accumlation in these red beet leaves compares closely with the level of sodium accumulation found in the foliage of sugar beets on saline or alkaline soil (3) . Although the level of accumulation of sodium in storage roots is relatively small compared with that which may take place in the leaves, it is evident that under the experimental conditions here imposed there was found to be a four-fold increase in the content of sodium in the storage roots with increasing level of $NaHCO_3$ Such a trend in sodium accumulation in sugar beets might have an adverse effect on quality. As variations in treatment brought about higher accumulations of sodium in the tissues, there were observed correspondingly lower levels of potassium accumulation, even though the supply of potassium to the plants was a constant. Beet plants are characteristically very low in content of calcium, and this is evident in the data of Table 3. Increasing levels of sodium bicarbonate in the growing medium were found to be inhibitive of calcium accumulation.

Table 2—Growth Response of Beets Under the Four Treatments.

$NaHCO_3$ in substrate	Green weight per plant (Ave. of nine plants) Tops	Roots	Total	Top/root ratio	Dry weight per plant
m.e./liter	gms.	gms.	gms.		gms.
0	105	111	216	0.95	17.8
8	110	107	217	1.03	17.8
16	82	76	158	1.08	13.5
32	81	48	129	1.69	11.3

Table 3.—Cationic Content of Leaf Blades and Storage Roots.

	Mineral content of tissues									
	Na		K		Ca		Mg		Total cations	
$NaHCO_3$ in substrate	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root
m.e./liter	m.e. per 100 gms. dry tissue									
0	51	17	162	159	35	7	225	24	473	207
8	178	49	100	129	27	4	189	22	494	204
16	238	70	70	86	29	5	175	20	512	181
32	312	77	56	76	23	3	179	19	570	175

Beets are remarkable for the high level of magnesium accumulation which may be found in the tissues. Here again, however, as in the case with the sodium ion, the level of the accumulation in the leaves is much higher than in the roots.

Total accumulation of cations in the leaf blades tends to increase with increasing concentration of $NaHCO_3$ in the growing medium, but a reverse trend was observed in the storage roots.

It is recognized that accumulation of cations in plant tissues is in large degree electrovalently balanced by accumulation of organic anions. It may be noted from data presented in Table 4 that total organic acid accumulation in the two tissues studied tended to approach that observed for total cation content of the tissues, with the exception that total organic acids tended to increase with level of treatment in both tissues. It is evident that *in* the blades oxalic acid represents the preponderant proportion of the total organic acids assayed, and that citric and malic acids contribute relatively insignificantly to the total. In the roots, however, oxalic acid represents less than one-third of the total organic acids and the preponderant proportion of the organic acids is represented by some constituent not assayed.

Table 4.—Organic Acid Content of Leaf Blades and Roots.

$NaHCO_3$ in substrate	Total organic acids		Oxalic acid		Citric acid		Malic acid	
	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root	Leaf blades	Storage root
m.e./liter	m.e. per 100 gins, of dry tissue							
0	374	107	354	32	7	2	7	4
8	386	104	346	27	7	7	6	5
16	403	122	344	33	12	9	4	11
32	527	129	444	30	17	8	12	11

The data recorded suggest that beets grown under alkaline conditions (see 3) may contain rather high accumulations of sodium oxalate in the foliage, since the resulting accumulation of sodium in the tissues is largely counterbalanced electrovalently by oxalate.

Summary

Red beets were grown in sand cultures supplied with nutrient solutions adjusted to pH 8 with the added level of sodium bicarbonate being the only variant in order to test the response of this species to the bicarbonate ion. Four different nutrient solutions were employed: (a) No added sodium bicarbonate; (b) addition of 8 m.e./liter $NaHCO_3$; (c) addition of 16 m.e./liter, and (d) 32 m.e./liter. The growth of beets was less influenced by the presence of the bicarbonate ion in the substrate than has been found for numerous other species studied; but this ion had a definitely adverse effect at the higher levels of concentration used.

Since beets are outstanding as accumulators of sodium, it is to be noted that even with a moderate level of sodium in the substrate (32 m.e./liter) the beets so produced contained 7.8 percent of sodium *in* the dry matter of the blades, but only 0.8 percent sodium in the dry matter of the large

roots. Sodium accumulation tended to be accompanied by oxalate accumulation.

With respect to both content of cations and accumulation of organic acids, the large roots were found to be less sensitive than the leaves to variations in sodium bicarbonate concentration in the growing medium.

Literature Cited

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