Effect of Salinity on Grain Yield and Quality, Vegetative Growth, and Germination of Semi-Dwarf and Durum Wheat[1]

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ABSTRACT

Semi-dwarf bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum turgidum* L., Durum Group) are often grown on saline soils in the western United States. Because of the lack of information on salinity effects on vegetative growth and seed yield of these two species, a 2-yr field plot study was conducted. Six salinity treatments were imposed on a Holtville silty clay [clayey over loamy, montmorillonitic (calcareous), hyperthermic Typic Torrifluvent] by irrigating with waters salinized with NaCl and $CaCl_2$ (1:1 by wt). Electrical conductivities of the irrigation waters were 1.5, 2.5, 5.0, 7.4, 9.9, and 12.4 dS/m the first year, and 1.5, 4.0, 8.0, 12.0, 16.1, and 20.5 dS/m the second year. Grain yield, vegetative growth, and germination were measured. Relative grain yields of one semi-dwarf wheat cultivar and two durum cultivars were unaffected by soil salinity up to 8.6 and 5.9 dS/m (electrical conductivity of the saturated-soil extract), respectively. Each unit increase in salinity above the thresholds reduced yield of the semi-dwarf cultivar by 3.0% and the two durum cultivars by 3.8%. These results place both species in the salt-tolerant category. Salinity increased the protein content of both grains but only the quality of the durum grain was improved. Vegetative growth of both species was decreased more by soil salinity than was grain yield. Both species were less salt tolerant at germination than they were after the three-leaf stage of growth.

***Additional index words:* Triticum aestivum L., Triticum turgidum L., Durum Group, Salt tolerance, Sodium chloride, Calcium chloride.**

Wheat (*Triticum aestivum* L.) continues to be a predominant crop in the agriculture of the western United States. In 1982, 70% of the wheat grown in the United States was produced in the 17 western states (17). Much of this wheat is grown on soils where salinity problems already exist or may develop.

Considerable research has been conducted on the salt tolerance of various bread wheat cultivars over the past 30 years (1, 2, 12). However, with the development of the Mexican semi-dwarf cultivars, additional research is needed. Although a few preliminary studies on the salt tolerance of the Mexican wheats have been conducted in small pot cultures (14, 15, 16), salt-tolerance data are not available to predict yield responses in the field.

This field plot study was initiated to determine the effect of soil salinity on vegetative growth and grain yield of semi-dwarf bread wheat. In addition, the lack of salt tolerance information on durum wheat (*Triticum turgidum* L., Durum Group) prompted the authors to include this species in the study.

METHODS AND MATERIALS

This study was conducted at the Irrigated Desert Research Station, Brawley, CA, on a Holtville silty clay soil [clayey over loamy, montmorillonitic (calcareous), hyperthermic Typic Torrifluvent]. The crops were grown in 6.0- by 6.0-m plots that were enclosed by acrylic fortified fiberglass borders which extended 0.75 m into the soil. The top of the fiberglass borders protruded 0.15 m above the soil level of the plot and was covered with a berm 0.18 m high and 0.60 m wide. Walkways 1.2 m wide between plots and good vertical drainage effectively isolated the treatments in each plot.

Prior to planting, triple superphosphate was mixed into the top 0.25 m of soil at the rate of 73 kg P/ha. To assure adequate N fertility throughout the experiment, $Ca(NO_3)_2$ was added at a rate of (0.14 kg N/ha)/mm of water applied at every irrigation. Since the soil contained adequate levels of K, no additional K was added.

One bread wheat and one durum wheat cultivar were planted in level plots on 1 Dec. 1981 and 30 Nov. 1983. The bread wheat cultivar for both years was Northrup King Probred. The durum wheat cultivars were Westbred 1000-D in 1981 and Northrup King Aldura in 1983.

The cultural practices used at planting were identical for both experiments. Each plot contained 17 rows of Probred and 17 rows of the durum cultivar. The rows were planted 0.15 m apart with the seed placed approximately 25 mm apart within the row.

