depth of 90 cm. We then averaged these composite values to establish the mean soil water electrical conductivity.

Differences among data for the three years were larger than differences between irrigation methods. This was caused, in large part, by differences in rainfall and management of the water table depth during the winter. Soil salinity early in the growing season was significantly lower than later in the season.

Of paramount concern in the organic soils of the Delta is the change in the relation between salinity of irrigation water and of soil water as irrigation water salinity increases. For 1981, the year when irrigation water salinity had the greatest influence on soil water salinity, the rate of change was 0.94 for subirrigation (fig. 3), and 0.95 for sprinkled treatments (not shown). Thus, the relation between soil water and irrigation water salinity was less than 1:1 for every year of the study and for both irrigation methods. In other words, increasing the salinity of irrigation water above 0.2 dS/m (about 130 ppm) should only increase average soil salinity in the root zone by a like amount if winter rainfall is normal (about 400 mm) and irrigation, leaching, and groundwater control practices are similar to those for the subirrigated treatments of the field experiment. From the relationship given in figure 3 for the combined subirrigation data, the electrical conductivity of the irrigation water that accompanied the threshold value of soil water salinity for corn grain (3.7 dS/m) would be 1.9 dS/m. For below-normal rainfall as in 1981, electrical conductivity of irrigation water at the threshold value for grain would be 0.8 dS/m.

In an environmental impact report on the Delta by the State Water Resources Control Board in 1978, average soil water salinity was reported to be about eight times greater than the salinity of the irrigation water in a number of fields in the Delta where irrigation water salinity probably averaged 0.3 dS/m. Thus, the expected average soil water salinity based on the earlier report would be just over 2 dS/m, which is essentially the average value we found in this field trial when irrigation water salinity was 0.2 dS/m (fig. 3). Based on the results of the field trial, however, the ratio is not constant; the factor decreases as irrigation water salinity increases.

Summary

In these studies, we found that above-average rainfall and maintaining the water table about 1 meter below the surface effectively leached the upper soil profile. Under present conditions of low salinity in the irrigation water and with normal winter rainfall, soil salinity is about 8 times greater than the salinity of the irrigation water. As the salinity of the irrigation water increases, however, the factor 8 becomes substantially smaller. At the soil water salinity threshold for corn grain (3.7 dS/m), the factor is 2.3 for subirrigation, which results in a maximum value of 1.9 dS/m (about 1,200 ppm) for the salinity of the irrigation water without yield loss under normal conditions. With subirrigation and below-normal rainfall as in 1981, the maximum salinity of the irrigation water without yield loss would be 0.8 dS/m (about 500 ppm). □

Salt sensitivity of corn at various growth stages

Eugene V. Maas □ Glenn J. Hoffman

As a followup to the field test of salt tolerance of corn, we attempted to determine in greenhouse studies the salt sensitivity of corn at various growth stages. If corn is more sensitive during one stage than another, the salinity of the irrigation water could be regulated during the season to minimize salt injury during the more sensitive stage. Standards are needed, particularly during droughts and during the later part of the growing season when the water supply may be limited.

The objectives of this study were to determine: (1) the sensitivity of corn to soil salinity during germination, emergence, and seedling growth stages and (2) how rapidly and to what extent the salinity of the irrigation water can be increased during the cropping season without decreasing yield.

Experimental procedures

We measured germination in covered 9 x 9 cm germination dishes containing 20 corn seeds buried to a depth of 1 cm in presalinized organic soil. Sixteen cultivars were tested at eight levels of soil salinity with four replications. Germination dishes were kept in the dark at a constant temperature of 22°C. Germination counts were made daily over a period of two weeks.

In the emergence and seedling experiment, corn was grown in the greenhouse in 55-liter plastic pots filled with Rindge muck topsoil obtained from near Terminous, California. Treatments consisted of six irrigation waters having electrical conductivities of 0.2, 1, 3, 5, 7, and 9 dS/m, with each replicated 12 times. Each replication contained four pots with a different cultivar in each pot. Four corn cultivars were planted in each of four separate trials. Nine cultivars — seven field corn and two sweet corn — were tested. Pioneer 3780 was grown in each trial as a benchmark cultivar. At one, two, and three weeks after planting, we harvested plants to measure dry matter production.

