Effect of Sodic Water and Irrigation on Sodium Levels and the Development of Early Leaf Spot in Peanuts

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ABSTRACT

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Concentrations of sodium in plant tissues and soil, and the severity and incidence of early leaf spot (*Cercospora arachidicola*), were influenced by water quality (sodic or nonsodic water) and method of irrigation (sprinkle or trickle). Mean Na levels were always higher in tissues (leaf, stem, root, and seed) of plants receiving sprinkle-applied deep-well water containing an average Na concentration of 220 mg L^{-1} and a sodium absorption ratio (SAR) of 103, than in plots receiving sprinkle-applied shallow-well water containing an average Na concentration of 4.8 mg L^{-1} and an SAR of 3.1. Na levels also were usually higher in tissues of sprinkle-irrigated than of trickle-irrigated plants. Na in root tissues generally was highest in sprinkle-irrigated plants receiving sodic water. Soil Na was higher in plots receiving sodic water; irrigation method (sprinkle or trickle) did not influence soil Na. The incidence and severity (percentage of defoliation, diseased leaflets, and number of lesions per leaflet) of early leaf spot was usually greater in sprinkle-irrigated plants and in plants receiving sodic water. The mean percentages of diseased leaflets, defoliation, and number of lesions per leaflet were 25, 60, and 35% greater, respectively, in plants receiving sodic irrigation water than in plants receiving nonsodic water.

Major (N, P, and K), secondary (Ca and Mg), and minor (B, Cu, Mn, Mo, and Zn) nutrients have been implicated in the enhancement or reduction of plant diseases (7,11). Nutrient imbalances have been implicated in decreasing or enhancing the severity or incidence of several peanut (*Arachis hypogaea* L.) diseases. Peanut pod rot severity increased with increased K (9); N and K enhanced Cercospora leaf spot of peanut (20); Zn and Cu (10) suppressed Sclerotinia blight of peanut; and peanuts grown in a Mg-deficient soil were more susceptible to Cercospora leaf spot (5).

Sodium decreased the severity of cotton root rot (*Phymatotrichum omnivorum* Duggar) (13), yellow rust of greenhouse-grown wheat (*Puccinia striiformis* Westend.) (18), and powdery mildew of wheat (*Erysiphe graminis* DC.) (12). In contrast, Na-fed plants were more susceptible to Fusarium wilt of tomato (*Fusarium oxysporum* Schlechtend.:Fr. f. sp. *lycopersici* (Sacc.) W.C. Snyder & H.N. Hans.) (6,22).

An interest in the use of supplemental irrigation to reduce drought stress and to sustain peanut productivity has developed in the Virginia–Carolina peanut production area during the past decade as the result of several droughts. Usually, supplemental water is applied through overhead sprinkle systems; however, recent research has demonstrated the effectiveness of trickle irrigation in peanut production (2,8). In the mid-Atlantic coastal plain, irrigation water can be obtained from deep wells (100 m or more in depth), shallow wells (depths below 15 m), impoundments, or streams. Water from deep wells in the Virginia–Carolina coastal plain has a Na imbalance which can be expressed as the Na absorption ratio (SAR). The SAR is defined as: $SAR = [Na]/([Ca]+[Mg])^{1/2}$ where [ ] denotes concentration expressed in mmole L^{-1}. Sodium absorption ratios for deep wells in the Virginia–Carolina coastal plain can be as high as 200 (2). Waters with SAR values above 15 are classified as sodic, and such water poses a potential risk to soil (24). A preliminary study indicated that the irrigation method and the quality of water (sodic vs. nonsodic) affected the mineral composition of the soil and of peanut leaves, stems, pods, and roots. Concentrations of Cu, Fe, Mn, and Zn were not affected by irrigation method or water quality. Sodium concentration in peanut tissues and soil increased when deep-well sodic water was used for either sprinkle or trickle irrigation (3).

Early leaf spot, (*Cercospora arachidicola* S. Hori), occurs worldwide; and it attacks peanuts wherever they are grown (15). The high humidity and temperature typically found in dense peanut canopies favor disease development. Overhead irrigation with nonsodic water resulted in luxuriant peanut plant growth (25) and enhanced severity of *C. arachidicola* (16). The relationship between water quality and leaf spot development is not known.

