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Foliar and yield response of santa rosa plum to saline water spray

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Summary. Canopies of 22-year-old Santa Rosa plum trees irrigated with mini-sprinklers below the canopy with nonsaline (0.3 dS/m) water were sprayed weekly during one irrigation season with water having six levels of salinity (0.3, 1.1, 2.1, 3.3, 4.5, and 6.8 dS/m) to evaluate the extent of leaf injury, foliar absorption of Cl and Na, and yield response. Recognizable leaf injury was caused by spray water containing 29 mol/m^3 of chloride and 15 mol/m^3 of sodium. Severe leaf damage occurred when the leaf chloride and sodium concentrations exceeded 300 and 125 mmol/kg (dry weight), respectively. These concentrations were higher than those causing foliar damage on other trees in the same orchard which had been irrigated below the canopy with water having the same salinity as that sprayed on the canopy. No residual foliar injury was observed during the irrigation season following the year when the spray treatments were applied. Fruit yield measured six weeks after treatments were initiated was unaffected. In the following 2 years, yield was reduced by the highest salinity levels, even though the salt spray treatments were not continued and no foliar injury was visible.

Some crops, when irrigated by sprinkling, experience foliar injury and yield reductions that may not occur when they are surface or drip irrigated with water of similar quality (Harding et al. 1958; Maas et al. 1982b). As the salinity of the sprinkled water increases, crops become increasingly prone to salt injury as a result of foliar absorption of salts that accumulate on the leaf as the sprinkled water evaporates from the leaf surface (Maas 1985).

Various studies have documented the potentially harmful effects of wetting the leaves of grapes (Francois and Clark 1979) and of herbaceous plants (Bernstein and Francois 1975; Busch and Turner 1967; Goldberg and Shmueli 1971; Maas et al. 1982a; Nielsen and Cannon 1975) with saline water. Leaves of deciduous fruit and nut trees are believed to absorb chloride and sodium more readily than many herbaceous crops. Ehlig and Bernstein (1959) found that leaves of sprinkled young plum trees were injured at a lower foliar concentration of chloride and sodium than the other tree species tested.

No investigations on foliar spray damage have been reported for mature, deciduous fruit trees. The objective of this study was to evaluate the extent of foliar damage and the yield response of mature plum (*Prunus saliciva* cv. Santa Rosa) trees as a result of wetting the foliage with water of various levels of salinity.

Materials and methods

The study was conducted as part of a salt tolerance field experiment at the Kearney Agricultural Center of the University of California near Fresno in the San Joaquin Valley on mature Santa Rosa plum trees (Hoffman et al. 1988). In the main experiment, six levels of saline water (electrical conductivities of 0.3, 1, 2, 4, 6, and 8 dS/m) were applied by mini-sprinklers below the tree canopy. The foliar spray treatments were applied to two border rows, the second row from the north edge of the orchard and the last row on the south edge, irrigated with non-saline water (0.3 dS/m) by mini-sprinklers. The prevailing wind is from the northwest so the northernmost row was maintained as a border.

Six levels of salinity (see Table 1) were applied with a spray nozzle from a 150 l portable orchard sprayer on four randomly-selected trees per treatment. The trees were sprayed in the morning, generally between 0900 and 1200 h; beginning with the low- and high-salt treatment on alternate weeks to minimize bias. Each tree was sprayed at weekly intervals for a total of fourteen weeks from May 6 until August 28, 1985. Every tree was sprayed with approximately 38 l of water to cover the entire canopy completely and produce run-off from the foliage. Depending on evaporative conditions, the leaves remained wet from one-half to one hour after spraying.

Twenty mature leaves, ten each from the north and south sides of the lower portion (below a height of 2.5 m) of each tree canopy were sampled separately before each spraying. The final set of leaf samples was taken on September 12, 2 weeks after the final foliar spraying. The leaves were rinsed twice in distilled water, dried at 70 °C, and ground in a blender. Chloride was determined on acid extracts (0.1 M nitric acid in 1.7 M acetic acid) by the coulometric-amperometric titration procedure (Cotlove 1963). Nitric-perchloric acid digests of the ground leaves were analyzed for P by molybdovanadate-yellow colorimetry (Kitson and Mellon 1944) and Na, Ca, Mg, and K were determined by atomic absorption spectrophotometry. On September 3, one week after the last spraying, a visual evaluation was made to scale leaf damage from 0 for no visual damage to 6 when over 90% of the leaves were severely damaged.

