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Salt Tolerance of Corn in the Sacramento-San Joaquin Delta of California *

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Summary. A three year field experiment was conducted to establish the salt tolerance of corn in the Sacramento-San Joaquin Delta of California. The study was essential because of the grave consequences of allowing the surface waters in the Delta to become excessively saline and the absence of salt tolerance information on organic soils. The relative yield (Y_r) of corn grain was found to be related to soil salinity (the average electrical conductivity of soil water in the root zone during the growing season, $\overline{EC}_{sw}$) by $Y_r = 100 - 14\ (\overline{EC}_{sw} - 3.7)$ when $\overline{EC}_{sw} \geqq 3.7$. Below an $\overline{EC}_{sw}$ of 3.7 dS/m, grain yield was equivalent statistically to nonsaline conditions. As $\overline{EC}_{sw}$ exceeded the threshold value of 3.7 dS/m, Y_r was reduced at the rate of 14%/(dS/m). Excess salinity reduced yield by reducing both kernel mass and, to a lesser extent, plant density. An almost identical relationship was found between $\overline{EC}_{sw}$ and total shoot growth on a relative basis. Thus, to prevent loss in corn yield, the salinity of the applied water and management practices (including irrigation timing, irrigation amount, and leaching) must prevent $\overline{EC}_{sw}$ from exceeding 3.7 dS/m, on the average, during the growing season.

Introduction

As competition for fresh water intensifies, the quality of water required to preserve agricultural production will become an important issue throughout the world. Throughout California, water quality is of grave concern. Even in the Sacramento-San Joaquin Delta which receives almost 28 km^3 of fresh water inflow in a normal year (California State Water Resources Control Board 1978), water quality is the dominant issue. Two major water distribution systems, the State Water Project operated by the California Department of Water Resources and the Central Valley Project operated by the U.S. Bureau of Reclamation, withdraw water from the

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Delta for use elsewhere in the state. Major issues pending include the reasonable water quality needs of the Delta and protection of this vital water resource from seawater intrusion from San Francisco Bay. Accurate response to these issues will indicate the amount of water that can be safely withdrawn from the Delta.

In total area, the Delta is about 300,000 ha, of which more than 200,000 ha are cultivated. Over 50,000 ha are muck soils, having an organic matter content between 25 and 65% by weight. Near the margins of the Delta where the soil surface is at sea level, the muck is shallow or non-existent; whereas in the Delta's interior which is several meters below sea level, the organic soil may be 10 m thick. The organic soils in the Delta are characterized by a very high water-holding capacity, high permeability, and being acidic. With depth, the soil type changes from muck to peat (undecomposed plant material) and then to a comparatively impervious mineral soil substratum.

Corn is the major crop on the organic soils. Other prominent crops, all of which are more salt tolerant than corn (Maas and Hoffman 1977), are wheat, barley, and asparagus. The salt tolerance of a crop can be represented mathematically as $Y_r = 100 - B(\overline{EC}_{sw} - A)$ for $\overline{EC}_{sw} \geqq A$ and $Y_r = 100$ for $\overline{EC}_{sw} < A$ where Y_r is relative crop yield, EC_{sw} is the average electrical conductivity of the soil water in the crop root zone (soil salinity), A is the tolerance threshold, and B is the tolerance slope. The threshold is the maximum $\overline{EC}_{sw}$ that does not significantly reduce yield below a comparable nonsaline treatment. The slope is the rate of yield decline per unit increase in $\overline{EC}_{sw}$ beyond the threshold. The salt tolerance of corn has not been well established and the published studies, none of which were done on organic soils, were thought to be site specific. The consensus of the published salt tolerance data for corn gives a value of 3.4 dS/m for A and 6% per dS/m for B when soil salinity is reported as $\overline{EC}_{sw}$ (Maas and Hoffman 1977). Because of the sensitivity of corn to salinity, water quality standards and water management techniques that are acceptable for corn grown on organic soils should be suitable for more tolerant crops.

The objective of this study was to determine the salt tolerance of corn grown on a typical muck soil in the Delta. Tolerance was compared under two methods of irrigation, subirrigation which is the typical local method and mini-sprinklers to achieve uniform water applications.

Experimental Procedure

The experiment was located along Glasscock Road about 1 km north of State Highway 12 on Terminous Tract in San Joaquin County, California. The experimental area, shown schematically in Fig. 1, was approximately 3 ha, being 135 m wide by 225 m long. The soil surface was about 3 m lower than the water surface in the South Fork of the Mokelumne River which is near sea level. An earthen levee holds the river in its course. One of the tract's main open drains borders the experiment on the east. A 1-m deep open drain, deepened to 2 m in 1980, separated the site from adjacent fields on the south and the river on the west.

