Irrig Sci (1982) 3:157–168

Irrigation Science

Foliar Salt Accumulation and Injury in Crops Sprinkled with Saline Water

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Received December 11, 1981

Summary. Many crops accumulate salts through the leaves when they are wetted by sprinkler irrigation. This accumulation may cause foliar injury and decrease crop yield. This study was conducted to test the salt sensitivity of sprinkled alfalfa, barley, cauliflower, cotton, potato, safflower, sesame, sorghum, sugarbeet, sunflower and tomato. Plants were grown in a greenhouse in covered sand cultures that were trickle-irrigated with nonsaline nutrient solutions. Sprinkling with 15 and 30, and in the case of cotton and sunflower, 30 and 60 meq/l waters (9:1 $NaCl:CaSO_4$) was begun when plants were 1 to 3 months old and was continued for 4 to 7 weeks at a frequency of 1 h/day, 5 days/week.

Except for sorghum, Na^+ and Cl^- absorption through the leaves was essentially a linear function of salt concentration and duration of sprinkling. Most species absorbed Na^+ at approximately the same rate as Cl^-; however, in potato and sugarbeet Na^+ absorption exceeded Cl^- and in barley and sesame Cl^- exceeded Na^+. The mean rates of Na^+ and Cl^- absorption among species increased in the order: sorghum $\ll$ cotton = sunflower < cauliflower < sesame = alfalfa = sugarbeet < barley = tomato < potato = safflower. Susceptibility to leaf injury among species did not vary in strict relation to rates of salt absorption from 30 meq/l water. Potato and tomato readily absorbed Na^+ and Cl^-, and quickly exhibited symptoms of leaf tip and margin necrosis. On the other hand, safflower, with one of the highest rates of salt absorption was only slightly injured by sprinkling. Barley readily absorbed salt, particularly Cl^-, and exhibited minor injury symptoms; whereas sesame and alfalfa had intermediate absorption rates but were somewhat more susceptible to injury. Sugarbeet was uninjured by sprinkling but absorbed appreciable amounts of Na^+; whereas sorghum developed some necrosis along leaf edges but absorbed very little salt. Cauliflower, cotton, and sunflower absorbed salt slowly and exhibited almost no injury.

Crop salt tolerance data are generally expressed as a function of soil salinity (Maas and Hoffman 1977). When plants are irrigated with traditional soil surface

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systems, they initially experience salinity problems when the roots encounter excess salts in the soil water. This is not the case with sprinkler irrigation when foliage is wetted by saline irrigation waters. Because of salt absorption direct through the leaves, some crops experience foliar injury and yield reductions that may not occur when they are surface irrigated with the same water. It is likely, therefore, that the relative tolerance of crops to saline sprinkling waters may not be the same as their tolerance to soil salinity.

Despite the current wide use of sprinkler irrigation, there are relatively few data available on crop tolerance to saline sprinkling waters. The first experimental data appeared after reports of foliar injury in citrus groves (Harding et al. 1958). Ehlig and Bernstein (1959) concluded that orange, apricot, almond, and plum were sensitive to sprinkler-applied salt solutions while avocado and numerous vegetable and forage crops were not. More recently, however, foliar injury in nonwoody species has been reported and foliarly absorbed salts from sprinkling waters have been suspected as the cause (Bernstein and Francois 1975, Busch and Turner 1967; Gornat et al. 1973; Nielson and Cannon 1975). Other studies indicated that sugarcane (Bernstein et al. 1966) and strawberry (Ehlig 1961) absorb salts slowly through the leaves; whereas grapes (Francois and Clark 1979) and peppers (Maas et al. 1982) readily absorb salts and are susceptible to foliar injury.

We conducted a series of greenhouse experiments to test the salt sensitivity of crops to sprinkler irrigation. The specific objectives were to determine the rates of foliar absorption of Na^+ and Cl^- as a function of sprinkling time and to assess the relative effects of saline sprinkling water on plant growth and foliar injury.