The objectives of this study were to determine the effects of water quality (sodic or nonsodic) and irrigation method (sprinkle or trickle) on concentrations of Na in peanut tissues and soil, and the relationship of Na to the incidence and severity of early leaf spot.

MATERIALS AND METHODS

Peanut cultivars VA 81B and NC 7 were grown at the Tidewater Research Farm in Suffolk, Virginia, in rotation with corn (*Zea mays* L.) from 1986 through 1988. The soil type was a Kenansville loamy sand (loamy, siliceous, thermic Arenic Hapludult) with a pH of 6.8 and 1.1% organic matter. Peanuts were planted 25 May 1986, 20 May 1987, and 9 May 1988. Except for irrigation, peanuts were grown according to production practices recommended by the Virginia Cooperative Extension Service. Recommendations included four to six chlorothalonil applications per year at 1.75 L ha^{-1} in each application for the control of early leaf spot. Peanuts were irrigated with either sodic deep-well or nonsodic shallow-well water, as described by Adamsen (2), with either overhead sprinklers or buried trickle lines. The deep well was approximately 142 m deep, and the water had an average Na concentration of 220 mg L^{-1}, an SAR of 103, and a pH of 8.5. The shallow well was 10 m deep, and the water had a Na concentration of 4.8 mg L^{-1}, an SAR of 3.1, and a pH of 4.8. The timing of irrigation was based on soil-moisture availability. Sprinkle-irrigated plots were watered when tensiometers read 30 kPa or higher, but not more often than every 8 days. Trickle-irrigated plots were irrigated daily to maintain a soil moisture of 10–30 kPa. When irrigated with sodic water, sprinkle-irrigated plots received 321 kg ha^{-1} of Na in 1986, 807 in 1987, and 286 in 1988; and trickle-irrigated plots received 141 kg ha^{-1} of Na in 1986, 279 in 1987, and 209 in 1988. By contrast, when irrigated with nonsodic water, sprinkle-irrigated plots received 7 kg ha^{-1} of Na in 1986, 18 in 1987, and 6 in 1988; and trickle-irrigated plots received 3 kg ha^{-1} of Na in 1986, 6 in 1987, and 5 in 1988.

At harvest, four healthy plants were

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dug from the nonharvest rows (rows 1 and 4) from each four-row subplot. Plants were washed with deionized distilled water, then separated into leaves, stems, roots, and seeds. Leaves included both the leaf blades and the petiole, and roots included the crown. Plant parts were oven dried for 48 hr at 70 C, then finely ground in a stainless steel coffee mill and/or a Wiley mill. Subsamples (1.0 g) of tissue were completely ashed at 450 C, and the nutrient ash constituents were dissolved in 100 ml of 0.5 M HCl. Sodium concentrations were determined by atomic absorption spectrophotometry.

Soil samples (surface to 15-cm depth) were obtained for each replicate after the peanuts were harvested. Sodium concentrations were determined with 1 M $NH_4C_2H_3O_2$ extracts (23).

The incidence and severity of early leaf spot, arising from natural inoculum sources of *C. arachidicola,* were determined on 8 September 1986, 16 September 1987, and 19 September 1988. The percentage of leaflet disease, defoliation, and lesion number per leaflet were determined with one randomly selected lateral branch from each of 10 plants from each plot. Disease levels on the upper eight fully expanded leaves of each branch (a total of 320 leaflets) were determined for each plot. The percentage of leaflet disease was determined by dividing the number of leaflets with leaf spot lesions by the number of leaflets on the branch. Plant defoliation percentages were determined by dividing the number of leaflets shed from each branch by the total number of potential leaflets per branch (4 leaflets per leaf × 8 leaves = 32 total leaflets). Lesion number per leaflet was determined by counting the number of lesions on the leaflets remaining on the branch, and dividing by the number of leaflets on the branch.

Experiments were replicated four times in a split plot experimental design. Main plots were a factorial combination of water type and irrigation method plus a nonirrigated control, and the split was variety. Main plots were 8.5 m long and eight rows wide (row width 0.9 m) with four rows between plots. Main plots were divided into four-row subplots. Data were statistically analyzed by the general linear model procedure from SAS (19). Orthogonal comparisons were used to compare water types, irrigation methods, and irrigated vs. nonirrigated treatments.