Fruit were harvested on June 18, 1985, after the sixth spray application. Foliar sprayings were discontinued after 1985, but the fruit were harvested in June 1986 and June 1987 to evaluate after-effects from the saline spray treatments. Yields were also measured in 1984, the year prior to the spray treatments, to evaluate tree variability. The total yield and a subsample of fruit from each tree were weighed, and the number of fruit in the subsamples were counted.

Results and discussion

Salt absorption

The accumulation of chloride and sodium in plum leaves increased linearly during the treatment period for all of the spray treatments. Figure 1 shows the concentrations of Cl and Na for three of the treatments. The concentrations for the 6.8 dS/m treatment on September 12 were not used in determining the linear relationships because the canopy was severely damaged by that time, and further absorption had apparently ceased. Concentrations of Cl in the leaves were twice those of Na, similar to the relative concentrations in the spray water (Table 1).

The daily rates of absorption of Cl and Na for all treatments (i.e., slope of the linear relationships illustrated in Fig. 1) are presented in Fig. 2. The absorption rates

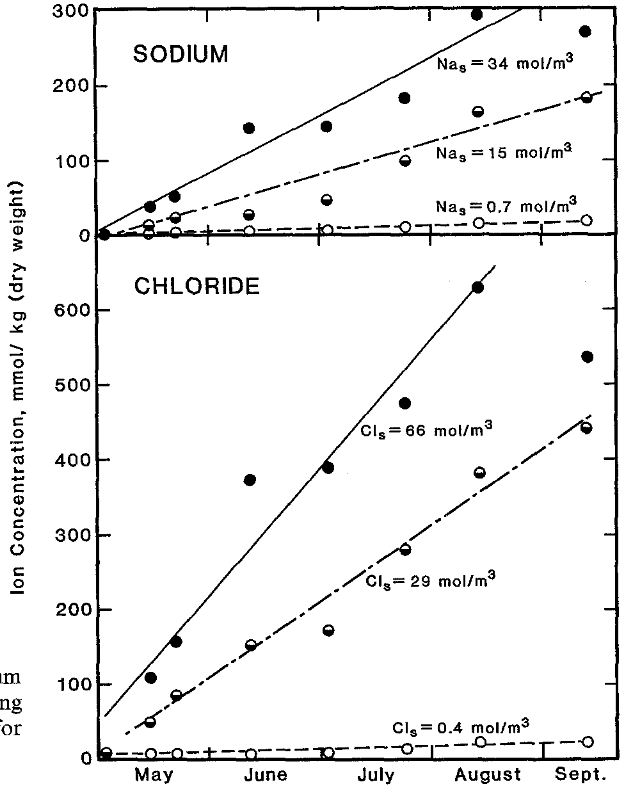

Fig. 1. Concentration of sodium and chloride in dry leaves during the 1985 irrigation season for three spray waters

Table 1. Average composition of waters sprayed on the plum foliage

Spray water salinity (dS/m)	Ion concentration (mol/m^3)				Sodium adsorption ratio $(mol/m^3)^{1/2}$
	Cl	Na	Ca	Mg	
0.3	0.4	0.7	0.9	0.3	0.6
1.1	7.4	4.6	2.3	0.3	2.8
2.1	17.5	10.0	4.4	0.3	4.6
3.3	29.2	15.4	7.3	0.3	5.6
4.5	39.2	20.8	10.1	0.3	6.5
6.8	65.6	33.7	14.7	0.3	8.7

were linear functions of the salt concentration of the spray water for both ions. Again, because the concentration of Cl in each spray treatment was double that of Na, Cl was absorbed twice as fast as Na; slopes of the relationships in Fig. 2 are 0.83 for Cl and 0.37 for Na.

Leaf concentrations of Cl and Na in plum are apparently less than those of many herbaceous crops for similar conditions. After 3 weeks of almost daily (5 times per

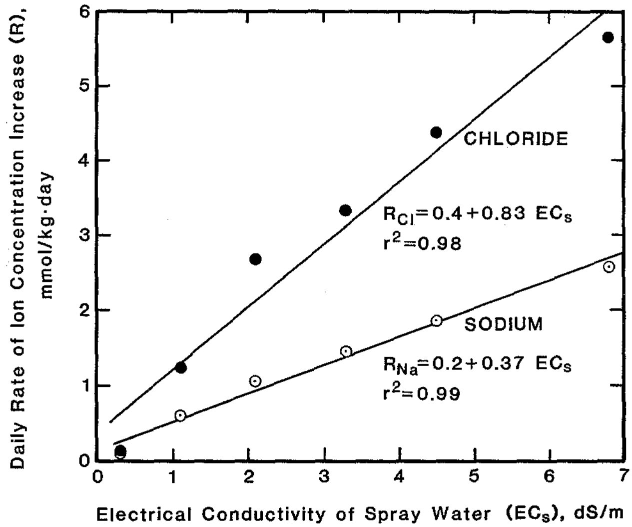

Fig. 2. Rate of accumulation of chloride and sodium in plum leaves as a function of the salinity of the spray water. The concentration of sodium was half that of chloride for each spray water