Materials and Methods

Plant Culture

The species and cultivars tested in this study were alfalfa (*Medicago sativa* L. cv. WL-512), barley (*Hordeum vulgare* L. cv. UC-566), cauliflower (*Brassica oleracea* var. botrytis L. cv. Snowball), cotton (*Gossypium hirsutum* L. cv. Delta Pine), potato (*Solanum tuberosum* L. cv. White rose), safflower (*Carthamus tinctorius* L. cv. Gila), sesame (*Sesamum indicum* L. cv. long pod), sorghum (*Sorghum bicolor* L. Moench cv. Paymaster R1014), sugarbeet (*Beta vulgaris* L. cv. USH10), sunflower (*Helianthus annuus* L. cv. Color Fashion), and tomato (*Lycopersicon lycopersicum* L. Karst. ex Farw. cv. Heinz 1350). Plants were grown in a greenhouse in 30-liter plastic containers filled with washed plaster sand. After emergence, the number of plants in each container were thinned to either 12 (barley), 6 (alfalfa), 2 (sesame, safflower, or sorghum), or 1 (for the other crops). Plants were trickle-irrigated 3 to 4 times daily, each time with one liter of a complete nutrient solution consisting of 2.5 mM $Ca(NO_3)_2$, 3 mM KNO_3, 1.5 mM $MgSO_4$, 0.17 mM KH_2PO_4, 50 μM Fe (as sodium ferric diethylenetriamine pentaacetate), 23 μM H_3BO_3, 5 μM $MnSO_4$, 0.4 μM $ZnSO_4$, 0.2 μM $CuSO_4$, and 0.1 μM H_2MoO_4.

Sprinkling

Sprinkling was begun after the plants developed a sufficient number of fully-expanded leaves to sample once each week during the next five weeks. These leaves were tagged for later identification. In the case of alfalfa, two cuttings were harvested and discarded before sprinkling was started. Comparable yields from the second cutting of all replications indicated that a uniform stand had been established. Dates of planting and plant ages at sprinkling and harvest are given in Table 1.

Table 1. Planting date and plant ages at sprinkling and harvest

Crop	Date Planted	Plant Age Sprinkling Started	Duration of Sprinkling	Plant Age at Harvest
		weeks		
Alfalfa	Feb 23	13[a]	5	19
Barley	Feb 24	5	5.5	11
Cauliflower	Nov 15	7	6	14
Cotton	May 29	7	6	13
Potato	Feb 24	5.5	6.5	12
Safflower	Apr 11	5	4	9
Sesame	Apr 23	6	6	12
Sorghum	Aug 1	4	7	14
Sugarbeet	Jan 20	9	7.5	18
Sunflower	Jul 12	4.5	5	9.5
Tomato	Aug 8	6	5	13.5

[a] Two cuttings were harvested before sprinkling was begun

Treatments consisted of an unsprinkled control and two sprinkling waters each replicated twice with six containers in each replicate. Cotton and sunflower plants were sprinkled with 30 and 60 meq/l waters (3.4 and 6.5 dS/m electrical conductivity), the other crops with 15 (1.8 dS/m) and 30 meq/l waters. The saline waters were prepared by adding NaCl and $CaSO_4$ in a 9 : 1 chemical equivalent ratio to demineralized water. The pH of the sprinkling waters was adjusted to 7.0 with potassium hydroxide. Four sprinkling nozzles, each of which delivered 0.5 l/min in a full cone pattern, were located 2.0 m above each row of containers. The four nozzles were adequate to wet thoroughly all the leaves of all crops except potato and tomato which required an additional set of four nozzles after the third week of sprinkling. The plants were sprinkled in the morning for one hour on five days for each week. During the sprinkling period, the water was continuously cycled on for 15 s and off for 45, to minimize the consumption of synthetic sprinkling water, and yet keep the leaves continuously wet. Less than 10% of the water retained on the leaves of the plants (as measured by weighing detached wet leaves) evaporated during the 45 s when the nozzles were turned off.

