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Short Communication

Effect of Germanium on Utilization of Boron in Tomato (*Lycopersicon esculentum* Mill.)

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Germanium as a substitute for boron increased growth and delayed the appearance of B-deficiency symptoms in sunflower (4, 5). Ge was less effective as a substitute for B at high than at low light intensity (4). Skok (5) and McIlrath and Skok (4) postulated that Ge delayed the appearance of B-deficiency symptoms by substituting for B in some chemical complex. We were unable to determine from their work (4, 5) whether Ge can nutritionally substitute for B.

While working with two tomato cultivars that differentially absorb and translocate B, we found that Ge apparently does

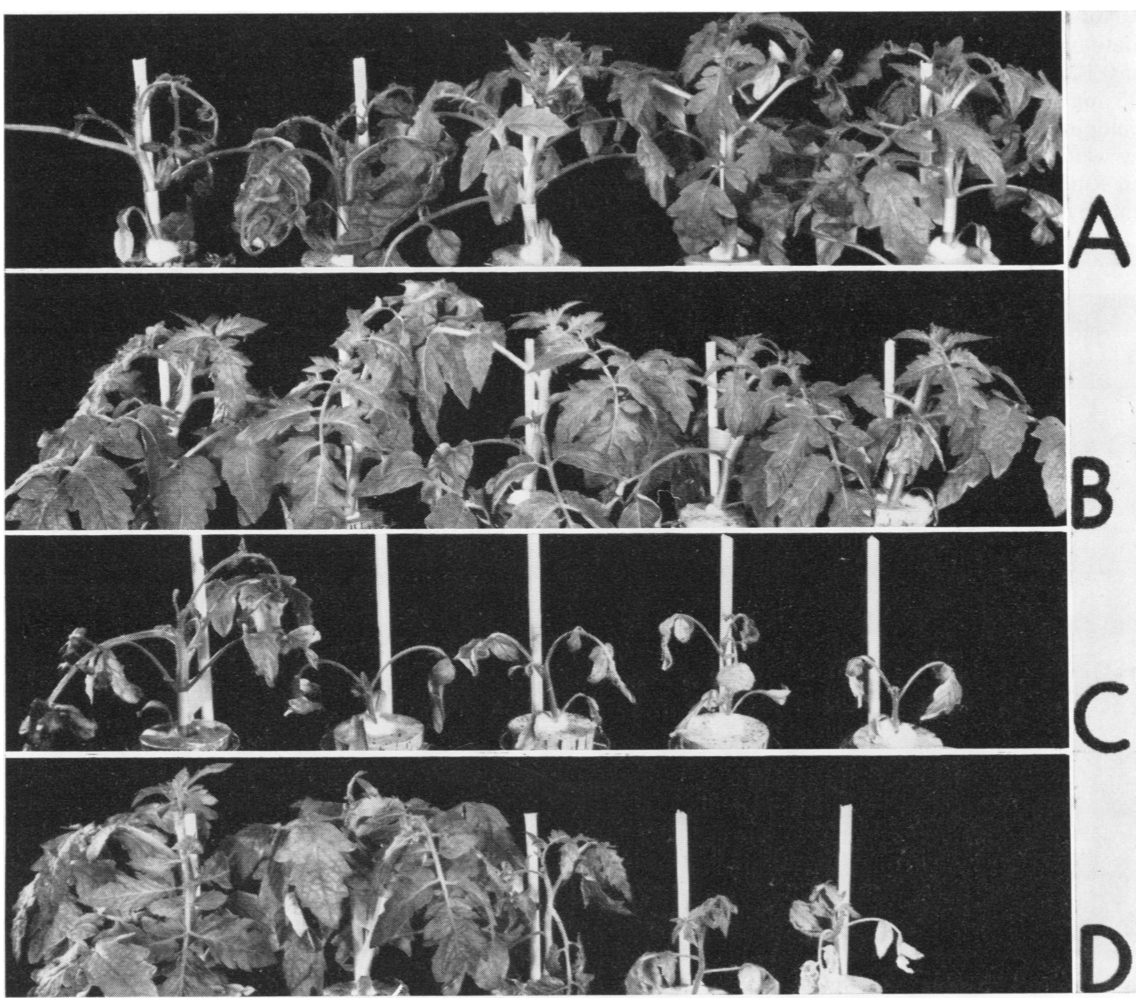

FIG. 1. Growth response of T3238 and Rutgers tomato to increasing B in nutrient solutions (1A and 1B) mg/liter: 0.06, 0.12, 0.35, 0.47, and 0.82; and to the same concentrations of Ge (1C and 1D) containing 0.06 mg/liter of B in all treatments. T3238 (1A) required more B for growth than Rutgers (1B), and T3238 (1C) developed B-deficiency symptoms on all Ge treatments. Ge was toxic to growth of Rutgers (1D) at the three highest Ge concentrations.

not nutritionally substitute for B. This observation places limits on the use of Ge as a substitute for B in studies related to B.

MATERIALS AND METHODS

Wall and Andrus (7) have shown that T3238 and Rutgers tomato (*Lycopersicon esculentum*) differentially absorb and transport B. These two cultivars were grown in a modified Steinberg (6) nutrient solution that contained in mg/liter: Ca, 76; K, 58; Mg, 11; N, 76; P, 3; S, 10; Cl, 9; Mn, 0.26; Zn, 0.08; Cu, 0.02; Mo, 0.02; and Fe, 0.5 as iron ethylenediamine-di-(*o*-hydroxyphenylacetic acid); solution pH was 6.5. Germanium dioxide (GeO_2, soluble form, sp. gr. 4.7, Matheson Coleman and Bell, East