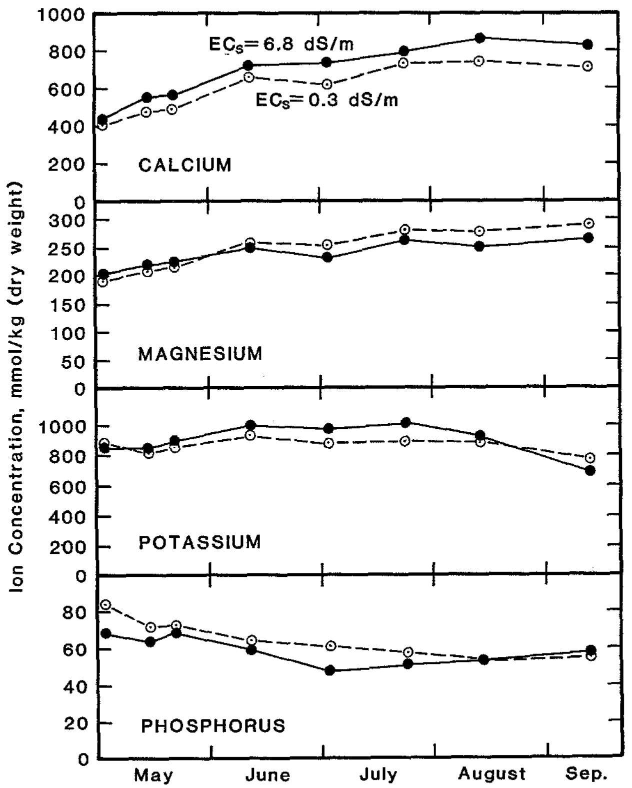

Fig. 3. Concentration of calcium, magnesium, potassium, and phosphorus in dry leaves during the 1985 irrigation season for the control and the most saline spray water

Fig. 4. Typical examples of leaf damage from spraying Santa Rosa plum trees with water of different salt contents for one irrigation season. The electrical conductivity of the spray waters from left to right are 0.3, 1.1, 2.1, 3.3, 4.5, and 6.8 dS/m

week) sprinkling with water having an electrical conductivity (EC_s) of 3.4 dS/m (30 mol/m^3 of both Cl and Na), Maas et al. (1982 b) found that nine of ten herbaceous crops studied had leaf Cl and Na concentrations ranging from 350 to 1250 mmol/kg. After a similar treatment for plum (14 applications of 29.2 mol/m^3 of Cl for the EC_s treatment of 3.3 dS/m or 33.7 mol/m^3 of Na for the 6.8 dS/m treatment), the leaf Cl concentration was 450 mmol/kg and the Na concentration was 300 mmol/kg. The rate of absorption cannot be compared because of the large differences in time taken to apply the treatments; 3 weeks in the study by Maas et al. (1982 b) compared to 14 weeks for plums.

The influence of saline spray water on the leaf concentration of Ca, Mg, K, and P is illustrated in Fig. 3 for the nonsaline (0.3 dS/m) and highest salt (6.8 dS/m) treatments. Because the differences in concentrations between the two extreme treatments were not significantly different according to an analysis of variance, results from the intermediate treatments are not shown. The concentration of Ca doubled from about 400 in May to 800 mmol/kg (dry weight basis) in September with the concentration being slightly higher in the saline treatment throughout the season. Mg increased steadily from 200 to about 275 mmol/kg with the concentration consistently higher late in the season for the nonsaline treatment. Concentrations of P decreased slightly during the season with no consistent differences among treatments. Unlike the results of Maas et al. (1982 b) where sprinkling with saline water decreased the concentration of K below that of the nonsaline treatment for eight of the ten herbaceous crops, there were no significant differences among treatments for plum leaves.