Irrigation water for the control treatments was taken directly from the river. The electrical conductivity of river water varied from 0.14 to 0.20 dS/m during the

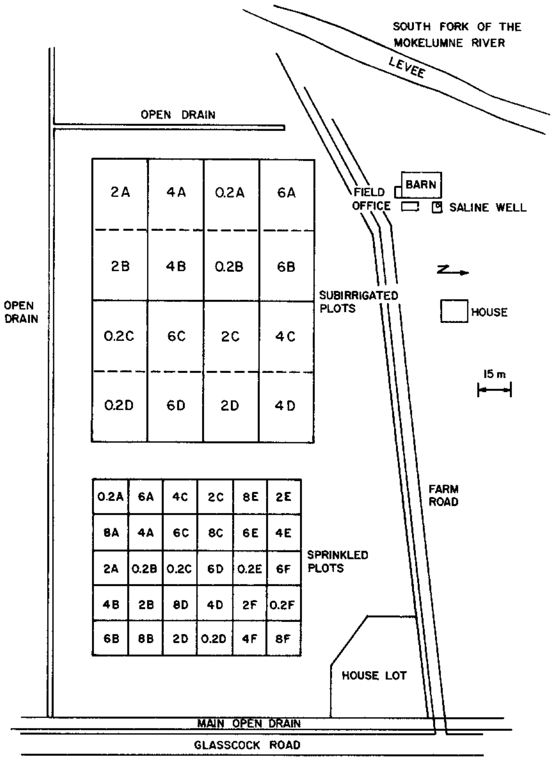

Fig. 1. Experimental design for the salt tolerance field trial in the Sacramento-San Joaquin Delta during 1980 and 1981. Treatment levels in 1979 are given in the text

experiment. Typical ion concentrations in mol/m^3 were: Ca, 0.22; Mg, 0.02; Na, 0.38; K, 0.03; HCO_3, 0.57; Cl, 0.24; and SO_4, 0.04. A well, drilled near the experiment to a depth of 100 m, supplied saline water. The electrical conductivity of the well water varied from 7.4 to 8.4 dS/m. Typical ion concentrations in mol/m^3 were: Ca, 12.2; Mg, 4.7; Na, 43.8; K, 0.2; Cl, 76.2; and SO_4, 0.8.

The soil was Rindge muck (Typic medisaprist, euic, thermic) and is typical of Delta organic soils. The soil profile changes from muck to peat at a depth of 60 to 90 cm and then to mineral soil at a depth of 2 m. The organic matter content by weight averaged 45% in the muck and 59% in the peat. Soil bulk density was very low, indicative of organic soil, and dropped from 0.70 Mg/m^3 in the surface 15-cm depth increment to only 0.23 in the 60- to 90-cm depth increment. The higher density in the upper part of the profile is about half the density of typical mineral soils.

The experimental design consisted of five sprinkler-irrigated treatments on the eastern portion of the site and four subirrigated treatments on the west side. All of the areas surrounding the experiment were also planted to corn and served as borders. In 1979, the first year of the study, the five sprinkler-irrigated treatments were irrigated with waters having electrical conductivities (EC_i's) of 0.2, 0.6, 1, 2, and 3 dS/m. Water for the 0.2 dS/m (control) treatment was taken directly from the river. The other treatments were a blend of river and well waters. Each sprinkler treatment was replicated six times. The five salinity treatments were located randomly within each replication block. The salinity levels of the irrigation water (EC_i) for the four subirrigated treatments were 0.2, 0.6, 1, and 2 dS/m in 1979. Each subirrigation treatment was replicated twice with two subplots in each replicate. In 1980 and 1981, the salinity levels were increased to 0.2, 2, 4, 6, and 8 dS/m for the sprinkled treatments and 0.2, 2, 4, and 6 dS/m for the subirrigated treatments (see Fig. 1). The salinity levels were increased because no significant yield reductions occurred in 1979. The 8 dS/m treatment in the sprinkled treatments was well water. The well did not have sufficient capacity to supply 8-dS/m water for the larger subirrigated plots.

Corn (*Zea mays* L. cv. DeKalb XL75) was planted on May 14, 1979 and on April 28 in 1980 and 1981. Corn rows, spaced 76 cm apart, were planted in an east-west direction in one continuous operation for all plots and borders. The sowing density was 7.2 seeds per m^2 providing an average spacing of 18 cm within the row.