RESULTS

During the 3-yr study, total precipitation during each growing season was less than the 56-yr average of 61 cm (Table 1). Precipitation was lower in 1987 than in 1986 or 1988. At the end of each growing season, plants were larger and growth was more dense in irrigated than in nonirrigated plots. Although fungicides were used to control early leaf spot,

Table 1. Monthly rainfall recorded at Suffolk, Virginia, and amount of water applied through irrigation during the peanut growing seasons of 1986, 1987, and 1988

	Rainfall/irrigation (cm)								
	1986			1987			1988		
Month	Rainfall	Sprinkle	Trickle	Rainfall	Sprinkle	Trickle	Rainfall	Sprinkle	Trickle
May	2.3	0.0	0.0	4.8	0.0	0.0	13.2	0.0	0.0
June	10.9	1.6	0.8	6.6	12.4	3.3	9.1	0.0	0.3
July	16.8	9.7	4.0	5.8	19.4	4.0	11.4	3.2	2.4
August	21.3	3.3	1.6	14.2	4.9	2.0	12.5	9.8	6.8
September	1.3	0.0	0.0	15.5	0.0	0.8	6.9	0.0	0.0
Total	52.6	14.6	6.4	46.8	36.7	12.7	53.1	13.0	9.5
No. of days/applications	47	5	39	43	8	53	46	4	36

Table 2. Effects of irrigation method (trickle or sprinkle) and water source (sodic or nonsodic) on the concentrations of Na (mg kg^{-1}) in peanut tissues of two cultivars (VA 81B and NC 7)

	Year		Trickle irrigated		Sprinkle irrigated		
Tissue	Cultivar	Nonirrigated	Sodic	Nonsodic	Sodic	Nonsodic	LSD
Seed	1986						
	VA 81B	101	84	89	216	70	54[z]
	NC 7	127	133	72	374	135	146
	1987						
	VA 81B	120	86	76	217	83	48
	NC 7	75	136	67	340	83	110
	Mean	106	110	76	287	93	
Leaf	1986						
	VA 81B	446	388	658	565	385	305
	NC 7	383	378	435	537	433	225
	1987						
	VA 81B	383	393	370	548	467	144
	NC 7	414	411	436	512	393	170
	Mean	407	393	475	541	420	
Root	1986						
	VA 81B	929	2,664	919	4,359	869	1,652
	NC 7	971	4,167	1,384	6,181	1,038	2,035
	1987						
	VA 81B	1,221	6,294	937	12,187	982	2,950
	NC 7	1,449	4,368	1,151	12,958	1,743	3,937
	Mean	1,143	4,373	1,098	8,921	1,158	
Stem	1986						
	VA 81B	384	326	274	608	180	157
	NC 7	251	442	518	643	263	231
	1987						
	VA 81B	643	734	443	2,430	535	745
	NC 7	548	575	595	3,186	517	874
	Mean	457	519	458	1,717	374	

[z] LSD = Least significant difference at $P = 0.05$; applies to row.

the disease was apparent by August and was evident throughout the test area by mid-September in all 3 yr of the study.

Sodium levels in seed and leaf, stem, and root tissue were influenced by both irrigation method and water type (Table 2). Seeds of NC 7 tended to be higher in Na than those of VA 81B. Leaf tissues from sodic sprinkle-irrigated plants were always higher in Na than leaf tissues of plants from other treatments. Sodium concentration in the stems of plants sprinkle irrigated with sodic water was significantly higher than the concentration in the stems of plants sprinkle irrigated with nonsodic water or nonirrigated. In 1987, the year in which the most irrigation water was applied, the Na concentration in stem and root tissues was the highest. The Na content of stem tissue from plots irrigated with sodic water was several times higher than that from any other treatment. Sodium concentration in the roots was also elevated in plants sprinkle irrigated with deep-well water. During both years, the Na content of roots, stems, and seeds reflected the amount of Na applied in irrigation water during the growing season.

Soil Na levels were highest in plots receiving sodic water applied either with sprinklers or through trickle tubing (Table 3). The amounts of Na in plots receiving nonsodic water were comparable with the amounts in plots receiving no supplemental water.