In the experiment on increasing salinity during the growing season, Bonanza, a sweet corn cultivar, was grown in the same pots used in the preceding experiment. The experiment consisted of 18 treaments, each replicated four times with four pots per replication. The same six saline waters were also used in this experiment.

The first six treatments were irrigated throughout the experiment without changing the salinity of the irrigation water during the season, as is typical of a salt tolerance trial. The remaining 12 treatments were designed to determine the maximum salinity in the root zone that corn could tolerate at three growth stages during the season without a loss in yield. The salinity of the irrigation water in these treatments was increased by different amounts after 30 or 60 days. The three 30-day periods represent the vegetative, tasseling, and grain-filling stages during the growing season.

Results

Germination tests in salinized organic soil indicated that corn is much more tolerant during germination that at the seedling stage. Some cultivars appeared more tolerant during germination than others. For example, seven days after planting, germination of Pioneer 3369A, Funk G4141, and Northrup King PX32 was reduced significantly at soil water salinities above 8 dS/m, but several other cultivars germinated as well at 15 dS/m as in nonsaline soil (fig. 1).

In the emergence and seedling trials, increasing the salt concentration of irrigation water up to an electrical conductivity of 9 dS/m delayed emergence but did not affect the emergence percentage at six days after planting. The average soil water salinity in the seedling root zone was about 0.3 dS/m higher than irrigation water salinity. These results confirm the germination data obtained in petri dishes.

Seedling growth during the first three weeks was much more sensitive to salinity than was germination. Dry matter production of the nine cultivars when irrigated with 9 dS/m water averaged between 44 and 59 percent of those of the controls (see table). The average threshold soil water salinity for seedling growth (the maximum salinity without growth reduction) was 0.7 dS/m, but there were differences among cultivars. In this experiment, this threshold would have been reached with 0.4 dS/m irrigation water, which is well below that reported for grain production. For each dS/m increase in salinity above the threshold, growth decreased 4.9 percent in all cultivars.

The effects of increasing salinity during either tasseling or grain-filling stages of growth were compared with salinity treatments that were unchanged throughout the season. Salinity in the irrigation water significantly affected grain and stover yield when increased above 5 dS/m at all three stages of growth, but not when increased only during the tasseling and grain-filling stages (fig. 2). Even 9 dS/m irrigation water did not reduce yield significantly when applied after 30 days of growth. Where salinity was the same during all three stages, grain yield decreased about 10 percent per unit increase in soil water salinity above a threshold of 5.5 dS/m.

Conclusion

The results of this study agree with those of other investigators, which indicate that corn is most sensitive during the vegetative growth stage. Although salinity delays germination, corn is most tolerant at that stage of growth. Of 16 cultivars tested, all but three germinated within seven days at soil water salinities up to 10 dS/m (about 6,400 ppm) and seven germinated as well at 15 dS/m (about 9,600 ppm) as in the nonsaline soils. In separate pot experiments, emergence of nine corn cultivars was delayed by increasing soil salinity, but the final emergence percentage after six days was unaffected by soil water salinity up to 9.3 dS/m.

Seedling growth, on the other hand, is sensitive to soil salinity. Shoot growth during the first three weeks was reduced approximately 5 percent for each unit increase in soil water salinity above 0.7 dS/m (about 450 ppm).

Salt tolerance during later stages of growth was much higher than during the seedling stage. Salt tolerance response curves for Bonanza, a sweet corn cultivar, showed that fresh ear yields decreased 10 percent per unit increase in average soil water salinity above 5.5 dS/m (about 3,500 ppm). These data indicate that the salt tolerance of sweet corn in the greenhouse was greater than that of field corn grown in the field.