Each sprinkled plot was 15 by 15 m (Fig. 1). Twenty rows of corn were sown in every sprinkled plot, but one row on each side of every plot was removed to create walkways. Each subirrigated plot was 24 m wide by 30 m long with 32 rows of corn per plot. The middle 7.6-m portion of the center six rows of each plot was harvested for yield. A guard area of corn, which was at least 15-m wide, surrounded both the sprinkled and subirrigated plots to prevent edge effects. The guard areas around the sprinkled plots were divided into five sections and irrigated with one of the five water quality treatments. The guard areas for the subirrigated plots were irrigated with the same water as the adjacent plot.

Water was withdrawn from the river by pump and mixed with well water in a concrete tank to achieve the desired salinity level for the sprinkled treatments. The blended water was withdrawn from the tank by pump, forced through both sand and screen filters, and delivered under pressure to each sprinkled plot. An irrigation controller activated the pumps and an electric solenoid valve at each replication to be sprinkled. The salinity of the water was monitored throughout the irrigation period and, if necessary, changes in the blend were made to maintain the desired salinity level. Water for each sprinkled plot passed through a water meter, an electric solenoid valve, and a pressure regulator (set at 140 kPa), before passing through 16-mm diameter polyethylene laterals placed in every other corn row. Water was applied by mini-sprinklers which had a wetted diameter of about 4 m, spaced 1.5 m apart along each lateral. The sprinklers were staggered on every other lateral so that nine sprinklers were equally spaced on four laterals and ten on the alternate five laterals in every plot. The average application rate was a depth of 16 mm over the entire plot area in one hour.

Irrigation water for the subirrigated plots was also a blend of river and well waters mixed directly in the pipeline so that all four treatments could be irrigated simultaneously to minimize soil water movement among plots. Gate valves were adjusted manually to control the proportions of river and well waters to maintain the desired salinity levels for each treatment. The main pipelines for the subirrigation system split the subirrigated plots into equal halves. Each subirrigation plot was irrigated by filling two ditches spaced 16 rows of corn apart. The ditches were approximately 15 cm wide and 60 cm deep and were dug by a trencher each year in mid-June. A gate valve controlled the flow rate into each ditch. In 1980 and 1981 the rate of flow entering and leaving each ditch was monitored with orifice plates.

After corn emergence, instruments were installed in every plot in the row adjacent to the harvest area. An access tube was installed to measure water content with a neutron probe; mercury-manometer type tensiometers monitored matric potential; and four-electrode salinity probes (Rhoades 1979) measured soil salinity. Beginning in 1980, suction cups were installed to extract soil water for measuring soil water salinity. In 1979 instruments were installed at soil depths of 15, 45, 75, 105, and 135 cm. Instrument depths in 1980 were changed to 30, 60, 90, and 120 cm because the most shallow depth in 1979 (15 cm) was frequently too dry to provide measurements. In 1981 the depths were altered to 30, 45, 60, and 90 cm because the 120-cm depth was below the root zone. Soil samples were taken at the start and finish of each growing season in 1979 and 1980 and at monthly intervals in 1981. Soil samples were brought to saturation in the laboratory without either drying or grinding and the extracts were analyzed for electrical conductivity and ion concentrations. Water table depth was monitored throughout the growing season in 1980 and 1981 with 1-cm diameter plastic tubes perforated along their length and installed to a depth of 1.5 m.

To keep the salinity profile in the root zone as uniform as possible, water was applied in the sprinkled plots at about twice the expected rate of evapotranspiration (ET) to achieve 50% leaching. The ET of the crop was estimated from ET$=k_c k_p E_p$ where k_c is the crop coefficient, k_p is the pan coefficient, and E_p is the rate of evaporation from a Class A evaporation pan (Doorenbos and Pruitt, 1977). Average monthly coefficients ($k_c \cdot k_p$) were 0.12, 0.33, 0.88, 0.92, and 0.60 for the months of May through September. Early in the season, excess water was applied to approach the desired soil salinity levels. Sprinkler irrigations were applied weekly except for a few brief periods early in the season when light, frequent irrigations were applied for plant stand establishment.

The subirrigated treatments were managed to simulate the irrigation practices of the area. Two or three subirrigations were applied during each season. Each subirrigation continued for several days and ended when the water table rose to within about 15 cm of the soil surface midway between the irrigation ditches.