Foliar damage

Typical examples of leaf damage from spraying with the different saline waters at the end of the irrigation season are shown in Fig. 4. Comparisons of visual foliar damage evaluated on September 3 and the leaf concentration of Cl and Na determined from

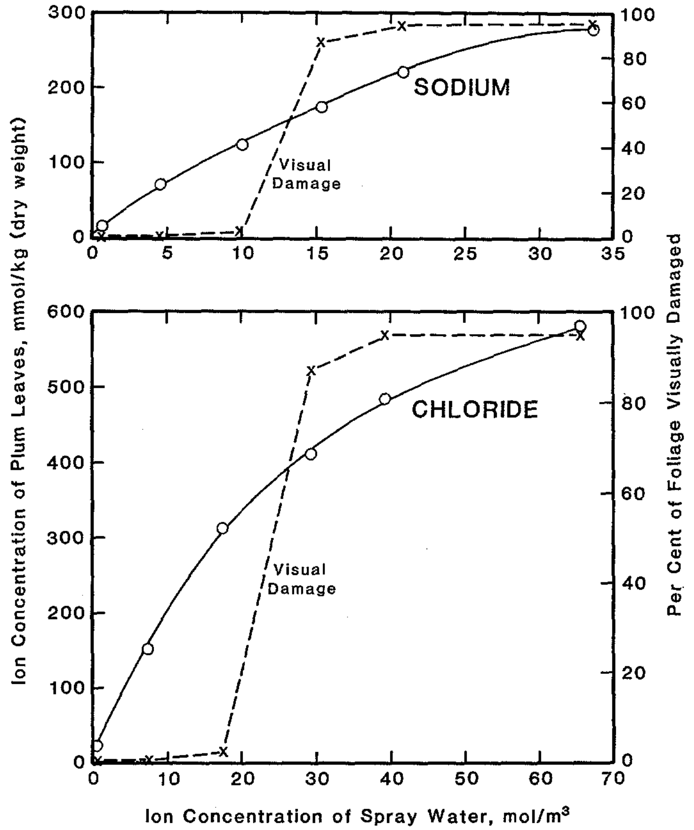

Fig. 5. Impact of saline spray water for one irrigation season on visual foliar damage and the leaf concentration of chloride and sodium at the end of the irrigation season for mature Santa Rosa plum trees

leaves sampled on September 12 for the various salt treatments are given in Fig. 5. Visual foliar damage was insignificant for the three lowest salt spray treatments, but at EC levels of 3.3 dS/m and greater leaves over the entire tree canopy were severely damaged. The results suggest that until the leaf Cl levels exceed 300 mmol/kg and/or Na exceeds 125 mmol/kg, foliar damage from spraying is not apparent visually. Spraying the trees weekly with waters having an EC of 3.3 dS/m (Cl concentration of 29 mol/m^3 and Na concentration of 15 mol/m^3) or more, caused more than 85% of the canopy to be severely damaged by the end of the irrigation season. With the highest salt spray treatment, the trees were almost completely defoliated. Less than 5% of the leaves showed any necrotic symptoms for the 2.1 dS/m treatment (17.5 mol/m^3 of Cl and 10 mol/m^3 of Na). No visual signs of foliar injury were noted during the first (1986) and second (1987) irrigation seasons following the season (1985) when saline sprinkler waters were applied.

The difference in foliar damage caused by saline waters applied to the soil surface and those sprayed on the foliage is of interest. Figure 6 shows the foliar concentrations of chloride and sodium for mature plum trees when saline waters were applied by mini-sprinklers to the soil surface without wetting the foliage. The composition of the