The experimental design consisted of six treatments replicated three times in a randomized split-plot design, with salinity as main plots and species as subplots. At the time of planting, the soil profiles were still salinized from previous experiments. The initial κ_e (electrical conductivity of the saturated-soil extract) averaged to a depth of 1.2 m for the six treatments in 1981 were 3.0, 4.9, 7.3, 9.5, 11.4, and 12.4 dS/m, while in 1983 they were 3.7, 4.6, 7.1, 8.2, 9.6, and 11.6 dS/m. To assure good germination, 70 mm of nonsaline water (1.5 dS/m) was applied prior to planting to leach salts from the top 0.15 m of soil; another 50-mm nonsaline irrigation was applied after planting.

Thirty days after planting, when the plants were approximately 60 mm tall, differential salination was initiated. Irrigation water salinities were increased stepwise in one-third increments over a 2-week period by adding equal weights of NaCl and $CaCl_2$ until desired salt concentrations were achieved. In 1981–1982, the electrical conductivity of the six irrigation waters (κ_{iw}) was 1.5 (Control), 2.5, 5.0, 7.4, 9.9, and 12.4 dS/m. The salinity of the irrigation waters was increased to 1.5, 4.0, 8.0, 12.0, 16.1, and 20.5 dS/m in the 1983–1984 season to obtain greater yield reductions. During both growing seasons, all plots were irrigated approximately every 2 to 3 weeks to keep the matric potential of the control treatments above −85 J/kg in the 0.15- to 0.3-m zone. The total amounts of irrigation water applied after planting were 680 mm in 1981–1982 and 480 mm in 1983–1984.

Soil samples were collected from each plot approximately 2, 4, and 6 months after planting. Two soil cores per plot were taken in 0.3-m increments to a depth of 0.9 m. The average κ_e for each of the three depths for both years is presented in Table 1.

The monthly mean daytime-high temperatures ranged from 22°C in December, 1983, to 29.5°C in April, 1984; monthly mean nighttime-low temperatures for the same period ranged from 5 to 10.5°C. In 1982, the monthly mean daytime-high temperatures ranged from 20.5°C for January to 29.5°C for April, and the monthly mean nighttime-low temperatures ranged from 4 to 11°C. In December, 1981, the mean high and low temperatures were 24 and 5°C, respectively. The mean Class A pan evaporation ranged from 3 mm/day in December to 11 mm/day in May. The accumulative pan evaporation during the 1981–1982 and 1983–1984 growing seasons were 805 mm and 680 mm for Probred, and 910 mm and 760 mm for 1000-D and Aldura, respectively.

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Table 1. Average electrical conductivities of the saturated-soil extracts (κ_e) for two years with six saline irrigation waters.

Soil sample depth	1982					
	Irrigation water salinities (κ_{iw}) – dS/m					
	1.5	2.5	5.0	7.4	9.9	12.4
m	dS/m (κ_e)					
0-0.3	2.4	3.4	4.9	6.0	8.0	9.0
0.3-0.6	3.2	4.9	6.1	7.6	9.5	11.0
0.6-0.9	3.2	4.6	6.7	8.9	11.2	12.3
Average	2.9	4.3	5.9	7.5	9.6	10.8
Soil sample depth	1984					
	Irrigation water salinities (κ_e) – dS/m					
	1.5	4.0	8.0	12.0	16.1	20.5
	dS/m (κ_e)					
0-0.3	1.8	3.6	6.2	9.1	10.7	12.6
0.3-0.6	4.9	7.4	10.5	12.6	14.4	16.5
0.6-0.9	3.9	4.6	7.5	9.8	11.6	12.9
Average	3.5	5.2	8.1	10.5	12.2	14.0

Table 2. Growth stage designations for 'Aldura' and 'Probred' during 1983-84.†

Soil salinity	Dates of observation			
	13 Feb.‡	11 Mar.§	29 Mar.	15 Apr.
dS/m				
		Aldura		
3.5	18, 25, 41	35, 60	73	83
5.2	17, 23, 41	35, 61	73	85
8.1	17, 24, 41	34, 61	74	85
10.5	17, 23, 43	34, 63	75	87
12.2	17, 23, 43	34, 65	77	87
14.0	17, 23, 49	34, 67	79	88
		Probred		
3.5	18, 25, 41	35, 63	74	84
5.2	18, 23, 41	35, 65	75	84
8.1	18, 23, 41	35, 66	76	85
10.5	17, 25, 41	35, 67	77	88
12.2	17, 23, 49	35, 67	79	88
14.0	17, 24, 49	35, 69	81	88

