Association of Marginal Leaf Scorch with Sodium Accumulation in Salt-stressed Peach

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Abstract. **The effect of specific ion toxicity during salt stress was tested in the present study. The experiment was repeated twice, in 1996 and 1998, with 'Nemaguard' peach seedlings and rooted cuttings grown in hydroponics under two NaCl concentrations (50 and 30 mM). Foliage was separated in symptomatic and symptomless leaves and the amount of sodium (Na^+) and chloride ($C1^-$) was determined. Significantly higher Na^+ content was found in symptomatic than in symptomless leaves in both experiments, whereas in only two of the six cases was Cl^- content higher in symptomatic than in symptomless leaves. The Na^+ threshold for leaf scorch was somewhere between 4 and 6 mg·g^{-1} dry weight. Results indicated that Na^+ accumulation, rather than Cl^- accumulation, was associated with the familiar marginal and interveinal scorch symptoms seen in salt-stressed peach leaves.**

Peach [*Prunus persica* (L.) Batsch.] is relatively sensitive to soil salinity compared with other crop plants (Maas, 1987, 1993). As with most woody species, its response to salinity not only depends on the osmotic potential of the soil water, but also on the toxic effects of specific ions (Bernstein, 1965). Specific ion toxicity results in yield losses significantly greater than those predicted from osmotic effects alone, and is directly responsible for marginal and interveinal scorch symptoms in peach leaves (Bernstein, 1965). Early research on salinity in peach suggested that accumulation of chloride ($C1^-$), rather than sodium (Na^+) or sulfate, in leaves caused leaf scorch (Wadleigh et al., 1951). Further research on several stone fruit species supported the conclusion that $C1^-$ accumulation caused leaf scorch (Bernstein et al., 1956), and this paradigm was later applied to several fruit species, including grapes (*Vitis vinifera* L.) (Bernstein et al., 1969), strawberry (*Fragaria* ×*ananassa* Duch.) (Bernstein, 1965), citrus (*Citrus* sp.) (Walker and Douglas, 1983), and avocado (*Persea americana* L.) (Bingham et al., 1968). The association of $C1^-$ accumulation with leaf scorch has led to research focused on exclusion of leaf $C1^-$ as a means of reducing salt stress (Rogers et al., 1997; Walker and Douglas, 1983). However, Na^+ rather than $C1^-$ has been associated with leaf scorch in Japanese plum (*Prunus salicina* Lindl.) (Ziska et al., 1991) and reduced photosynthesis in 'Valencia' orange [*Citrus sinensis* (L.) Osb.] (Lloyd et al., 1989). Furthermore, Na^+ and Cl^- may act synergistically to produce greater toxicity than when either ion is applied alone (Martin and Koebner, 1995).

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Our earlier research indicated that paclobutrazol (PBZ) ameliorated the effects of salt stress on peach by reducing leaf accumulation of Na^+ and Cl^- (Abou El-Khashab et al., 1997). Subsequently, we performed hydroponics experiments using PBZ and gibberellic acid (GA) (an antagonist of PBZ) to determine whether Na^+ and/or Cl^- was excluded or tolerated differently in peach leaves treated with these growth regulators during NaCl stress. The experiments involved separating leaves into those with (scorched), and without symptoms (normal), measuring their Na^+ and Cl^- contents, and relating this to the presence/absence of leaf scorch. These experiments failed to demonstrate consistent effects of PBZ or GA on Na^+ and Cl^- uptake or accumulation in leaves, but the data suggested that leaf Na^+ content (and not Cl^-) was closely correlated with leaf scorch in peach regardless of growth-regulator treatment. This paper presents a portion of the data collected in these experiments to test the hypothesis that Na^+ accumulation in peach leaves is better correlated with expression of leaf scorch than is Cl^- accumulation.

Materials and Methods

The experiment was conducted during Jan.–Mar. 1996 and repeated in Mar.–June 1998. The two experiments differed in two respects: 1) in 1996 'Nemaguard' seedlings were used, whereas in 1998 rooted cuttings of 'Nemaguard' were used, and 2) the NaCl concentration was 50 mM in 1996 and 30 mM in 1998. Both experiments were conducted in a greenhouse in Athens, Ga. (34°N lat. and 83°40´W long.), with ≈70% integrated daily solar radiation transmission, natural photoperiod (range = 10.5 to 13.5 h), and temperatures ranging from 22 to 35 °C. In both cases, 48 plants were transplanted to 8-L hydroponic containers filled with nutrient solution, the composition of which was described by Jones (1985). Two plants were placed in each container, which constituted one experimental unit. Each experiment was a factorial combination of two NaCl levels (0 and 50 or 30 mM) and three growth-regulator treatments (none, PBZ, GA), with four replications. The growth-regulator treatments produced occasional significant, yet inconsistent, effects on growth and ion accumulation; thus, data could not be pooled across growth-regulator treatments. In the interest of brevity, growth-regulator effects *per se* are not discussed. Plants were sprayed with PBZ (200 mg·L^{-1}), GA (200 mg·L^{-1}), or water twice at an interval of 15 d starting the day that treatment with NaCl began. Exposure to NaCl treatments began after acclimation of plants to hydroponics for 2 weeks and was stopped after ≈7 (1996) or 11 (1998) weeks. Containers were arranged in a randomized complete-block design.

