NOTE

Effect of Salinity on Yield, Seed Quality, and Biochemical Characteristics in *Setaria italica* L.

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Setaria italica L. is one of the important minor millets used for human consumption in India and Northern China (Parvathy and Sadashivam 1982). Because it is considered to be relatively salt and drought tolerant compared to other field crops (Anonymous 1983), it is grown extensively in the arid and semiarid zones of India, where the lack of sufficient good water for irrigation necessitates the use of water of relatively high salt content. It is generally recognized that higher concentrations of cations and associated anions in irrigation waters may adversely affect the growth, yield, nutrient composition, and seed quality characteristics of cereals. However, information on minor millets grown under such conditions is rather scanty. Hence, the present investigation was undertaken to study the effect of salinity on the yield, seed quality, and biochemical characteristics in *Setaria*.

MATERIALS AND METHODS

Preparation of Saline Waters

Saline waters were prepared artificially using commercial grade NaCl, $NaHCO_3$, $MgSO_4$, and $CaCl_2$. The different salinity levels (2, 4, 8, and 16 decisiemens per meter [dS/m]) in irrigation waters were attained by dissolving calculated amounts of salts in 1 dS/m water, i.e., the control. The amount (g/L) of each salt in 16 dS/m water was as follows: NaCl, 5.00; $NaHCO_3$, 4.44; $MgSO_4$, 2.78; and $CaCl_2$, 2.22.

Harvests from Rainy Season Seed Samples

A field experiment was conducted at Agricultural College Farm, Dharwad, Karnataka, India, during *kharif* (June–September) 1986, under a randomized block design in four replications. The crop was grown under different salinity levels in irrigation waters (from 1.0 to 16.0 dS/m) applied six times during the growing season. At harvest, seed and straw yield and 1,000-kernel weight were recorded. Harvest index was calculated from the ratio of economical to biological yield. Chemical analyses, seedling vigor, and total amylolytic enzyme activity studies were carried out in seed samples pooled from replicated treatments.

Chemical Analyses

Seed samples from pooled seed lots were dried to 9% (±1%) moisture and ground to fine powder for chemical analyses. Nitrogen content was determined by the micro-Kjeldahl method (no. 38.014) of the AOAC (1965), and the Kjeldahl nitrogen was converted to protein using the conversion factor 6.25. Starch content was determined by the method followed by Clegg (1956), and the reducing and total soluble sugars by Nelson's modification of Somogyi's method (Nelson 1944) and the method of Dubois et al (1956), respectively. Glucose was used as a standard in the quantification of both these sugars.

Total phenols and free amino acids were determined by the methods of Bray and Thorpe (1954) and Moore and Stein (1948), respectively. Phosphorus (by vanadomolybdophosphoric yellow color method), sodium, and potassium (by flame photometry) after digestion of the sample in a triacid mixture of HNO_3/H_2SO_4/$HClO_4$ (10:1:4) were estimated as in Jackson (1968).

Germination and Seedling Vigor Studies

Seeds were germinated by the ISTA (1985) procedure, being placed between wet rolled paper towels and then kept in the germination chamber maintained at 25°C (±1°C) and 95% (±1%) relative humidity. Observations on germination, root and shoot length were recorded, and seedling vigor index was calculated as in Abdul-Baki and Anderson (1973).

Assay of Total Amylolytic Enzyme Activity

Ungerminated seeds (zero time) and/or whole seedlings of various stages (from one to seven days) were used for extraction and assay of total amylolytic enzyme activities as described by Bernfeld (1955). The enzymatic activity was expressed as micromoles of reducing sugars produced per hour per gram weight of seed and/or fresh seedling. The data points represent the average of three determinations.

RESULTS AND DISCUSSION

Yield and Yield Component

The yield and yield component showed significant variation with respect to different salinity levels (Table I). With salinity increased from 1 to 16 dS/m in irrigation waters, a linear decrease in seed and straw yield, harvest index, and 1,000-kernel weight was noticed. The seed yield recorded at 1 dS/m (control) was significantly higher than at 4.8 and 16 dS/m and was reduced by 28 and 57% respectively at 8 and 16 dS/m compared to control.