† Values follow the 2-digit Zadoks-Chang-Konzak scale (20). The first digit refers to the following stages: 1 = seedling growth, 2 = tillering, 3 = stem elongation, 4 = booting, 5 = inflorescence, 6 = anthesis, 7 = milk development, and 8 = dough development. The second digit refers to the number of leaves, tillers, or nodes for stages 1, 2, and 3, respectively, and indicates the progressive maturation within stages 4, 5, 6, 7, and 8.

‡ 2nd node detected in all treatments (Code 32).

§ Plants in all treatments had 8 leaves and 2 tillers (Code 18, 22).

Table 3. Vegetative parameters at maturity for a semi-dwarf bread wheat and two durum wheat cultivars grown at six soil salinities in two different years.

Soil salinity (κ_e)	Straw yield	Plant height	Straw yield	Plant height
dS/m	g/m²	m	g/m²	m
	1982			
	Probred		1000-D	
2.9	457	0.75	583	0.87
4.3	486	0.73	565	0.85
5.9	417	0.72	562	0.83
7.5	412	0.67	503	0.80
9.6	392	0.64	445	0.78
10.8	383	0.61	437	0.74
	1984			
	Probred		Aldura	
3.5	560	0.70	545	0.74
5.2	549	0.70	490	0.73
8.1	528	0.67	462	0.72
10.5	546	0.63	465	0.70
12.2	461	0.60	414	0.67
14.0	393	0.58	426	0.66

Analysis of variance

Source	df	Mean squares			
		Straw yield†	Plant height‡	Straw yield†	Plant height‡
		1982			
		Probred		1000-D	
Salinity	5	4.74	8.93***	12.32*	7.25***
Linear	1	18.88*	43.81***	58.15***	35.58***
Quadratic	1	0.04	0.40	1.00	0.28
Cubic	1	1.09	0.06	1.22	0.06
Error	10	2.18	0.11	2.55	0.21
		1984			
		Probred		Aldura	
Salinity	5	12.95***	7.88***	6.68*	3.44***
Linear	1	45.95***	37.29***	28.51***	16.41***
Quadratic	1	12.23**	1.15	1.35	0.43
Cubic	1	3.25	0.81	0.54	0.02
Error	10	1.21	0.56	1.61	0.15

*,**,*** Significant at the 5, 1, and 0.5% levels of probability.

† Table values must be multiplied by 10^3.

‡ Table values must be multiplied by 10^{-3}.

During the 1983-1984 growing season, plant growth and development were rated biweekly with the Haun (6) and Zadoks-Chang-Konzak (20) stage-of-growth scales. A combination of the two scales was used to rate leaf development, whereas only the Zadoks-Chang-Konzak scale was used for the tillering, stem elongation, inflorescence, and maturation stages. A good description of these and other scales has been published by Bauer et al. (3).

In 1982, the bread wheat and durum were harvested 154 and 164 days after planting and in 1984, at 140 and 145 days, respectively. To determine grain and straw yield of each cultivar, a 4.64 m² area was harvested from the center of each half of each plot. Spikes were harvested by hand, weighed, counted, and threshed. The seed was then cleaned and weighed. Total straw yield from the harvest area was weighed and a subsample dried in a forced-air drier at 70°C to determine water content.

The first and second leaves below the flag leaf were sampled after spike emergence. The leaves were washed, dried at 70°C, and finely ground in a blender. Chloride contents were determined on 0.1 *M* nitric acid in 1.7 *M* acetic acid extracts of the leaf material by the Cotlove (4) coulometric-amperometric titration procedure. Nitric-perchloric acid digests of the ground leaves were analyzed for P by molybdovanadate-yellow colorimetry (8), and Na, Ca, Mg, and K by atomic absorption spectrophotometry.