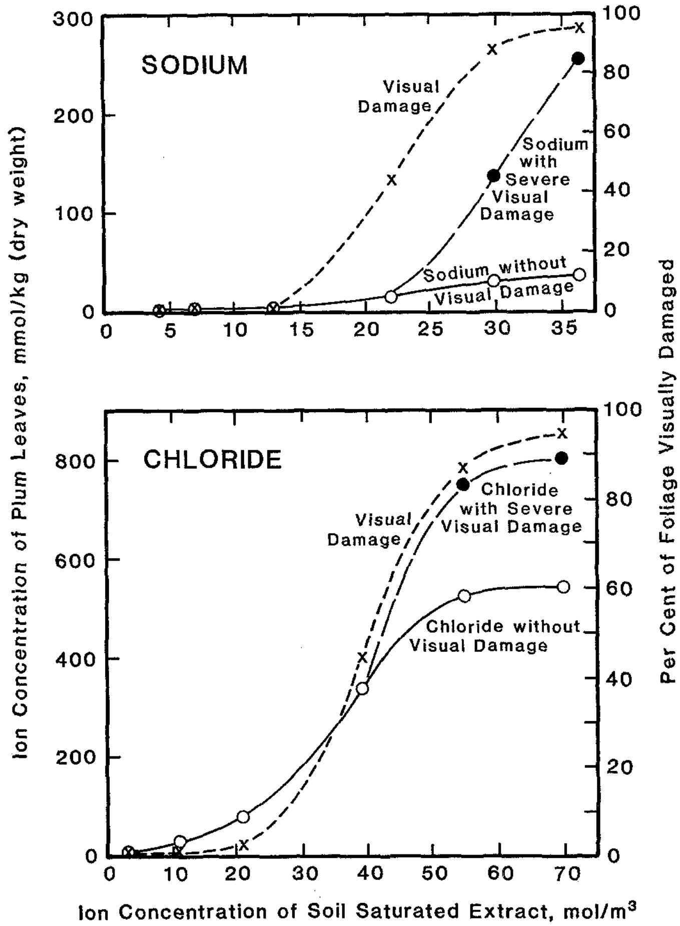

Fig. 6. Influence of chloride and sodium concentrations in saturated soil extracts on ion concentration and visual foliar damage of mature plum leaves

irrigation waters was the same as for the spray water. The Cl and Na concentrations presented in Fig. 6 are the average soil profile values taken the end of June 1985 through a depth of 1.2 m. With the high leaching fraction employed in the experiment the concentrations did not change appreciably with soil depth. Leaves were sampled on August 7. For the two highest salt treatments, separate samples were taken of leaves with severe visual damage and leaves without visual damage. Both types of leaves were found on the same trees. Visual foliar damage was evaluated on September 20.

No significant visual foliar damage was observed from foliar spraying until the Cl concentration of the leaves exceeded 300 mmol/kg; but when saline waters were applied to the soil surface for two irrigation seasons, over 40% of the foliage had been damaged when leaf Cl levels were 340 mmol/kg (Fig. 6). Similarly, no visual foliar damage from spraying occurred until Na concentrations in the leaves exceeded 125 mmol/kg whereas over 40% of the foliage had been damaged when the leaf Na level was only 16 mmol/kg when saline waters were applied on the soil surface.

Table 2. Fruit yield, number of fruit per tree, and individual fruit size for foliar sprayed Santa Rosa plum trees

Spray water salinity (dS/m)	Fruit yield (kg/tree)				Number of fruit per tree (#/tree)			Single fruit size (g/fruit)		
	1984[1]	1985	1986	1987	1984	1985	1986	1984	1985	1986
0.3	62a[2]	84a	74a	66	1290	1310	1280	49	65	58
1.1	81a	60a	44ab	68	1610	900	770	50	68	58
2.1	70a	63a	47ab	46	1360	1050	820	51	68	57
3.3	72a	72a	47ab	46	1460	1010	800	52	70	58
4.5	71a	76a	51ab	48	1420	1110	910	51	69	56
6.8	66a	62a	30b	50	1260	920	550	54	69	55
LSD[3]	35	31	33							

[1] Yields from 1984 are for the year prior to the spray treatments; yields for 1985 are after six of the fourteen weekly sprayings; yields for 1986 are for the year following the spray treatments; and 1987 yields are two years following spraying

[2] Mean separation within columns by Duncan's Multiple Range Test at the 5% level

[3] Least significant difference at the 5% confidence level

Yield

The influence of the saline spray treatments on fruit yield is summarized in Table 2. Because of the limited number of trees available for the experiment and the normal large variation in yield among trees, the treatment effects are difficult to demonstrate statistically. The year before the experiment began in 1984 there were no significant differences in fruit yield among the treatment trees, but individual tree yields ranged from 28 to 106 kg per tree. Thus, very large treatment effects are required to show statistical differences with this wide range of yields.

The harvest in 1985 occurred only 6 weeks after initiation of the foliar sprayings and no treatment effects were noted. In 1986, however, analysis of variance showed that the yield of trees sprayed at the highest concentration was significantly lower than that for trees sprayed at the lowest concentration. This was caused primarily by a large reduction in the number of fruit set (Table 2) which was measured for all the saline spray treatments. In 1987 only the two replications on the north edge of the orchard were harvested by individual tree, thus statistics could not be performed. However, the impact of the spray treatments is obvious with the two lowest salt treatments having larger yields than the remaining treatments. Thus, the impact of saline sprays persisted for at least two seasons after the treatments ceased.

Average fruit size was not reduced significantly the year following the spray treatments (1986) although the size is slightly less for the highest salt treatment. In previous years (1984 and 1985) the trees in the highest salt treatments had produced some of the largest fruit.

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