The decrease in seed yield with increased salinity was observed earlier in *Setaria* (Kubsad 1988) and other millets such as finger millet (Sarma et al 1981) and pearl millet (Singh et al 1985).

Harvest index values decreased from 0.340 to 0.276 with the increase in salinity levels. Thousand-kernel weight as a yield component also decreased from 3.15 to 1.90 g with increased salinity. The decrease in these parameters may result from decreased vegetative growth caused by increased soil salinity.

Chemical Composition

The salinity levels also showed significant variation with respect

TABLE I
Effect of Salinity on the Yield and Yield Component[a] in *Setaria italica* L.

Salinity Levels (dS/m)	Seed Yield (q/ha)	Straw Yield (q/ha)	Harvest Index	1,000-Kernel Weight (g)
1.0[b]	20.63	40.06	0.340	3.15
2.0	19.20	39.25	0.327	3.00
4.0	18.22	37.78	0.325	2.95
8.0	14.81	31.72	0.321	2.80
16.0	8.93	23.48	0.276	1.90
SEM	0.63	1.20	0.009	0.07
CD[c] (5%)	1.94	3.69	0.027	0.22

[a] Average of four replications.
[b] Control, good water.
[c] Critical differences ($P = 0.05$).

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TABLE II
Chemical Composition[a] of *Setaria italica* L. as Influenced by Salinity

Salinity Levels (dS/m)	Protein (N × 6.25)	Starch (%)	Sugars: Reducing (%)	Sugars: Total Soluble (%)	Total Phenols (%)	Total Free Amino Acids (μmol/g)	Phosphorus (%)	Potassium (%)	Sodium (%)
1.0[b]	12.43	64.54	0.02	0.33	0.22	0.34	0.36	1.45	0.22
2.0	13.25	63.71	0.02	0.28	0.21	0.32	0.38	1.39	0.28
4.0	12.95	66.99	0.01	0.26	0.17	0.35	0.39	1.31	0.21
8.0	14.12	71.92	0.02	0.33	0.09	0.16	0.38	1.23	0.20
16.0	13.94	74.31	0.03	0.32	0.27	0.22	0.39	1.21	0.29
SEM	0.10	3.04	0.001	0.01	0.01	0.01	0.01	0.03	0.02
CD[c] (5%)	0.32	9.58	0.01	0.04	0.02	0.04	N.S.	0.08	0.06

[a]Average of three determinations at 9% (±1%) moisture.
[b]Control, good water.
[c]Critical differences ($P = 0.05$).

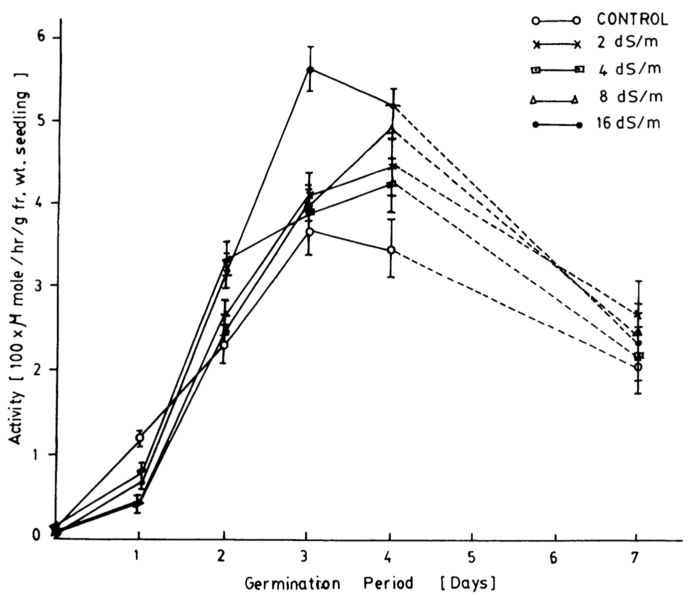

Fig. 1. Effect of salinity on the total amylolytic activity in germinated *Setaria italica* L. Assayed in 25 m*M* phosphate buffer (pH 7.0) at 37°C using 1% soluble starch as substrate. The amount of reducing sugars formed (micromoles) was determined colorimetrically at 540 nm. Data points represent the average of three determinations ($P = 0.01$).