The corn seed, treated to control wire worm, was sown at a rate of 23 kg/ha at a soil depth of 7 cm. Fertilizer was applied at planting at a rate of 17.4 kg/ha of nitrogen, 44.3 kg/ha of phosphate and 1.0 kg/ha of zinc. When necessary, pesticides were applied to control cut worm and spider mite, and herbicides were applied to control weeds. The corn was harvested early in October each year. The number of plants within each harvest area (34.7 m^2, six rows each 7.6 m long) was counted and ten plants were selected at random for subsamples to determine water content of various plant parts. After subsampling, the ears were removed and the number of mature ears and nubbins determined. The plants were then cut off at the soil surface and the stover weighed. Ear mass was measured before shelling and kernel mass after shelling. A random sample of kernels was taken to determine average kernel mass and water content. Root density was determined in 1980 and again in 1981 by collecting volumetric soil samples and carefully separating roots from the organic soil by washing. Plant height was measured several times during each season.

Results and Discussion

Water Balance

The average amounts of water applied each month for the sprinkled and subirrigated treatments are summarized in Table 1 along with pan evaporation and estimated evapotranspiration for the nonsaline treatments. The values are presented as the depth of water applied uniformly over the entire plot area. The same amount of water was applied to each sprinkled plot in any given year. The leaching fraction for the control, sprinkled treatment ($L=(D_i-\mathrm{ET})/D_i$) was estimated to be 0.47, 0.58, and 0.50 for 1979, 1980, and 1981, respectively. These values are close to the desired L of 0.5 for salt tolerance trials (Maas and Hoffman 1977). The amount of water applied to the subirrigated treatments was not measured in 1979, but values are given for 1980 and 1981 for the total and net (inflow minus outflow) amounts applied. The average net application in 1980 and 1981 was about 1100 mm for the subirrigated treatments and about 1400 mm for the sprinkled treatments. Rainfall each year was insignificant during the growing season (Table 1).

The depth of the water table below the soil surface is given in Fig. 2 for both irrigation methods. The time period for each subirrigation is obvious from the resultant rise in water table. The water table in the sprinkled treatments remained at or below 90 cm except for a few brief periods.

Table 1. Pan evaporation, estimated evapotranspiration for the control treatments, and irrigation applications for the sprinkled and subirrigated treatments; all data are in mm

	May	June	July	Aug.	Sept.	Total
1979						
Pan Evaporation	195	252	236	199	167	1049
Evapotranspiration	22	82	197	188	111	600
Sprinkler Application	0	234	458	273	173	1138
Rainfall	2	0	5	0	0	7
1980						
Pan Evaporation	187	186	240	233	154	1000
Evapotranspiration	23	61	215	209	75	583
Sprinkler Application	168	319	332	367	216	1402
Subsurface Irrigation						
Total Applied		1110		1510		2620
Net Applied		370		690		1060
Rainfall	9	0	16	0	0	25
1981						
Pan Evaporation	179	274	288	221	183	1145
Evapotranspiration	23	94	254	202	121	690
Sprinkler Application	86	300	500	397	87	1370
Subsurface Irrigation						
Total Applied		690	710	850		2250
Net Applied		420	340	350		1110
Rainfall	0	0	0	0	0	0

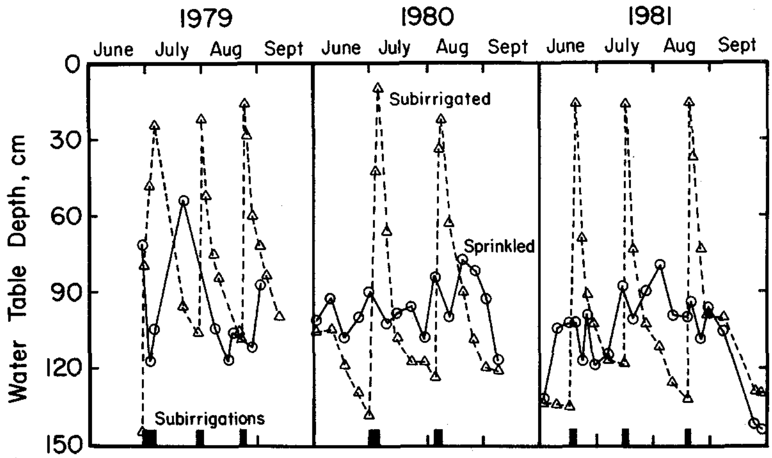

Fig. 2. Time course of water table depth for the three cropping seasons for both sprinkled and subirrigated treatments