At the end of each experiment, leaves were divided into symptomless and symptomatic (scorched) classes, and the total leaf area per plant in each class was measured with a leaf-area meter (LI-COR LI-3000; LI-COR, Lincoln, Nebr.). Leaves were dried at 70 °C, finely ground, and used for analyses of Na^+ and Cl^- content. Sodium was determined using a Na^+-selective electrode (Corning Science Products, Corning, N.Y.) according to the method of Rieger and Litvin (1998). Chloride was determined using a Cl^--selective electrode (Fisher Scientific, Pittsburgh) after the method of Islam et al. (1983).

The data were analyzed by *t* test comparing symptomatic and symptomless leaf classes within a given year and growth-regulator treatment using SAS (SAS Institute, Cary, N.C.).

Results and Discussion

Growth of plants was affected by NaCl similarly in the 1996 and 1998 experiments. Total, stem, and root dry weight were lower in salt-treated plants than in nonsalinized plants in both experiments regardless of growth-regulator treatment, but total leaf dry weight was not affected by NaCl in either experiment (data not shown). Defoliation of NaCl treated plants ranged from 2% to 15% of the total leaf area per plant in both experiments. Leaf scorch symptoms were evident in 36% to 64% of the total leaf area of salt-treated plants in 1996, but in only 22% to 32% in 1998 (data not shown). Differences in percentages of canopy leaf scorch between years probably resulted from the higher concentration of NaCl used in 1996 vs. 1998.

Leaf Na^+ and Cl^- contents increased significantly in response to NaCl treatment in each experiment (Table 1). Significantly higher Na^+ content was found in symptomatic than in symptomless leaves regardless of growth-regulator treatment in both experiments. However, in only two of the six cases was Cl^- content higher in symptomatic than in symptomless leaves (Table 1). The Na^+ threshold for leaf scorch was somewhere between 4 and 11 mg·g^{-1} dry weight in 1996, and between 2 and 6 mg·g^{-1} in 1998. Similar results were obtained for 'Nemaguard' rooted cuttings grown in hydroponics in another study in 1997 with 50

Table 1. Effects of exposure to NaCl and treatment with paclobutrazol (PBZ) or gibberellic acid (GA) on Na^+ and Cl^- contents of 'Nemaguard' peach seedlings after 7 weeks of exposure to NaCl (50 mM) in solution in 1996, and of rooted cuttings of 'Nemaguard' after 11 weeks of exposure to NaCl (30 mM) in solution in 1998.

		Na^+ or Cl^- content in leaves ($mg \cdot g^{-1}$ dry wt)			
		NaCl treatment			
		No	Yes		$P > t$,
Ion	Growth regulator		Symptomless leaves	Symptomatic (scorched) leaves	symptomless vs. symptomatic
			1996		
Na^+	None	0.02	4.3	11.0	0.0001
	PBZ	0.02	5.7	12.7	0.0024
	GA	0.01	6.4	13.5	0.0001
Cl^-	None	0.55	19.5	18.1	0.4408
	PBZ	0.64	21.4	25.1	0.1760
	GA	0.62	15.7	19.5	0.0037
			1998		
Na^+	None	0.47	1.8	6.2	0.0004
	PBZ	0.62	1.9	6.4	0.0001
	GA	0.49	2.1	5.9	0.0002
Cl^-	None	0.44	7.6	8.5	0.2158
	PBZ	0.37	7.1	10.1	0.0001
	GA	0.46	7.1	8.1	0.1909

mM NaCl added (Rieger, unpublished data), yielding a threshold for leaf scorch at Na^+ contents between 3.5 and 6 $mg \cdot g^{-1}$. Thus, an approximate threshold range for Na^+ of 4-6 $mg \cdot g^{-1}$ was found consistently in three different experiments using 'Nemaguard' peach. In addition to the leaf Cl^- content being similar between symptomatic and symptomless leaves in two-thirds of the cases tested, the range of values obtained was much more variable, and showed no overlap between experiments, unlike the data for Na^+ content (Table 1).

Results indicate that Na^+ accumulation, rather than Cl^- accumulation, above a threshold of ≈4–6 $mg \cdot g^{-1}$, was associated with the familiar marginal and interveinal scorch symptoms seen in salt-stressed peach leaves. This finding is inconsistent with the paradigm that leaf scorch in stone fruits is associated with Cl^- accumulation (Bernstein et al., 1956), but consistent with more recent reports that associate Na^+ accumulation with leaf scorch in Japanese plum (Ziska et al., 1991). Future work on resistance to salt stress in stone fruits should therefore consider exclusion or tolerance of Na^+ in addition to that of Cl^-.

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