The surface of each container was covered with opaque plastic sheeting (0.3 mm thick) to prevent sprinkling water from entering the root media. The plastic sheeting was sealed to the stem of each plant with putty (Terostat IX)[1]. Periodically, the drainage water from the sand cultures was collected and analyzed for chloride to confirm that sprinkling water was excluded from the root media.

Environmental Conditions

Lighting was natural sunlight through glass. Air pollutants were removed by passing incoming air through activated charcoal filters. Temperature and relative humidity fluctuated diurnally. Relative humidity was uncontrolled and air temperature was partly controlled with heaters and evaporative coolers. The average daily maximum and minimum temperatures in °C in the greenhouse for each crop during the sprinkling period were: alfalfa 37, 18; barley 31, 17; cauliflower 29, 18; cotton 38, 19; potato 32, 17; safflower 32, 20; sesame 34, 18; sorghum 38, 20; sugarbeet 32, 17; sunflower 38, 21; and tomato 36, 19. All containers were insulated with fiberglass (9 cm thick) faced with aluminum foil to minimize temperature fluctuations in the growth media.

[1] Mention of company names or products is for the benefit of the reader and does not imply endorsement, guarantee, or preferential treatment by the USDA or its agents

Leaf Sampling and Analysis

Before sprinkling and each week thereafter, a sufficient number of tagged leaves (10–20 g fresh wt.) were detached from various plants of each replicate of six containers. In the case of alfalfa and barley, an entire plant shoot was sampled. To remove all salt residues on the leaf surface, leaves were washed twice, 30 seconds each, in separate 3-liter volumes of deionized water. Previous tests showed that this washing technique was effective (Grattan et al. 1981). Leaves were then dried at 70 °C and ground in a blender. Na^+, K^+, Ca^{2+}, and Mg^{2+} were determined on nitric-perchloric acid digests of the leaf powder by atomic absorption spectrophotometry. Chloride contents were determined on dilute nitric-acetic acid extracts of the leaf material by the Cotlove (1963) coulometric-amperometric titration procedure.

Harvest

At or within 21 days after the end of the sprinkling treatment, the plants were harvested and fresh and dry weights of the tops were obtained. Fresh weights of cauliflower heads, potato tubers, and the storage root of sugarbeet were obtained. Weights of fresh tomato fruit and dry sesame pods were also taken although neither crop was grown to maturity. Barley plants were about 90% headed out but not mature at harvest; therefore the green heads were included with top weights. Both cotton and sunflower were harvested before maturity but the immature cotton bolls and fresh sunflower heads were weighed separately.

Results

Salt Absorption

Na^+ and Cl^- absorption by the leaves of all crops, except sorghum, was a linear function of sprinkling time for 2 to 6 weeks (Figs. 1 and 2). The rates of absorption, as well as the period of linearity varied among species (Table 2). Absorption rates were linear for 6 weeks for cotton and cauliflower but only 2 weeks for alfalfa. Sorghum leaves absorbed very little salt and most of that occurred within the first week. The rates of foliar absorption varied from approximately 0.4 mol/kg dry wt.