Rutherford, N.J.) and B as boric acid were added at increasing concentrations. Four plants per 8 liters of nutrient solution were used in each treatment. All treatments were replicated and each experiment was repeated at least twice. The data reported are averages for the replicates of the last experiment in each case. Repeated experiments agreed with each other.

Boron was determined in the leaves and roots by the colorimetric curcumin-borate method of Dibble *et al.* (2).

RESULTS

Ge Does Not Nutritionally Substitute for B. T3238 and Rutgers tomato were grown in nutrient solutions that contained: 0.06, 0.12, 0.35, 0.47, and 0.82 mg/liter of B. T3238 required 0.35 mg/liter of B in the nutrient solution to grow without developing B-deficiency symptoms (Fig. 1A) while Rutgers grew well at all concentrations of B (Fig. 1B).

T3238 and Rutgers tomato were then grown in nutrient solutions containing 0.06 mg/liter of B and 0.06, 0.12, 0.35, 0.47, and 0.82 mg/liter of Ge. T3238 showed no response to Ge, in fact, growth was decreased at the higher Ge treatment (Fig. 1C). Ge was toxic to the growth of Rutgers at 0.35, 0.47, and 0.82 mg/liter of Ge (Fig. 1D).

Ge Affects Utilization of B. In this experiment, T3238 and Rutgers tomatoes were grown in nutrient solutions containing adequate B (0.47 mg/liter) for 26 days before they were transferred to nutrient solutions containing suboptimal B (0.12 mg/liter), and Ge was varied: 0.0, 0.06, 0.12, and 0.35 mg/liter of Ge. Within 72 hr after the tomatoes were transferred, B-deficiency symptoms had developed in T3238 plants where Ge was not added (Fig. 2-left), but no symptoms developed where 0.35 mg/liter of Ge was added (Fig. 2-right). There was less B in the tops of T3238 tomatoes that developed B-deficiency symptoms than in either T3238 or Rutgers where the symptoms did not develop (Table I). Boron deficiency symptoms were delayed approximately 4 days by adding Ge.