to different chemical constituents except phosphorus (Table II). The protein content was found to vary from 12.43 (control) to 14.12% (8 dS/m) and the starch content from 63.71 (2 dS/m) to 74.31% (16 dS/m). Interestingly, the proportion of protein plus starch in seeds increased with increased salinity. Of the sugar constituents, reducing sugars were present in minor amounts. The carbohydrate profiles of three minor millets grown under normal conditions were reported by Parvathy and Sadashivam (1982). The reducing sugar content was found to be 0.32 (*Setaria italica*), 0.20 (*Panicum miliaceum*), and 0.15% (*Echinochloa frumentacea*). Total phenols and free amino acids were found to be significantly lower at 8 dS/m.

Regarding mineral constituents, the phosphorus content increased under saline conditions. The phosphorus content of different *ragi* varieties grown under normal conditions is reported to vary from 230.76 to 276.92 mg/100 g (Shukla et al 1985). The potassium content decreased with increased salinity. Thus, salinity in irrigation waters can affect the chemical composition of *Setaria*.

Seedling Vigor

Germination and seedling vigor tests were made on seeds produced from plants grown under varied levels of salinity. The results revealed no significant differences in percent germination and seedling vigor between seeds produced from control and saline-grown plants. The means for percent germination and seedling vigor index were 79 ± 2 and 1,608 ± 49, respectively. Although saline conditions are known to cause a delay as well as a decrease in germination for barley (Rathore et al 1977) and sorghum (Padmanathan and Rao 1975), the direct effect of salinity on germination was not examined in this study. However, potential indirect effects of salinity on germination, through alteration of seed quality during seed formation, were examined and found to be negligible in *Setaria*.

Total Amylolytic Activity

Total amylolytic activity also showed significant variation with salinity (Fig. 1). The enzyme activity was very low at the initial stages of germination and increased steeply after the lag period. For seeds grown at 1.0 (control) and 16.0 dS/m, maximum activity was recorded on the third day of germination and thereafter a decline was noticed. However, the seeds of 2, 4, and 8 dS/m continued to show increased enzyme activity even after the third day of germination. Irrespective of the day(s) of germination, the highest significant enzyme activity was noticed in seeds of 16 dS followed by 8, 2, 4, and 1 dS/m. In general, the total amylolytic activity in seeds produced under saline conditions was higher than the control at or after the second day of germination.

Several significant changes, such as a decrease in starch and an apparent increase in amylose content are known to occur during the early germination of cereal grains (Parvathy and Sadashivam 1982). These changes were suggested to be caused by limited α-amylosis of starch. α-Amylase was therefore concluded to be the predominant enzyme involved during germination (Manners 1974). In the initial stages of germination, a major portion of soluble sugars in the dry seed may be utilized for respiratory activity (Nomura et al 1969) and for further energy, the system depends on increased amylolytic activity on starch. This may be the reason that total amylolytic activity increases in the early and decreases in the later stages of germination. Similar findings were also observed on the amylase activity in germinating seeds of minor millet grown under normal conditions. However, under saline conditions, the enzyme activity in *Setaria* was higher than the control, the reasons for which need to be ascertained further.

CONCLUSIONS

Salinity levels produced significant variation with respect to yield and yield component, chemical composition (except phosphorus content), and total amylolytic activity. A linear reduction in seed and straw yield, harvest index, and 1,000-kernel weight was observed with increased salinity. The proportion of protein plus starch content in seeds was found to increase with increased salinity. Seed quality characteristics such as germination percentage and seedling vigor index were not affected by salinity. The total amylolytic enzyme activity was very low at the initial stages of germination and increased steeply after the lag period. However, the activity was higher in seeds grown under saline conditions than the control on or after the second day of germination.

ACKNOWLEDGMENTS

The authors thank P. W. Basarkar, assistant professor of Biochemistry, University of Agricultural Sciences, Dharwad, for necessary laboratory help, and the University and ICAR for financial assistance.

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[Received May 26, 1988. Revision received June 13, 1989. Accepted June 19, 1989.]