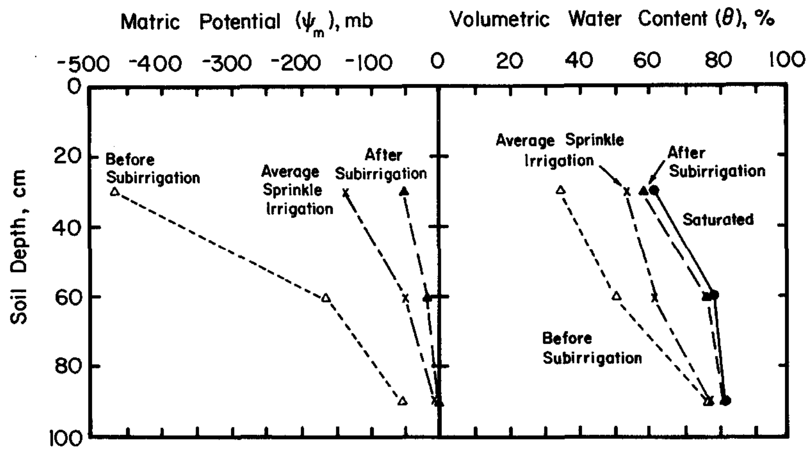

Fig. 3. Soil matric potential and volumetric soil water content as a function of soil depth for both irrigation methods. The saturated water content values are also given for comparison

Volumetric soil water content (θ) and soil matric potential (ψ_m) remained relatively constant throughout the growing season with nearly the same value for all sprinkled treatments. The average value of θ for the sprinkled treatments increased from 54% at a depth of 30 cm to 78% at 90 cm (Fig. 3). Although these values are high, they are well below saturation (see Fig. 4). The average values of θ just before and immediately following a subirrigation are also given in Fig. 3. These organic soils are considered dry when θ approaches 30%. Following a subirrigation the entire profile was nearly saturated. The average values of θ for the sprinkled treatments is intermediate between the two extremes for the subirrigated treatments. Similar results are evident for soil matric potential. ψ_m remained above –200 mb throughout the season for the sprinkled treatments at all

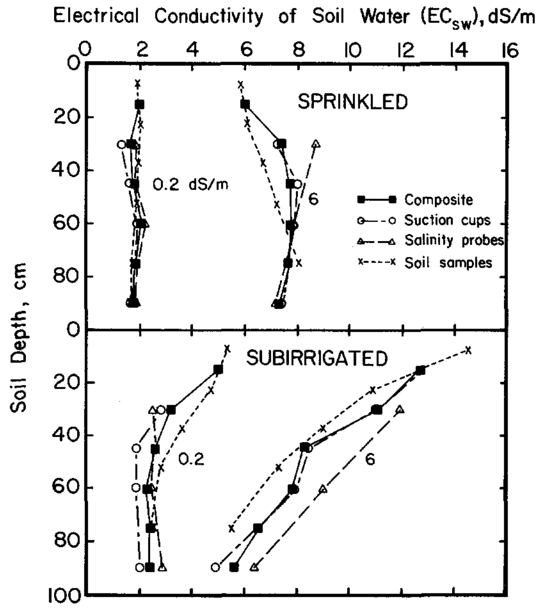

Fig. 4. Examples of the relationships among time-weighted averages of the electrical conductivity of soil water from suction cups, salinity probes, and soil samples and the composite averages of these data. Examples are for the 0.2 and 6 dS/m salinity treatments for 1981

soil depths monitored, indicating no lack of soil water. In the subirrigated treatments, ψ_m dropped to nearly –500 mb at the 30-cm depth just before each subirrigation but ψ_m at the 60- and 90-cm depths was above –200 mb. The high yields that were obtained indicate that the nonsaline, subirrigated treatment did not experience significant soil water stress.

Soil Salinity

Table 2 summarizes the mean electrical conductivity of soil water for the root zone ($\overline{EC}_{sw}$) by year for each salinity treatment and both irrigation methods. The mean values for the suction cups, the salinity probes, and the soil samples are linear averages over depth of the values weighted over time. The electrical conductivity of saturated extracts measured on the soil samples were changed to EC_{sw} values by correcting for water content. The salinity probes were calibrated against EC_{sw} values measured from suction cup extracts taken during July 1981. The composite value given in Table 2 is a depth-averaged value for the three measuring techniques.

