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High Zinc Concentrations in the Growing Medium Contribute to Chlorosis in Blueberry

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Abstract. **An experiment arranged in a randomized complete block design with four replications of two cultivars × six pH levels × four Zn levels was conducted to determine if Zn caused leaf chlorosis in rabbiteye (*Vaccinium ashei* Reade cv. Climax) and southern highbush (mostly *V. corymbosum* L. cv. Bladen) blueberry. 'Bladen' accumulated more foliar Mn and Zn than 'Climax', but Fe concentration was similar in the two cultivars. Leaf chlorosis ratings were similar for the two cultivars. Solution pH had no significant effect on Mn, Zn, or Fe leaf concentration or degree of chlorosis. Zinc level in the nutrient solution affected leaf concentration of Mn and Zn but not of Fe. A significant linear increase in chlorosis resulted from increasing Zn solution concentration from 30 to 120 mg·L^{-1}. We conclude that high levels of Zn may induce leaf chlorosis in rabbiteye and southern highbush blueberry.**

Iron chlorosis of blueberry has been observed on mineral soils since the 1930s (Bailey, 1936) and its causes have not yet been fully elucidated. At low soil pH, a requirement for blueberry culture, Zn can cause phytotoxicity directly and by increasing translocation of Mn to plant leaves in other crops (Chaney and Giordano, 1977). We have observed that almost all soil test results from small-fruit plantings in southern Mississippi indicate high or very high (3–5 kg·ha^{-1}) soil Zn content, yet Zn deficiency has been reported prevalent in the lower Gulf Coastal Plain region of the United States (Beeson, 1957). Pettry and Switzer (1993) found 34–183 ppm Zn in the surface horizon of Lower Coastal Plains soils in Mississippi. Zinc deficiency in tung (*Aleurites fordii* Hemsl.) trees was a problem in this area and was usually corrected by applying 56–112 g of zinc sulfate per tree (Barrows et al., 1960). The tung belt extended from eastern Texas along the Gulf of Mexico to the Atlantic Ocean and included about 81,000 ha (Kilby, 1970), indicating that much Zn was applied where blueberries are grown currently. The objective of our study was to determine if excessive Zn in the growing medium causes chlorosis in blueberry.

Materials and Methods

Two-year-old plants of 'Climax' rabbiteye (RE) and 'Bladen' southern highbush (SHB) were root-washed and transplanted into 8-L pots of washed sand. All plants were fertilized with STEM (Soluble Trace Element Mix, Grace-Sierra Horticultural Products, Milpitas, Calif.) at 500 mL/pot and Osmocote (14N–6P–12K) (Grace-Sierra Horticultural Products) at 20 g/pot 1 week before Zn applications were started.

Treatments were arranged in a randomized complete block with four replications of two cultivars × six solution pH levels × four solution Zn levels. The pH levels were 4.0, 4.5, 5.0, 5.5, 6.0, and 6.5 and Zn was at 30, 60, 90, and 120 mg·L^{-1} from zinc sulfate and STEM. Three milligrams per liter of the total Zn in each treatment was supplied by STEM and the remainder was supplied by $ZnSO_4 \cdot 7H_2O$. The Zn + STEM solutions were applied at 500 ml/pot every 2–5 days, as irrigation was needed, from 18 May until 1 Aug. 1994.

Degree of leaf chlorosis on a whole-plant basis was rated visually by two persons (26 July and 29 July 1994) on a scale of 1 = most chlorotic to 9 = least chlorotic. Means of the two visual ratings were used as data for analysis.

All leaves from each plant were collected 3 Aug. 1994 and oven-dried at 70 °C. The leaves were ground and dry-ashed using the procedures of Jones and Case (1990) with the following modifications: 1) 1 g of tissue was weighed and ashed at 450 °C; 2) the ash was dissolved in 5 ml of 20% HCl on a hot plate; and 3) the solution was transferred to a volumetric flask and brought to 100 ml with deionized water. Manganese, Zn, and Fe concentrations were determined by atomic absorption (Instrumentation Laboratory 157AA/AE spectrophotometer, Wilmington, Mass.).

Manganese, Zn, and Fe leaf concentrations and leaf chlorosis ratings were analyzed statistically by general linear model procedures (SAS Institute, Cary, NC). Main effects of cultivar, pH, and Zn concentration and their interactions were determined. Zinc concentration effects were subdivided into linear, quadratic, and cubic effects. Cultivar means were pooled across pH and Zn levels because there were no significant interactions with these sources. Likewise, leaf Mn and Zn concentrations and leaf chlorosis ratings were pooled across cultivars and pH levels.

Results and Discussion

Zinc and Mn leaf concentration differed significantly between RE and SHB cultivars (Table 1). No treatment interaction was significant. 'Bladen' (SHB) accumulated more foliar Mn and Zn than 'Climax' (RE), but Fe concentration was about the same for the two cultivars (Fig. 1). Field-grown SHB plants accumulated more Mn and about the same amounts of Fe and Zn as did RE plants (Clark et al., 1994). Zinc level was low in the soils where their plants were grown. Our results and those of Clark et al. imply that SHB may be more susceptible than RE to Mn and Zn toxicity when these elements are available in excessive amounts. Several authors, as reported by Chaney and Giordano (1977), have shown that when excessive Zn is added, chlorosis may occur in leaves containing apparently normal Fe levels. Korcak (1989) found high micronutrient (Cu, Zn, Mn, and B) levels associated with Fe chlorosis in blueberry.

Solution pH had no significant effect on Zn, Fe, or Mn leaf concentration or degree of leaf chlorosis, nor were any interactions of pH

Table 1. Effects of cultivar, pH, and Zn concentration in nutrient solution, and their interactions on four variables.