Grain quality was evaluated on the 1984 crop by standard methods at two USDA, Wheat Quality Laboratories. Aldura durum was evaluated at Fargo, ND, and Probred wheat at Pullman, WA.

Germination of Probred and 1000-D at different salinities was tested in the laboratory. Four replicates of 20 seeds each were planted in trays containing fine, washed sand. The sand had been premoistened with solution containing equal weights of NaCl and $CaCl_2$ to produce soil water salinities (κ_{sw}) of 0.6, 4.5, 8.8, 12.9, 16.6, and 21.1 dS/m. The trays were placed in a lighted, humid environment at 25°C. Seed germination counts were made daily over an 11-day period.

RESULTS AND DISCUSSION

Plant Development

When salination began on 30 December, the plants in the first two treatments were coded 13.6, 22; i.e., the plants had 3 fully unfolded leaves, with the fourth

Table 4. Grain yield parameters for a semi-dwarf bread wheat and two durum wheat cultivars grown at six soil salinity levels in two different years.

Soil salinity (κ_e)	Grain yield	No. of spikes	Seed wt per spike	100-seed wt	Grain yield	No. of spikes	Seed wt per spike	100-seed wt
dS/m	g/m²	no./m²	g	g	g/m²	no./m²	g	g
		Probred — 1982				1000-D — 1982		
2.9	757	409	1.86	5.63	831	250	3.32	5.27
4.3	745	399	1.87	5.53	793	246	3.22	5.23
5.9	754	400	1.90	5.49	830	270	3.07	5.16
7.5	714	409	1.75	5.52	733	249	2.95	5.20
9.6	709	420	1.69	5.40	655	247	2.66	5.08
10.8	679	416	1.63	5.44	586	218	2.67	5.11
		Probred — 1984				Aldura — 1984		
3.5	643	285	2.26	5.37	630	270	2.33	5.57
5.2	633	299	2.12	5.27	614	260	2.37	5.57
8.1	681	330	2.07	5.15	622	267	2.33	5.43
10.5	658	335	1.97	4.60	594	281	2.11	5.08
12.2	581	286	2.03	4.57	527	256	2.06	4.87
14.0	544	301	1.82	4.40	459	245	1.88	4.66

Analysis of variance

Source	df	Grain yield†	No. of spikes†	Seed wt per spike	100-seed wt	Grain yield†	No. of spikes†	Seed wt per spike	100-seed wt
			Probred — 1982				1000-D — 1982		
Salinity	5	2.83	0.22	0.04	0.02	30.05***	0.84	0.23***	0.02
Linear	1	12.21*	0.55	0.15*	0.07	130.91***	1.39	1.12***	0.06
Quadratic	1	0.60	0.20	0.02	0.00	12.68	1.72	0.00	0.00
Cubic	1	0.01	0.32	0.00	0.00	0.00	0.14	0.01	0.00
Error	10	2.45	2.32	0.02	0.02	3.35	0.37	0.02	0.10
			Probred — 1984				Aldura — 1984		
Salinity	5	7.87***	1.38	0.07***	0.52***	13.77***	0.47	0.12***	0.44***
Linear	1	16.65***	0.21	0.29***	2.43***	52.11***	0.50	0.49***	2.08***
Quadratic	1	17.61***	3.79*	0.00	0.01	14.48*	0.71	0.07	0.12*
Cubic	1	0.37	0.18	0.03	0.05	1.17	0.63	0.00	0.02
Error	10	0.75	0.43	0.01	0.01	1.88	0.59	0.01	0.01

*,*** Significant at the 5 and 0.5% levels of probability.

† Table values must be multiplied by 10^3.

leaf 0.6 the size of the third leaf, and two tillers. All other treatments averaged 13.3, 21, indicating the presalinized soil profiles had little effect on seedling growth and development. Further development as a function of salinity is given in Table 2. Although the morphological development of the plants was not affected by salinity until the booting stage, plant height of both species at maturity was significantly reduced by salinity (Table 3). The inflorescence emerged from the boot approximately 10 to 12 days earlier on the high-salt treatments than on control treatments. This difference was maintained throughout the grain filling and maturation stages. Although both species reached anthesis at the same time, the Probred wheat was fully mature 1 week earlier than the Aldura durum.