Increasing the salinity of the irrigation water to 9 dS/m at the tasseling and grain-filling stages did not significantly decrease grain yield below that obtained where salinity was constant throughout the growing season. If water of acceptable quality is used during vegetative growth, poorer quality water can be used during and after tasseling without reducing yields. □

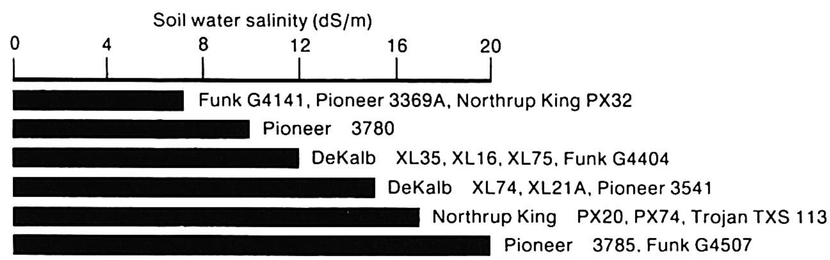

Fig. 1. Some corn cultivars were more salt-tolerant than others during germination, but for all, soil salinity had to exceed 7 dS/m before germination was reduced.

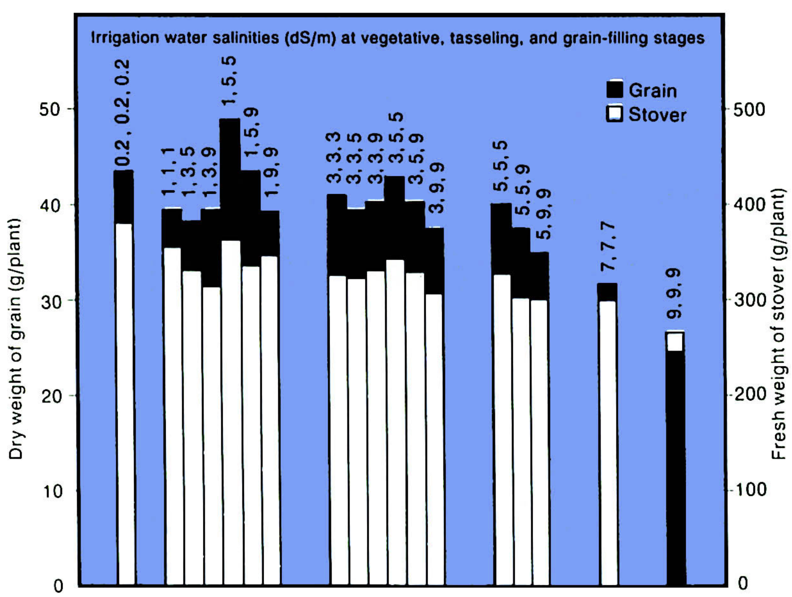

Fig. 2. Grain and stover yields dropped when irrigation water salinity exceeded 5 dS/m at the vegetative stage of growth, but during the tasseling and grain-filling stages, salinity could exceed 5 dS/m without further reduction.

Influence of irrigation water salinity on shoot growth of nine corn cultivars 21 days after planting

Cultivar	Control dry matter production	Relative dry matter production at following soil water salinities (dS/m) 1	3	5	7	9
	g/plant	*% of control*				
Pioneer 3780*	0.71	100	93	81	74	57
Pioneer 3906†	0.72	91	89	79	69	54
Pioneer 3541†	0.62	93	92	80	71	59
DeKalb XL75†	0.70	92	92	79	69	59
Northrup King PX20†	0.82	92	88	74	71	51
Northrup King PX74‡	0.68	99	89	76	63	55
Funk G4507‡	0.76	87	82	70	57	44
Bantam Golden Cross‡	0.56	117	103	75	79	57
Bonanza‡	0.40	108	99	92	83	56

* Treatment means averaged over four trials.
† Treatment means averaged over two trials.
‡ Treatment means for one trial.