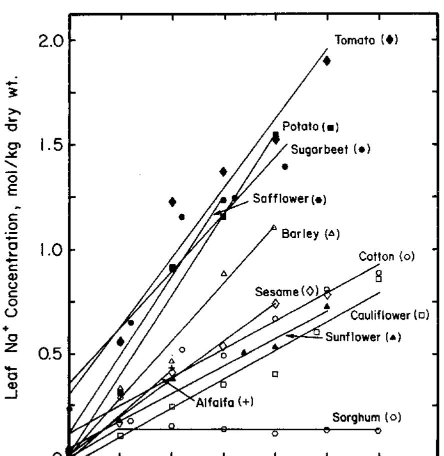

Fig. 1

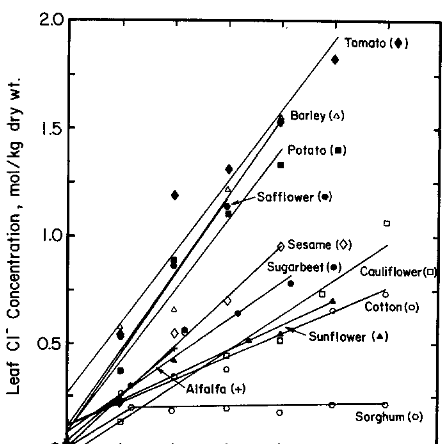

Fig. 2

Fig. 1. Time course of Na^+ accumulation in leaves of 11 plant species sprinkled with 30 meq/l water (9 : 1 NaCl : $CaSO_4$)

Fig. 2. Time course of Cl^- accumulation in leaves of 11 plant species sprinkled with 30 meq/l water (9 : 1 NaCl : $CaSO_4$)

Table 2. Regression coefficients for rates of Na^+ and Cl^- absorption by leaves of ten crop species sprinkled with waters at two concentrations

Crop	Concn Sprinkling Water	Sodium Initial Leaf Na^+ Concn	slope	intercept	r^2	Chloride Initial Leaf Cl^- Concn	slope	intercept	r^2	Duration of Linear Absorption
	meq/l	[a]	[b]	[c]		[a]	[b]	[c]		weeks
Alfalfa	15	0.010	0.098	0.019	0.97	0.045	0.111	0.062	0.95	2
	30		0.216	−0.016	0.92		0.214	0.038	0.99	2
Barley	15	0.015	0.158	0.023	0.93	0.010	0.247	0.091	0.89	5
	30		0.278	0.008	0.96		0.368	0.074	0.94	4
Cauliflower	15	0.010	0.068	−0.016	0.93	0.020	0.084	−0.007	0.94	6
	30		0.138	−0.037	0.92		0.165	−0.028	0.94	6
Cotton	30	0.038	0.135	0.120	0.96	0.013	0.106	0.121	0.84	6
	60		0.270	0.074	0.97		0.213	0.079	0.96	6
Potato	15	0.007	0.222	−0.034	0.87	0.010	0.206	−0.025	0.89	5
	30		0.388	0.009	0.89		0.328	0.088	0.92	4
Safflower	15	0.010	0.174	0.119	0.73	0.015	0.185	0.099	0.84	3
	30		0.385	0.107	0.96		0.354	0.115	0.96	3
Sesame	15	0.022	0.126	−0.012	0.98	0.006	0.157	−0.015	0.98	4
	30		0.182	0.010	0.97		0.237	0.017	0.98	4
Sugarbeet	15	0.227	0.184	0.220	0.84	0.002	0.101	0.060	0.76	4
	30		0.270	0.363	0.79		0.175	0.085	0.86	4
Sunflower	30	0.018	0.132	0.054	0.87	0.033	0.121	0.100	0.91	5
	60		0.272	0.103	0.94		0.250	0.099	0.98	4
Tomato	15	0.008	0.217	0.094	0.97	0.004	0.201	0.073	0.97	5
	30		0.335	0.281	0.91		0.329	0.268	0.91	5

[a] Leaf ion concentration in mol/kg D. W. when sprinkling began. Concentrations in unsprinkled control plants did not change significantly during the experiment
[b] Slope is rate of ion absorption expressed in mol/kg D. W. per week
[c] Intercept is ion concentration in the leaf in mol/kg D. W.