Water source (sodic vs. nonsodic), irrigation method (sprinkle vs. trickle), and irrigation vs. nonirrigation significantly influenced the incidence and severity of early leaf spot in some years (Table 4). Over all years, the number of diseased leaflets was 16% greater in sprinkle-irrigated than in trickle-irrigated plots. In plots irrigated with sodic water, the number of diseased leaflets was 25% greater than in plots irrigated with nonsodic water. In 1986 and 1988, the percentage of diseased leaflets was generally greatest in plots sprinkle irrigated with sodic water. Percentages of diseased leaflets were highest in 1988 and lowest in 1987. Disease was less severe in 1987, a year in which droughty conditions prevailed (Table 1). During all years of the study except 1987, leaflet disease was generally greater in VA 81B than in NC 7.

Over all years, the number of lesions per leaflet caused by *C. arachidicola* averaged 63% greater in sprinkle-irrigated than in trickle-irrigated plots, although the difference was not always significant (Table 5). Lesion percentages were 35% greater in plots receiving sodic water than in plots receiving nonsodic water. With the exception of 1987, when droughty conditions prevailed, the lesion number per leaflet was significantly greater in VA 81B plots sprinkle irrigated with sodic water than in other plots. Similar trends prevailed with NC 7. Only in 1988 did nonirrigated plants have fewer lesions per leaflet than irrigated plants. In the other two years of the study, irrigation did not significantly increase lesion number per leaflet. The number of lesions per leaflet was greater in VA 81B than in NC 7.

Although seldom significant, defoliation was influenced by the method of irrigation and the water type (Table 6). Over all years, the percentage of leaflet defoliation was 31% greater in sprinkle-irrigated than in trickle-irrigated plots. Defoliation percentages were 60% greater in plots receiving sodic water than

Table 3. Effects of irrigation method and water source on the amount of Na in the surface 15 cm of soil

Treatment	Na (kg ha^{-1}) 1986	1987	1988	Mean
Nonirrigated	2,022	1,172	1,076	1,423
Trickle-irrigated				
Sodic water	2,178	1,666	1,301	1,715
Nonsodic water	2,100	1,122	1,089	1,437
Sprinkle-irrigated				
Sodic water	2,295	1,505	1,341	1,714
Nonsodic water	2,056	1,130	1,125	1,437
LSD	135[z]	157	73	

[z]Least significant difference at $P = 0.05$; applies to columns.

Table 4. Effects of irrigation method and water type (sodic or nonsodic) on percentage of diseased peanut leaflets infected with *Cercospora arachidicola*

	Diseased leaflets (%)						
	1986		1987		1988		
Treatment	NC 7	VA 81B	NC 7	VA 81B	NC 7	VA 81B	Mean
Nonirrigated	1.9	4.5	1.2	3.2	0.8	0.8	2.1
Trickle-irrigated							
Sodic water	3.1	6.0	0.7	2.9	1.3	2.8	2.8
Nonsodic water	2.3	3.4	1.5	3.0	1.4	1.7	2.2
Sprinkle-irrigated							
Sodic water	3.3	4.0	0.6	2.1	1.8	7.1	3.2
Nonsodic water	3.0	3.7	0.7	3.2	2.2	2.7	2.6
LSD	1.30[z]	1.64	1.38	2.64	0.89	1.67	

[z]Least significant difference at $P = 0.05$; applies to columns.

Table 5. Effects of irrigation and water type (sodic or nonsodic) on the number of lesions per leaflet caused by *Cercospora arachidicola*

	Lesions/leaflet (no.)						
	1986		1987		1988		
Treatment	NC 7	VA 81B	NC 7	VA 81B	NC 7	VA 81B	Mean
Nonirrigated	2.0	7.0	2.1	5.8	1.0	1.1	3.2
Trickle-irrigated							
Sodic water	3.5	5.1	1.0	6.3	2.0	5.7	3.9
Nonsodic water	3.0	5.5	2.3	6.2	1.8	3.4	3.7
Sprinkle-irrigated							
Sodic water	4.9	11.4	0.7	4.9	3.2	20.7	7.6
Nonsodic water	4.6	6.5	1.4	6.7	4.0	5.6	4.8
LSD	2.55[z]	4.16	2.18	6.00	2.26	7.41	

[z]Least significant difference at $P = 0.05$; applies to columns.