Grain Yield

Grain yield parameters for the two wheat species are presented in Table 4. In 1982, Probred grain yield, as well as all parameters associated with grain yield, showed no significant reduction with soil salinity up to 10.8 dS/m. However in 1984, with higher soil salinities, grain yield was significantly reduced. The decreased yield resulted from decreased seed weight per spike and individual seed weight (expressed as the weight of 100 seeds). The number of spikes harvested per unit area was not affected by salinity.

Grain yield of the durum cultivar 1000-D was significantly reduced by salinity in 1982. This reduction was attributed almost entirely to the reduction in seed weight per spike. In 1984, the effect of salinity on Aldura grain yield was similar to that reported for Probred. Reduction in both seed weight per spike and individual seed weight were the main contributing factors to the grain yield reduction. The number of spikes produced per unit area again was not significantly affected by increased levels of salinity.

The combined grain yield data for the 2 yr was statistically analyzed with a piecewise linear response model (10, 19). The data indicate that the tolerance thresholds, i.e., the maximum allowable κ_e without a

Table 5. Grain quality data for 'Aldura' durum grown at six soil salinity levels.†

Soil salinity (κ_e)	Fraction of large kernels	Wheat Ash	Wheat Protein	Semolina Ash	Semolina Protein	Semolina Color	Spaghetti cooking residue
dS/m		g/kg	g/kg	g/kg	g/kg		g/kg
3.5	0.93	13.2	110	5.5	97	93.3	63.7
5.2	0.94	13.0	125	5.3	110	90.0	61.3
8.1	0.91	12.4	127	5.3	112	91.7	55.0
10.5	0.82	10.4	130	5.1	115	95.0	58.7
12.2	0.74	10.4	129	5.0	114	95.0	53.3
14.0	0.49	10.6	129	5.0	114	98.3	50.0
CV	4.8	2.7	1.8	2.4	2.0	2.3	7.0
$P > F$‡	0.0001	0.0001	0.0001	0.0049	0.0001	0.0115	0.0153

† The mean values for eight other quality factors that were not significantly affected by salinity were: test weight = 813 kg/m³ (63.2 lb/bu); fraction of small kernels = 0.01; falling number = 400; fraction of semolina extracted = 0.65; mixogram score = 3.89 (medium strength); specks/10 sq. in. = 30; visual spaghetti color = 9.1 (good); and firmness = 8.32 g/cm (good). See Nolte et al. (11) for methods of scoring quality factors.

‡ Probability that an *F* value would occur by chance.

Table 6. Mineral composition of leaves from a semi-dwarf bread wheat (cv. Probred) grown at six levels of salinity for 2 yr.

Soil salinity (κ_e)	Cl	Na	Ca	Mg	K	P
dS/m	mmol/kg dry wt					
			1982			
2.9	378	11.0	117	94.4	801	93.4
4.3	374	9.4	119	93.4	810	89.9
5.9	370	11.2	127	91.7	806	87.1
7.5	397	8.0	146	88.0	836	75.2
9.6	366	10.1	150	81.5	818	76.5
10.8	294	10.6	144	75.1	757	69.5
			1984			
3.5	411	4.5	142	98.6	851	69.2
5.2	467	5.7	146	99.8	912	72.8
8.1	479	7.0	173	104.3	882	70.0
10.5	547	9.7	191	94.2	894	59.9
12.2	520	11.8	207	92.1	810	50.9
14.0	463	10.4	207	90.7	700	48.5

Analysis of variance

		Mean squares					
Source	df	Cl†	Na	Ca†	Mg	K†	P†
				1982			
Salinity	5	3.78	4.22	0.62*	173.73***	2.07	0.27**
Linear	1	7.21	0.37	2.63***	798.90***	1.12	1.25***
Quadratic	1	6.51	5.29	0.11	67.79*	5.30	0.00
Cubic	1	4.66	0.90	0.33	1.39	3.12	0.00
Error	10	1.74	3.91	0.14	7.20	2.37	0.04
				1984			
Salinity	5	6.74	24.31***	2.47***	80.54*	18.28*	0.32***
Linear	1	11.90	109.71***	12.00**	215.96*	42.53*	1.36***
Quadratic	1	15.34	1.25	0.04	84.93	43.02*	0.16
Cubic	1	2.31	5.73	0.27	41.31	0.78	0.09
Error	10	4.00	2.39	0.18	22.22	4.50	0.04