Table 3. Change in leaf *K* concentration during the period of sprinkling for control and 30 meq/l treated plants

Crop	Initial concn	% change during sprinkling period[a]	
		Control	30 meq/l
	mol/kg D.W.		
Alfalfa	1.1	−15	−25
Barley	1.6	+10	−30
Cauliflower	1.5	0	0
Cotton	1.2	− 5	−20
Potato	1.5	+30	−20
Safflower	2.8	−50	−60
Sesame	0.6	+25	−50
Sorghum	1.1	−35	−35
Sugarbeet	2.0	0	−20
Sunflower	2.0	−20	−35
Tomato	0.8	+75	−40

[a] Sprinkling period varied among crops. See Table 1

per week for potato and safflower to less than 0.03 for sorghum. Barley, sesame, and cauliflower absorbed Cl^- faster than Na^+; whereas sugarbeet, cotton, and potato absorbed Na^+ fastest. For the other crops the relative rates of Na^+ and CL^- absorption were nearly the same. Mean rates of Na^+ and Cl^- absorption among species increased in the order: sorghum ≪ cotton = sunflower < cauliflower < sesame = alfalfa = sugarbeet < barley = tomato < potato = safflower. The absorption rates were also nearly linear functions of the salt concentration in the sprinkling water. Absorption rates of both ions increased 1.4 to 2.2 times as the NaCl concentration was doubled from 13.5 to 27 meq/l. In the case of cotton and sunflower, the rates were twice as high for sprinkling water with 54 meq/l NaCl as they were with 27 meq/l.

Regardless of whether leaf K^+ concentrations in control plants increased or decreased during the treatment period, sprinkling with 30 meq/l water decreased the concentrations below that of control leaves for all species except cauliflower and sorghum (Table 3). Similar but smaller decreases in K^+ concentrations occurred with 15 meq/l water while larger decreases occurred with 60 meq/l water in the case of cotton and sunflower. K^+ concentrations in alfalfa leaves increased the first two weeks and decreased the last two weeks in both control and sprinkled leaves but the latter always had lower K^+ levels.

Except for safflower, sprinkling had no effect on Ca^{2+} and Mg^{2+} concentrations of the leaves. During the 4-week-period of sprinkling, Ca^{2+} concentrations in leaves of control safflower plants approximately doubled while concentrations in leaves sprinkled with either 15 or 30 meq/l water only increased half as much.

Injury Symptoms

Symptoms of salt injury on the 11 crop species are presented in Table 4 in increasing order of sensitivity. Sugar beet, cotton, sunflower, and cauliflower appeared to be the most tolerant crops. The leaves of both sugarbeet and cauliflower did not appear to be wetted by the sprinkled solution; the waxy cuticle caused water to coalesce into droplets and quickly run off the leaf. The only obvious injury on cauliflower were necrotic spots that developed in leaf depressions where a few droplets repeatedly collected and remained for some time after sprinkling. Potato and tomato, on the other hand, were very susceptible to leaf injury. Injury increased during the sprinkling period and many of the older leaves in the lower half of the canopy became completely necrotic and abscissed. Little or no injury was apparent in the upper, younger part of the canopy.

Safflower, barley, alfalfa, and sesame all developed some injury symptoms but the injury progressed slowly and remained relatively minor with continued sprinkling. Although sorghum absorbed very little salt, some tip and margin necrosis developed on sprinkled leaves that was not apparent on unsprinkled controls.

Table 4. Foliar injury symptoms on crops sprinkled with waters at two concentrations

Crop	Concn Sprinkling/ Water (meq/l)	Foliar Injury Symptoms
Sugarbeet	15	No injury.
	30	No injury.
Cotton & Sunflower	30	Slight tip necrosis at 6 weeks on cotton; no injury on sunflower.
	60	Tip and margin necrosis developed at 3 weeks; symptoms increased only slightly.
Cauli-flower	15	No injury.
	30	Slight necrotic spotting at 5 weeks.
Safflower	15	Little or no injury.
	30	Slight tip and margin necrosis at 3 weeks.
Barley & Sorghum	15	Very slight tip and margin necorsis.
	30	Tip and margin necrosis developed at 3 weeks but symptoms remained minor.
Alfalfa	15	Very slight margin necrosis.
	30	Margin necrosis developed at 3 weeks but symptoms remained minor.
Sesame	15	Slight tip necrosis at 3 weeks.
	30	Tip necrosis at 2 weeks; injury progressed slowly; inter-veinal spotting and 2 – 3 cm dead tissue at leaf tips at 6 weeks.
Tomato	15	Margin chlorosis and necrosis at 4 weeks, injury progres-sively worsened.
	30	Margin chlorosis and necrosis at 2 weeks, injury increased and older leaves became completely necrotic.
Potato	15	Tip and margin necrosis at 2½ weeks, injury progressively worsened.
	30	Tip and margin necrosis at 1½ weeks; injury increased, older leaves became completely necrotic and abscissed at 6 weeks.