Figure 4 gives examples of how the time-weighted values for each measuring technique compare with the composite values as a function of soil depth. Each composite value is the average of all measurements within a depth of 15 cm of the depth in question. The examples are for the 0.2 and 6 dS/m treatments for both irrigation methods in 1981. These examples demonstrate that soil salinity was relatively constant throughout the root zone for the sprinkled treatments because of the high leaching fraction. As expected for subirrigation, soil salinity was high near the soil surface and decreased with soil depth through the root zone.

Table 2. The mean electrical conductivity of the soil water in the root zone ($\overline{EC}_{sw}$) for each season as determined by three measuring techniques. The composite values are depth-averages of the various measurements. All data are in dS/m

		Sprinkled Treatments			
1979					
EC_i	0.2	0.6	1	2	3
Salinity Probes	2.6	2.9	2.7	3.0	4.4
Soil Samples	2.7	3.0	3.2	3.9	4.1
Composite	2.7	3.0	3.1	3.7	4.2
1980					
EC_i	0.2	2	4	6	8
Suction Cups	1.2	2.8	4.1	5.0	6.3
Salinity Probes	1.2	2.3	4.0	5.0	6.1
Soil Samples	1.3	2.3	3.4	5.7	6.2
Composite	1.2	2.4	3.8	5.2	6.2
1981					
EC_i	0.2	2	4	6	8
Suction Cups	1.6	3.4	6.5	7.6	10.4
Salinity Probes	1.9	3.5	6.0	7.9	8.9
Soil Samples	1.9	3.6	6.0	6.8	9.1
Composite	1.9	3.5	6.1	7.3	9.3
		Subirrigated Treatment			
1979					
EC_i	0.2	0.6	1	2	
Salinity Probes	1.8	2.2	1.4	2.3	
Soil Samples	2.8	3.1	3.3	3.3	
Composite	2.4	2.7	2.6	2.9	
1980					
EC_i	0.2	2	4	6	
Suction Cups	1.8	2.4	3.0	4.0	
Salinity Probes	1.7	1.7	2.9	4.0	
Soil Samples	3.1	4.2	5.3	6.4	
Composite	2.3	2.9	3.8	4.8	
1981					
EC_i	0.2	2	4	6	
Suction Cups	2.2	4.4	5.7	8.0	
Salinity Probes	2.6	5.0	6.9	9.1	
Soil Samples	3.8	6.3	7.4	9.4	
Composite	3.0	5.1	6.5	8.6	

Table 3. Grain yield (Y) and total shoot growth (G) as a function of the electrical conductivity of the irrigation water (EC_i) and the irrigation method for corn grown in the Sacramento-San Joaquin Delta. Yield and shoot growth were adjusted to a water content of 15.5%. LSD denotes least significant difference at the 5% level

			Sprinkled Treatments			
						LSD
1979						
EC_i, ds/m	0.2	0.6	1	2	3	
Y, kg/m²	1.17	1.18	1.18	1.17	1.14	0.05
G, kg/m²	3.68	3.39	3.49	3.56	3.41	0.18
1980						
EC_i, dS/m	0.2	2	4	6	8	
Y, kg/m²	1.27	1.23	1.17	0.93	0.70	0.12
G, kg/m²	2.92	2.78	1.69	2.41	2.01	0.28
1981						
EC_i, dS/m	0.2	2	4	6	8	
Y, kg/m²	1.34	1.27	1.05	0.73	0.32	0.10
G, kg/m²	2.55	2.38	1.97	1.50	0.86	0.19
			Subirrigated Treatments			
1979						
EC_i, dS/m	0.2	0.6	1	2		
Y, kg/m²	1.12	1.14	1.14	1.08		0.07
G, kg/m²	3.93	3.91	3.79	3.89		0.33
1980						
EC_i, dS/m	0.2	2	4	6		
Y, kg/m²	1.22	1.20	1.17	1.07		0.07
G, kg/m²	2.84	2.73	2.83	2.53		0.16
1981						
EC_i, dS/m	0.2	2	4	6		
Y, kg/m²	1.32	0.93	0.70	0.34		0.06
G, kg/m²	2.35	1.65	1.31	0.75		0.13

Plant Response

Grain yield (Y) and total shoot growth (G) are given in Table 3 for each salinity treatment in 1979, 1980, and 1981. Grain yield for the control, sprinkled treatment during 1981 was 5% higher than in 1980 and 13% higher than in 1979. Part of the difference, at least, can be explained by a slight increase in both plant density and number of primary ears in 1981 (Table 4). Although grain yield increased each year, total shoot growth (Table 3) and plant height (Table 4) decreased.