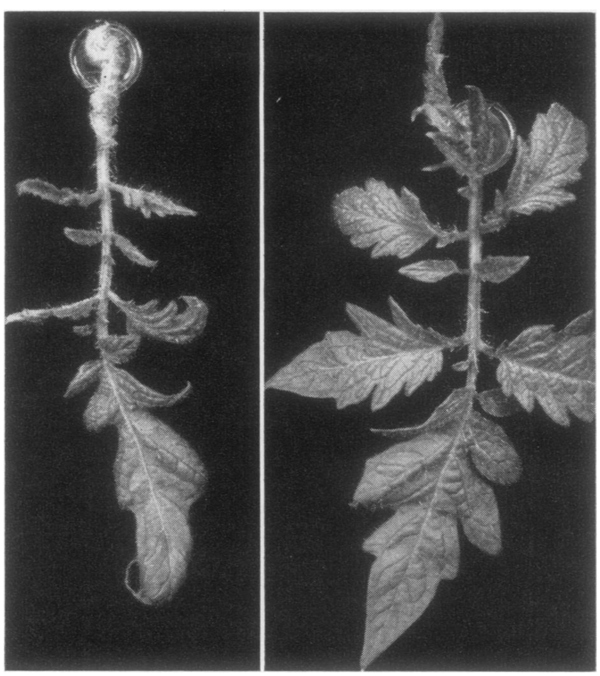

FIG. 2. Top leaves of T3238 tomato showing B-deficiency symptoms (left 0.12 mg/liter of B, no Ge). The addition of 0.35 mg/liter of Ge to the nutrient solution retarded the development of B-deficiency symptoms in T3238 (right). The plants were only in the Ge treatment for 3 days before harvest.

Table I. *Yield of Leaves and Effect of Ge on B in Roots and on the Translocation of B into Leaves of T3238 and Rutgers Tomatoes*

These plants were only in the Ge treatment for 3 days before harvest.

Treatment Ge	B in Leaves			B in Roots	Leaf Yield
	6–5[1]	4–3[1]	2–1[1]		
mg/liter		*μg/g*		*μg/g*	*g dry wt*
T3238					
0.00	15[2]	16	20	44	7.7
0.06	21	26	33	59	6.5
0.12	36	25	32	54	7.4
0.35	26	22	24	47	8.1
Rutgers					
0.00	37	25	30	66	7.5
0.06	35	62	74	57	6.6
0.12	52	81	77	42	7.5
0.35	47	35	34	41	7.9

[1] Refers to leaf position, *i.e.*, 6–5 = two youngest; 4–3 = two middle; and 2–1 = two oldest leaves.

[2] B-deficiency symptoms had developed at time of harvest.

DISCUSSION

Mobility of B from roots to leaves or old leaves to young leaves is difficult to assess because of the immobile nature of B once located in a plant part. A constant source of B is required for plant growth (3). Wall and Andrus (7) have shown that T3238 and Rutgers tomato differentially absorb and transport B from a growth medium. Brown and Jones (1) have shown that this difference is controlled in the root, but the controlling factors of B transport remain unknown.

Severe B-deficiency symptoms developed in T3238 tomato within 72 hr after transfer from relatively high to low B in a nutrient solution. By adding Ge as a substitute for B, B-deficiency symptoms were delayed in T3238. A similar observation was made by Skok (5) and McIlrath and Skok (4) using sunflower. We also found that Ge is toxic or can prevent a limited supply of B from functioning in the plant. This indicates that Ge may occupy metabolic sites normally occupied by B, but apparently Ge does not nutritionally substitute for B in either T3238 or Rutgers tomato. Instead, Ge appears to serve as a substitute, in a sparing role, allowing greater mobility of B to other sites in T3238 that require B. The apparent toxic nature of Ge as a substitute for B places limits on its usefulness in nutritional studies related to B.

LITERATURE CITED

1. Brown, J. C. and W. E. Jones. 1971. Differential transport of boron in tomato (*Lycopersicon esculentum* Mill.). Physiol. Plant. 25: 279–282.

2. Dibble, W. R., E. Truog, and K. C. Berger. 1954. Boron determination in soils and plants. Anal. Chem. 26: 418–421.

3. Gaugh, H. G., and W. M. Dugger, Jr. 1954. The physiological action of boron in higher plants: a review and interpretation. Agr. Exp. Sta., Maryland, Tech. Bull. A-80.

4. McIlrath, W. J. and J. Skok. 1966. Substitution of germanium for boron in plant growth. Plant Physiol. 41: 1209–1212.

5. Skok, J. 1957. The substitution of complexing substances for boron in plant growth. Plant Physiol. 32: 308–312.

6. Steinberg, R. A. 1953. Symptoms of molybenum deficiency in tobacco. Plant Physiol. 28: 319–322.

7. Wall, J. C. and C. F. Andrus. 1962. The inheritance and physiology of boron response in the tomato. Amer. J. Bot. 49: 758–762.