Table 5. Effect of Sprinkling on Plant Weights at Harvest

Species and Treatment	Top Weights (kg/plant)		Yield (kg/plant)
	Fresh	Dry	
Alfalfa, cv. WL 512	Third Cutting (Sprinkled 5 weeks)		
Control	0.090	0.020	–
15 meq/l	0.113	0.024	–
30 meq/l	0.099	0.022	–
* Barley, cv. UC 566	(Sprinkled 5.5 weeks)		
Control	0.113	0.023	–
15 meq/l	0.102	0.022	–
30 meq/l	0.112	0.021	–
Cauliflower, cv. Snowball	(Sprinkled 6 weeks)		Fresh Head
Control	1.00	0.074	0.39
15 meq/l	1.36	0.081	0.53
30 meq/l	1.39	0.079	0.56
* Cotton, cv. Delta Pine	(Sprinkled 6 weeks)		Green Boll
Control	0.60	0.20	0.57
30 meq/l	0.76	0.23	0.43
60 meq/l	0.76	0.24	0.36
Potato, cv. White Rose	(Sprinkled 6.5 weeks)		Tuber
Control	0.80	0.080	1.14
15 meq/l	0.79	0.082	1.14
30 meq/l	0.84	0.089	1.09
* Safflower, cv. Gila	(Sprinkled 4 weeks)		
Control	0.31	0.079	–
15 meq/l	0.29	0.079	–
30 meq/l	0.21	0.078	–
* Sesame, cv. Long Pod	(Sprinkled 4 weeks)		Dry Pod
Control	0.38	0.069	0.015
15 meq/l	0.42	0.077	0.019
30 meq/l	0.39	0.072	0.020
Sorghum, cv. Paymaster R 1014	(Sprinkled 7 weeks)		Dry Seed
Control	0.355	0.057	0.048
15 meq/l	0.376	0.057	0.053
30 meq/l	0.369	0.052	0.046

Table 5. (continued)

Species and Treatment	Top Weights (kg/plant)		Yield (kg/plant)
	Fresh	Dry	
Sugarbeet, cv. USH-10	(Sprinkled 7.5 weeks)		Storage Root
Control	0.92	0.078	0.68
15 meq/l	1.11	0.097	1.23
30 meq/l	1.04	0.088	1.10
* Sunflower, cv. Color Fashion	(Sprinkled 5 weeks)		Fresh Head
Control	0.56	0.100	0.33
30 meq/l	0.50	0.085	0.26
60 meq/l	0.49	0.084	0.23
* Tomato, cv. Heinz 1350	(Sprinkled 5 weeks)		Fruit
Control	2.05	0.159	0.309
15 meq/l	1.73	0.146	1.020
30 meq/l	1.78	0.161	0.568