In 1979, soil salinity was too low to cause significant yield reductions with either irrigation method. In the later 2 years, however, yields were reduced significantly in the higher salt treatments compared to the control treatment for both irrigation methods. The reductions in grain yield were associated with smaller kernels and fewer primary ears (Table 4).

Table 4. Plant density, primary ear density, mean kernel mass, and plant height as a function of the salinity treatment and irrigation method

	Sprinkled Treatments				
1979					
EC_i, dS/m	0.2	0.6	1	2	3
No. of plants per m^2	6.4	6.4	6.3	6.4	6.4
No. of primary ears per m^2	6.2	6.0	6.1	6.1	6.3
Mean kernel mass, mg	332	334	335	324	325
1980					
EC_i, dS/m	0.2	2	4	6	8
No. of plants per m^2	6.4	6.5	6.4	6.4	6.2
No. of primary ears per m^2	5.7	5.9	5.9	5.8	5.7
Mean kernel mass, mg	280	257	263	236	195
Max. plant height, m	3.6	3.4	3.4	3.2	2.9
1981					
EC_i, dS/m	0.2	2	4	6	8
No. of plants per m^2	7.2	7.1	7.1	6.9	6.5
No. of primary ears per m^2	6.8	6.7	6.4	6.4	5.8
Mean kernel mass, mg	311	298	257	193	147
Max. plant height, m	3.2	3.1	2.9	2.8	2.4
	Subirrigated Treatments				
1979					
EC_i, dS/m	0.2	0.6	1	2	
No. of plants per m^2	6.5	6.6	6.4	6.6	
No. of primary ears per m^2	6.0	6.1	6.2	5.7	
Mean kernel mass, mg	329	330	321	315	
1980					
EC_i, dS/m	0.2	2	4	6	
No. of plants per m^2	6.1	6.2	6.1	6.3	
No. of primary ears per m^2	6.1	6.1	5.7	5.9	
Mean kernel mass, mg	262	276	269	266	
Max. plant height, m	3.2	3.3	3.3	3.2	
1981					
EC_i, dS/m	0.2	2	4	6	
No. of plants per m^2	7.2	7.1	7.2	6.8	
No. of primary ears per m^2	6.9	6.7	6.4	5.9	
Mean kernel mass, mg	302	237	213	182	
Max. plant height, m	3.0	2.8	2.6	2.2	

Root density measurements were made in both 1980 and 1981 to determine the depth of the root zone. The mass of dry roots per unit volume indicated no significant differences between the 0.2 and 6 dS/m salinity treatments. There may have been slight differences, although not statistically significant, in root distribution through the root zone between irrigation methods (Fig. 5). Root density was slightly higher in the upper root zone for the subirrigated treatments compared to the sprinkled treatments but slightly lower near the bottom of the root zone. The total root mass of the root zone per unit of soil surface area was slightly higher for

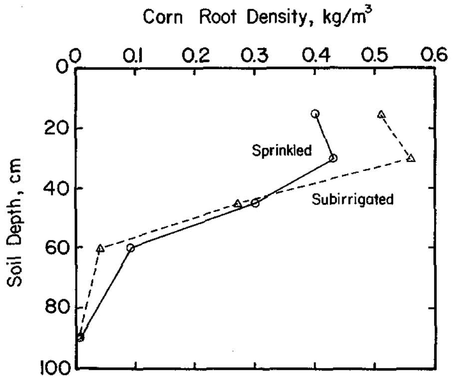

Fig. 5. Corn root density for the sprinkled and subirrigated treatments as a function of soil depth

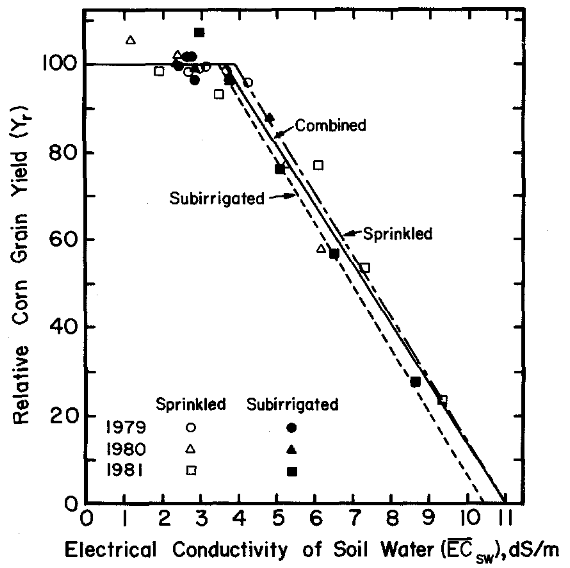

Fig. 6. Relative grain yield of corn grown in the Sacramento-San Joaquin Delta as a function of soil salinity for sprinkled and subirrigated methods

the subirrigated treatments (0.25 vs 0.22 kg/m²). For all treatments, the root zone was about 90 cm deep.