*,**,*** Significant at the 5, 1, and 0.5% levels of probability. † Table values must be multiplied by 10^3.

decline in grain yield, were 8.6 and 5.9 dS/m for Probred and the two durum cultivars, respectively (Fig. 1 and 2). Each unit increase in salinity above the threshold reduced the yield of Probred 3.0% and durum 3.8%.

According to the classification scheme of Maas and Hoffman (10), both the Probred and durum cultivars would be classified as tolerant to salinity. This places both of these wheat species in the same category as barley (*Hordeum vulgare* L.), one of the most salt tol-

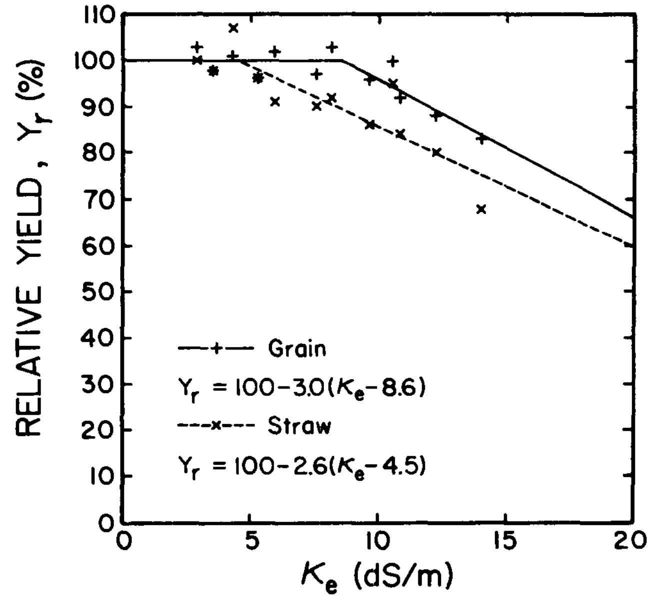

Fig. 1. Relative grain and straw yield of a semi-dwarf bread wheat (cv. Probred) as a function of increasing soil salinity. Standard errors for the threshold and slope values are 1.15 and 1.04 for grain and 1.78 and 0.59 for straw, respectively.

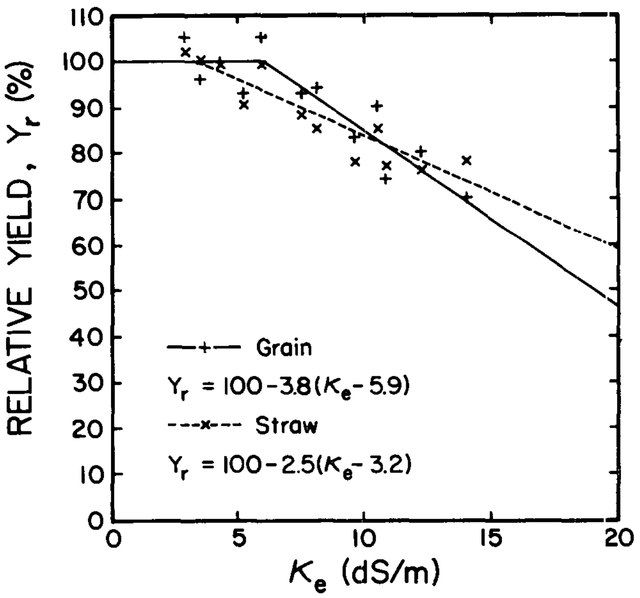

Fig. 2. Relative grain and straw yield of durum wheat as a function of increasing soil salinity. Standard errors for the threshold and slope values are 1.06 and 0.78 for grain and 2.60 and 0.50 for straw, respectively.

Table 7. Mineral composition of leaves from two durum wheat cvs. grown at six levels of salinity in 2 different yr.