* Not grown to maturity

Plant Growth

The effects of sprinkling on fresh and dry matter production for the 11 crops are shown in Table 5. Despite some leaf injury, the vegetative growth of the salt-sprinkled alfalfa was as high as the unsprinkled plants. Barley was harvested at 11 weeks of age after 5½ weeks of sprinkling. Top growth, which included the immature heads, was not significantly affected by sprinkling. Similar results were obtained with safflower and sorghum. Cauliflower was harvested at 14 weeks of age after 6 weeks of sprinkling. Sprinkling with saline water increased both the growth and yield. Potatoes harvested at 12 weeks of age after 6½ weeks of sprinkling exhibited considerable leaf injury but top and tuber weights were similar in all treatments. Tomatoes were sprinkled 5 weeks and then harvested 2½ weeks later at 13½ weeks of age. Despite considerable leaf injury, top growth of tomato, like that of potato, was unaffected by sprinkling. However, sprinkled plants were drier at harvest than control plants as indicated by their lower fresh weight. The fruit harvested were too immature and variable to quantify treatment effects on yield.

Sesame was harvested at 12 weeks of age but before the plants were completely mature. Sprinkling during the last 6 weeks seemed to increase both the top growth and pod yield. Sugarbeets also showed a positive response to sprinkling with saline water. After 7½ weeks of sprinkling, storage roots of 18-week-old plants were nearly twice as large as those of the unsprinkled control plants. Differences in top growth among the treatments were not apparent.

Sprinkling for 4 weeks had no effect on dry matter production by 9-week-old safflower. However, the fresh weight of plants sprinkled with 30 meq/l water was much lower than controls, indicating an earlier senescence and drying of the plants. Neither top growth nor seed production of sorghum were significantly affected by 7 weeks of sprinkling.

Both cotton and sunflower were sprinkled with waters twice as saline as the other crops. Although these crops were harvested before maturity it is likely that the mature yields would have been decreased by sprinkling. After 6 weeks of sprinkling with 60 meq/l water, the fresh weight of cotton bolls weighed only 63% of the control. Five weeks of sprinkling reduced the fresh weight of sunflower heads to 70% of the control. Although the vegetative growth of sunflower was also decreased, that of cotton appeared to increase.

Discussion

The results of this study showed that some herbaceous crop species are susceptible to foliar injury when sprinkled with saline irrigation waters. As demonstrated by earlier work with pepper (Maas et al. 1982), the injury occurred because salt was directly absorbed and accumulated by the leaves. Except for sorghum, all of the crops tested readily accumulated both Na^+ and Cl^- from sprinkling water. Both the rate and duration of absorption varied among crops. Safflower had one of the highest initial rates of absorption, but after three weeks the leaves stopped accumulating salt. Alfalfa leaves with an intermediate absorption rate stopped accumulating Na^+ and Cl^- even sooner than safflower. Sorghum accumulated the least salt of any crop and most of that was absorbed in the first week. For most of the crops, salt accumulation of a given leaf was a linear function of sprinkling time for about four to six weeks, but after that, accumulation began to level off. The reason for the decrease in absorption rates is not entirely clear. For alfalfa, it may, in part, reflect dilution caused by new growth that had not been sprinkled as long but which was included with the older leaves in the shoot samples. In the case of potato it may be due to an "umbrella effect" as new growth sheltered the older leaves below. It is also possible that as the leaves aged, the cuticle became impermeable to salt or that salt was translocated out of the leaves at the same rate as it was absorbed.

Susceptibility of a given crop to injury depended more on the rate of foliar absorption than on its tolerance to soil salinity. Cauliflower, which like potato and tomato is moderately sensitive to soil salinity (Maas and Hoffman 1977), was hardly affected by sprinkling waters that severly burned the three Solonaceae crops. Sesame, which appears quite sensitive to soil salinity (Yousif et al. 1972), was injured less than were potato and tomato by sprinkling. On the other hand, sugarbeet appears tolerant of both soil and sprinkling water salinity. The leaves of cauliflower, sorghum, and sugarbeet appeared non-wetable and this factor may certainly influence the rate of absorption.