Table 6. Effects of irrigation method and water type (sodic or nonsodic) on defoliation of peanut leaflets

	Defoliation (%)						
	1986		1987		1988		
Treatment	NC 7	VA 81B	NC 7	VA 81B	NC 7	VA 81B	Mean
Nonirrigated	2.0	2.0	1.6	0.5	3.6	3.5	2.2
Trickle-irrigated							
Sodic water	3.6	1.3	8.7	3.9	3.4	4.8	4.3
Nonsodic water	2.8	1.5	3.0	1.2	2.9	3.9	2.6
Sprinkle-irrigated							
Sodic water	4.1	1.8	11.6	7.0	3.9	5.0	5.6
Nonsodic water	3.9	1.3	5.2	2.9	3.3	4.9	3.6
LSD	1.57[z]	1.02	3.96	2.57	1.59	2.82	

[z]Least significant difference at $P = 0.05$; applies to columns.

in plots receiving nonsodic water. In each year of the study, defoliation was greatest in plots receiving sodic water applied with sprinklers.

DISCUSSION

Water quality could become an important issue in peanut production in the coastal plain of Virginia and North Carolina if sodic water is used for irrigation. In this study, the sodic water used (deep well) had an SAR exceeding 100 (2). Such Na levels could have a drastic effect on the peanut plant, because this plant cannot tolerate excessive Na (21). The long-term effects of deep-well water use would be detrimental to peanut production in Virginia and North Carolina. In this study, growth differences in sprinkle-irrigated and trickle-irrigated plants were not usually discernable at harvest. Only in 1987, a droughty year (Table 1), were visual differences in plant growth noted.

Concentrations of Na in plant tissues were usually lower in trickle-irrigated than in sprinkle-irrigated plots, and with one exception (roots in 1987), were higher in plants sprinkle irrigated with sodic water than with nonsodic water.

The severity and incidence of early leaf spot (*C. arachidicola*) was usually greater in plants irrigated with sodic water (Tables 4–6). The presence of a Na imbalance may cause disease suppression (12,13,18) or enhancement (22,26). Reasons for the effects of NA on disease are not known. Excessive Na levels in tissues of the peanut plant, especially the leaflets, could alter the physiological activities of both plant and pathogen. Sodium saturated pectate is easily degraded by fungi (4), and Na may reduce the amount of the less readily degraded Ca pectate. As a result, defense mechanisms that render plant tissue more or less susceptible to invading pathogens could be altered. High Na concentrations may also favor pathogen growth while suppressing the growth of the phylloplane competitors (6). Sodium has been demonstrated to increase stomatal opening (14); therefore, Na levels may affect the opening of stomates on the peanut leaflet. Open stomata could enhance the penetration of *C. arachidicola,* as stomatal penetration has been shown to be important with this pathogen (1).

Although less than half as much water was required for trickle irrigation, soil Na concentrations were similar to those observed with sprinkle irrigation (Table 3). The values given represent amounts of Na observed in the top 15 cm of soil. Sodium distribution in the soil depended upon irrigation method. Maximum Na concentration was at the soil surface of plots receiving sodic water. The similarity of the total amounts of Na present in the soil suggests that at least some of the Na applied in the sodic water was leached well below the top 15 cm.

Recent research (2,8) has demonstrated that water application may be reduced by at least half with trickle irrigation (Table 1). Further, leaflets are not wetted during the irrigation process, which reduces the possibility of the disease enhancement observed with sprinkle irrigation (16,17).

In these studies, NC 7 was more resistant to *C. arachidicola* than was VA 81B (Tables 4–6). Although the use of sodic water increased the incidence and severity of early leaf spot, enhancement was similar for NC 7 and VA 81B. The relative resistance noted in NC 7 did not change.

Peanut growers in Virginia and North Carolina have expressed some interest in irrigation to supplement water during droughty periods, although overhead irrigation is known to increase the severity and incidence of several peanut diseases (16,17). The work reported here indicates that the incidence and severity of early leaf spot (*C. arachidicola*) are affected by irrigation and water quality. Sodic water tended to predispose peanut plants to this pathogen and disease; therefore, growers should take into consideration the quality of available water as well as the type of irrigation system best suited to their farming operation.

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