Soil salinity (κ_e)	Cl	Na	Ca	Mg	K	P
dS/m	mmol/kg dry wt					
			1000-D, 1982			
2.9	396	140	85	48.6	940	96.4
4.3	331	120	77	48.1	899	87.0
5.9	377	121	83	46.6	920	84.5
7.5	440	134	101	45.8	895	76.6
9.6	408	94	83	41.3	893	701.
10.8	539	151	114	39.3	863	63.4
			Aldura, 1984			
3.5	394	256	126	75.8	509	59.0
5.2	542	299	149	84.5	510	57.7
8.1	537	274	154	76.8	490	50.0
10.5	787	343	166	67.4	572	44.5
12.2	791	319	177	68.1	529	40.9
14.0	1038	432	189	64.7	551	38.4

Analysis of variance

		Mean squares					
Source	df	Cl†	Na†	Ca†	Mg	K†	P†
				1000-D, 1984			
Salinity	5	15.02	1.19	0.60	42.74***	2.04	0.43*
Linear	1	42.66	0.02	1.36	198.30***	7.46	2.13***
Quadratic	1	11.49	1.18	0.19	13.50**	0.03	0.00
Cubic	1	0.00	0.52	0.02	0.04	1.16	0.01
Error	10	9.50	2.70	0.62	1.25	1.84	0.08
				Aldura, 1984			
Salinity	5	163.78***	11.80***	1.51***	168.29*	2.77	0.22***
Linear	1	742.96***	40.91***	7.22***	598.68***	5.49	1.11***
Quadratic	1	25.20*	6.41	0.00	36.44	0.13	0.00
Cubic	1	8.64	4.16	0.20	143.98	1.32	0.01
Error	10	4.78	1.31	0.14	33.69	1.78	0.03

*,**,*** Significant at the 5, 1, and 0.5% levels of probability. † Table values must be multiplied by 10^3.

erant crops (10), whose threshold and slope are 8 dS/m and 5% per dS/m, respectively. In addition, it indicates that the semi-dwarf cultivars may be more salt tolerant than the older bread wheat cultivars (1,2).

Grain Quality

The effects of salinity on 15 quality factors measured on Aldura durum wheat, semolina milled from the wheat, and one spaghetti processed from the semolina are shown in Table 5. Semolina is the ground endosperm used in pasta products. An analysis of variance indicated that salinity significantly decreased the percentage of large kernels but increased the percentages of wheat and semolina protein and increased the semolina color score. The wheat and semolina ash values as well as the residue concentrations remaining after cooking the spaghetti were decreased. Test weight and various other quality factors given in the table footnote were not significantly affected by salinity. The overall evaluation indicated that salinity significantly improved the quality of the durum. For Probred, only samples from the control and the highest saline treatments were evaluated. Salinity increased the flour protein content from 96 to 119 g/kg and decreased the flour ash content from 4.4 to 4.1 g/kg, both significant at the 5% level of probability. Ten other quality factors were not significantly affected by salinity. The mean values were: test weight = 825 kg/m^3; flour yield = 704 g/kg; milling score = 81.8; corrected mixograph absorption = 66%; bake water absorption = 69.4% (68.7% when corrected to 14% moisture basis); optimum mixing time = 5.53 min; bread loaf volume = 646 × 10^3 mm^3 (597 × 10^3 mm^3 when corrected to 10% protein basis); bread crumb grain rating = 8. Although salinity increased the protein content, the corrected loaf volume indicates that the protein was of poorer baking quality.

Straw Yield

Straw yield of both species was more sensitive to salinity than grain yield, with thresholds of 4.5 dS/m for Probred and 3.2 dS/m for the durum cultivars (Table 3 and Fig. 1 and 2). However, the reduction for each unit increase in salinity above these thresholds was less than that for grain yield at 2.6 and 2.5% for the Probred and durum cultivars, respectively. Corn (*Zea mays* L.) (7), rice (*Oryza sativa* L.) (13), and sorghum [*Sorghum bicolor* (L.) Moench] (5) show a greater reduction in grain yield than in straw yield under saline conditions.