The salt content of the leaves that was associated with the onset of injury also varied among species. Alfalfa, potato, and sesame developed injury symptoms when the NaCl concentration of the leaf tissue reached 0.4–0.5 mol/kg dry wt.; whereas tomato accumulated 0.9 mol/kg dry wt. before symptoms were apparent. Corresponding values were 0.8 for barley, cauliflower, cotton and sunflower and about 1.1 for safflower. Despite the low uptake of salt by sorghum, leaf margin necrosis was observed on plants sprinkled with 30 meq/l water when salt concentrations in the leaves were only 0.2 mol/kg dry wt.

The relative amounts of Na^+ and Cl^- accumulated in the leaves gave no indication as to which ion caused leaf injury. Of the three most sensitive crops, tomato accumulated nearly equal amounts of Na^+ and Cl^-, sesame accumulated more Cl^- than Na^+, and potato accumulated more Na^+. Unlike translocation of Na^+ and Cl^- from roots to leaves which occurs at markedly different rates in some crops, both ions were readily and similarly absorbed through the leaves of the crops that were tested here. For example, sesame, which restricts Na^+ but not Cl^- translocation from roots to leaves (Yousif et al. 1972), accumulated nearly as much Na^+ as Cl^- via foliar absorption.

Previous results with pepper plants (Maas et al. 1982), indicated that the degree of leaf injury was not correlated with Cl^- accumulation. That unexpected finding, however, does not necessarily eliminate Cl^- as contributing to the injury.

Sprinkling also strongly affected the K^+ concentration of the salt-sensitive crops. Potato, tomato, and sesame leaves which normally accumulated K^+ lost significant amounts of K^+ during the sprinkling period. The K^+ retained may have approached deficient levels in tomato and sesame (Ulrich and Ohki 1966). Smaller decreases relative to the controls also occurred in barley, cotton, sugarbeet, and sunflower but the levels were still adequate. Leaf K^+ concentrations in cauliflower, safflower and sorghum were unaffected by sprinkling. Ca^{2+} and Mg^{2+} concentrations, on the other hand, were unaffected by sprinkling for all species except safflower which accumulated less Ca^{2+} than the controls.

Despite considerable foliar damage to most of the lower half of the canopy, sprinkling had no adverse effect on the growth and yield of tomato and potato. In fact, sprinkling with 15 and 30 meq/l waters appeared to increase the yield of cauliflower, sesame, sugarbeet, and tomato. Since control plants were unsprinkled, possible beneficial effects of sprinkling with water cannot be separated from effects due to the presence of salts in the water. Previous studies with peppers indicated that sprinkling with demineralized water did not increase fruit yields as compared to unsprinkled controls (Maas et al. 1982). The growth and yield of other crops were not appreciably affected. However, sprinkling with 30 and 60 meq/l waters did reduce the yields of immature cotton bolls and sunflower heads. While these data are not meant to provide yield response curves, the cotton results are consistent with field results reported by Busch and Turner (1967). They found that sprinkling cotton with 4.4 dS/m water caused leaf burn and yield losses that were not apparent with surface irrigation where salts were only absorbed through the roots.

It should be kept in mind that, in the field, the sprinkling waters would also enter the soil, thereby increasing the potential hazard of saline waters. Also hot, dry, windy weather, not encountered in the humid greenhouse environment, could further stress salt-injured plants in the field. Nielson and Cannon (1975) reported that foliar injury on alfalfa was closely correlated with the amount of salt in sprinkler irrigation water. On hot, windy days sprinkling with 4 dS/m (40 meq/l) water completely killed the foliage of the alfalfa and some injury was noted with water having salinity as low as 1.3 dS/m. Our greenhouse data showed that leaf injury occurred after sprinkling 2–3 weeks with the 30 meq/l water but the injury never became critical.

This comparative study provides data on the relative rates of foliar salt absorption by 11 crop species grown in the greenhouse and indicates that several are susceptible to foliar injury. It is now necessary to test yield responses as a function of increasing concentrations of sprinkling water under field conditions.

Acknowledgement. We wish to express our appreciation to Don Layfield for his assistance with the chemical analyses.

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