Source	df	Leaf concn[z] Zn	Leaf concn[z] Mn	Leaf chlorosis
Cultivar (C)	1	**	**	NS
Replication	3	NS	NS	NS
pH	5	NS	NS	NS
ppm Zn	3	**	*	**
Linear	1	**	**	**
Quadratic	1	NS	NS	NS
Cubic	1	**	NS	NS
C × pH	5	NS	NS	NS
C × ppm Zn	3	NS	NS	NS
pH × ppm Zn	15	NS	NS	NS
C × pH × ppm Zn	15	NS	NS	NS

[z]Leaf Fe concentration was unaffected by any source of variation.
NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

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by other sources of variation significant (Table 1). Soil pH is known to be a dominant factor in Zn uptake (Chaney and Giordano, 1977); however, absence of organic matter in sand culture probably removed pH influence over the extent of minor element reaction with the medium. Soil pH also affects Zn diffusion (Chaney and Giordano, 1977), which is not a factor in sand culture. Solution pH in sand culture apparently does not play the same role as field soil pH in controlling minor element uptake.

Zinc concentration in the nutrient solution significantly affected Zn and Mn but not Fe leaf concentration (Table 1). Zinc leaf concentration increased but Mn concentration decreased linearly with increasing Zn level in the nutrient solution (Table 1). Except for leaf Zn concentration, no quadratic or cubic effect of solution Zn content was significant (Table 1). These results differ from those of Lee and Page (1967) and Lee and Craddock (1969) who found that soil additions of Zn in cotton (*Gossypium hirsutum* L.) and soybean (*Glycine max* L. Merr.) increased plant uptake of Mn. In a leaf chlorosis amelioration study, Spiers and Braswell (1989) found higher leaf Mn in RE plants fertilized with $ZnSO_4$ than those receiving Mn chelate. Korcak (1988) and Spiers (1990) reported that high Mn concentration in leaves resulted in poor plant growth and leaf chlorosis. A possible explanation of the differing results between plants grown in sand culture and the field may be soil organic matter effects on Mn and Zn interaction with the medium. It appears that high Zn levels in soil may cause increased Mn toxicity even though it would not be suggested from the results of this study.

Zinc concentration significantly affected the degree of leaf chlorosis (Table 1). A significant linear increase in chlorosis resulted from increasing Zn concentration between 30 and 120 $mg \cdot L^{-1}$ (Table 1). In reviews of other crops, Foy et al. (1978) concluded that chlorosis from excess Zn appears to be due to direct or indirect interaction with foliar Fe. White et al. (1974) hypothesized that Zn and Mn interfere with Fe use for chlorophyll synthesis in the leaves. Since Zn solution concentration did not affect leaf Fe concentration, our results support the hypothesis of White et al. Iron concentrations in chlorotic leaves equal to or higher than those found in green leaves were reported in blueberry (Korcak, 1989). Leaf chlorosis rating was similar for the two cultivars we tested. We conclude that high levels of Zn in the growing medium may induce leaf chlorosis in RE and SHB blueberry.

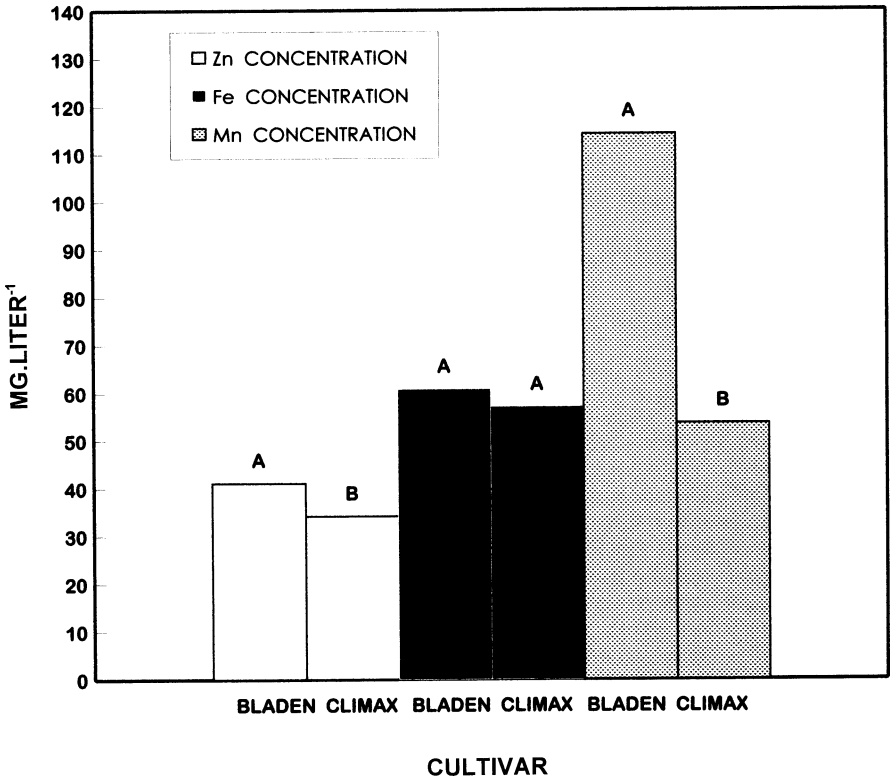

Fig. 1. Leaf micronutrient concentration of 'Bladen' (southern highbush type) and 'Climax' (rabbiteye type) blueberry plants averaged across four replications, six pH levels, and four Zn levels. Mean squares for difference between cultivars were 2289 ($P > 0.0007$), 667 (NS), and 175,774 ($P > 0.0001$) for Zn, Fe, and Mn, respectively.

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