Mineral Analysis

Chemical analyses of the leaves sampled from both cultivars in 1982 showed that increased levels of soil salinity had little effect on mineral composition although small reductions in Mg and P were significant (Tables 6 and 7). Similar trends were noted in 1984, however all measured ions, except Cl in Probred and K in Aldura, were significantly affected by increased salinity levels. The durum cultivars accumulated 10 to 40 times more Na than did Probred, with Aldura

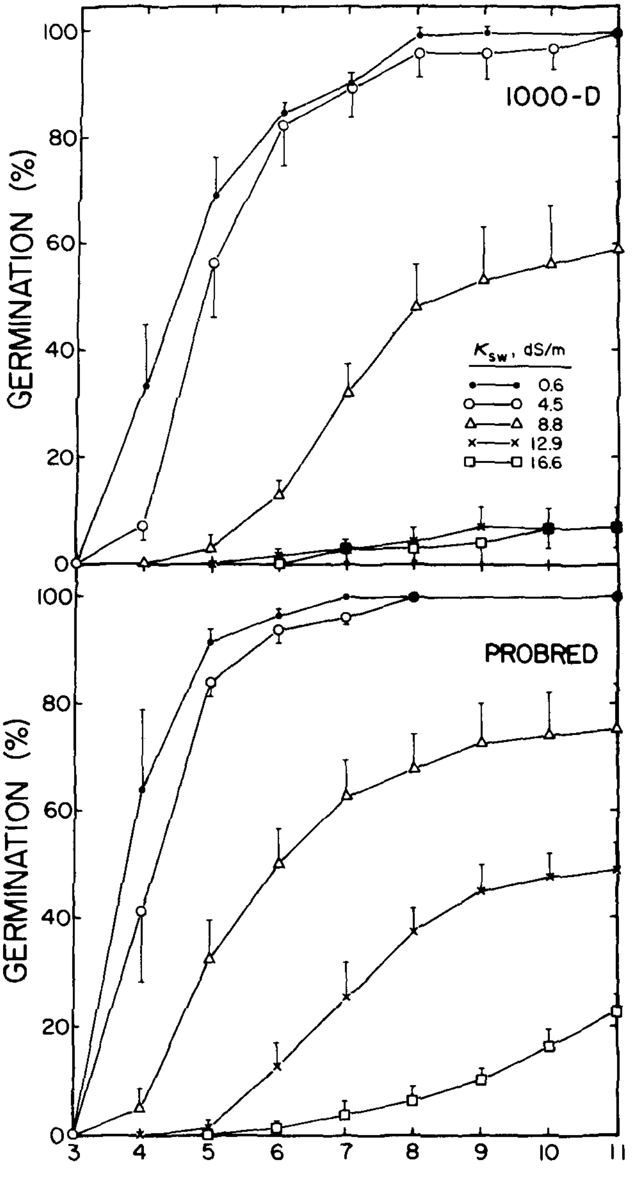

Fig. 3. Germination of two wheat species at five salinity levels. SE of mean indicated by bar when greater than symbol size.

accumulating much higher levels than 1000-D. Aldura also accumulated more Cl than did either Probred or 1000-D.

Germination

The effect of five salinity levels on germination was essentially the same for both species (Fig. 3). Germination was little affected by soil water salinity (κ_{sw}), up to 4.5 dS/m. At 8.8 dS/m and above, germination was significantly delayed and the final germination percentage was markedly reduced. The κ_{sw}'s for 50% reductions in germination were calculated to be 12.5 and 9.4 dS/m for Probred and 1000-D, respectively. These data indicate that both species are less tolerant at germination than when salt stress was imposed after the third-leaf stage. The data in Fig. 1 and Fig. 2 indicate no loss of grain yield for the wheat and durum species up to a κ_c = 8.6 and 5.9 dS/m, respectively. If one assumes that the soluble salt concentration of the soil solution at field capacity is about twice that of a saturated-soil extract (18), the equivalent thresholds for grain yields, expressed on the basis of soil water salinity (κ_{sw}) are 17.0 and 12.0 dS/m, respectively. These results also suggest that the semi-dwarf and durum wheat cultivars tested here are less tolerant to salinity at germination than indicated in the literature for the older, bread wheat cultivars (9).

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