Salt Tolerance

The salt tolerance of corn based upon the results of this field trial is illustrated in Fig. 6 where relative grain yield is given as a function of the mean composite value of soil salinity in the root zone (Table 2) for each of the treatments during each year of the study. A nonlinear, least-squares regression technique (personal communication, van Genuchten, 1982) similar to that of Feinerman, Yaron, and Bielorai (1982), was utilized to determine the slope and threshold for the salt tolerance

Table 5. Coefficients for the salt tolerance of corn in the Sacramento-San Joaquin Delta for both sprinkling and subirrigation

Irrigation Method	Slope (B) % per dS/m		Threshold (A) dS/m	
	Value	95% Confidence Limits	Value	95% Confidence Limits
	Relative Grain Yield $Y_r = 100 - B(\overline{EC}_{sw} - A)$			
Sprinkled	14.0	±3.0	3.9	±0.7
Subirrigated	14.5	±2.4	3.5	±0.5
Both Combined	13.8	±1.8	3.7	±0.4
	Relative Shoot Growth $G_r = 100 - B(\overline{EC}_{sw} - A)$			
Sprinkled	12.3	±2.2	4.0	±0.5
Subirrigated	14.0	±3.1	3.7	±0.6
Both Combined	12.7	±1.9	3.9	±0.4

equation. The coefficients for the equations are given in Table 5 for each irrigation method separately and the two combined. There was very little difference in either the threshold or slope between irrigation methods and the standard error of each value was low. Based on these data and this statistical analysis the salt tolerance of corn for grain in the Delta is $Y_r = 100 - 14\ (\overline{EC}_{sw} - 3.7)$ for $\overline{EC}_{sw}$ greater than 3.7 dS/m and $Y_r = 100$ for $\overline{EC}_{sw}$ less than 3.7. This relationship is shown as the solid line in Fig. 6. The threshold is close to the value calculated from published salt tolerance data (3.7 vs. 3.4) but the slope is considerably steeper (14 vs 6) (Maas and Hoffman 1977).

Based upon our field trial results, the salt tolerance of corn harvested as forage can be represented by a slope of 13 and a threshold of 3.9 (Table 5). Again, irrigation method had little effect on the coefficients. The threshold is similar to the 3.7 dS/m threshold for grain and that calculated for corn forage (3.6 dS/m) from published data (Maas and Hoffman 1977). The slope, however, is considerably greater than the value of 3.7%/(dS/m) obtained for forage from published data.

Conclusion

The field trial in the Sacramento-San Joaquin Delta of California to determine the salt tolerance of corn in organic soil gave threshold values similar to those published for mineral soils. Neither the climate nor the organic soil in the Delta significantly altered the salt tolerance threshold. The salt tolerance slopes obtained for this field trial, however, were more than twice as steep as published values.

Water management prevented any water stress in sprinkled treatments and very little water stress, if any, in the subirrigated treatments. Good agreement was found among measurements of the electrical conductivity of soil water from suction cups, four-electrode salinity probes, and soil samples. Because of the high water-holding capacity of the soil and high leaching, the electrical conductivity of the soil water was never more than several dS/m higher than the electrical conductivity of the applied water. Plant yields were high on nonsaline treatments but were reduced when soil salinity exceeded 3.7 dS/m. Excess salinity reduced yields by reducing kernel mass and, to a lesser extent, ear density. Root density measurements indicated a root zone depth of 90 cm.

The method of irrigation did not affect the salt tolerance of corn significantly. For corn grain, salt tolerance can be represented as $Y_r = 100 - 14\ (\overline{EC}_{sw} - 3.7)$ for $\overline{EC}_{sw}$ greater than 3.7 dS/m and $Y_r = 100$ when $\overline{EC}_{sw}$ is less than 3.7. For total shoot growth the relationship is $G_r = 100 - 13\ (\overline{EC}_{sw} - 3.9)$ for $\overline{EC}_{sw}$ greater than 3.9 dS/m and $G_r = 100$ when $\overline{EC}_{sw}$ is less than 3.9. Thus, for either grain or forage the maximum soil salinity, averaged throughout the growing season, before any significant yield depression is 3.7 dS/m.

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