SALT TOLERANCE IN BARLEY

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This is a report on one year's field work which measured grain and biomass (grain plus straw) yield of barley grown in a saline field near Borden, Saskatchewan. The experimental methodology and step-by-step procedures followed in the data analysis will be described. The results will be interpreted with reference to two of our current definitions of SALT TOLERANCE.

Both definitions are based on productivity in a saline environment, productivity meaning economic yield, total biomass or both. For lack of other reliable ways to identify 'salt tolerant' plants agronomists and plant breeders tend to use productivity as a measure.

The first definition is ABSOLUTE SALT TOLERANCE meaning grain yield or total dry weight at a specified level of salinity, measured as electrical conductivity (EC).

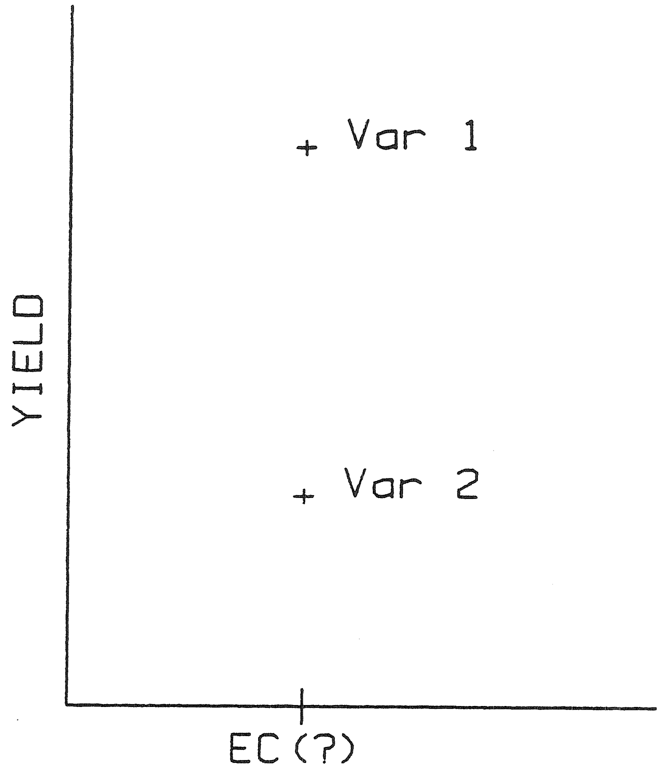


FIGURE 1. ABSOLUTE SALT TOLERANCE

The interpretation of Figure 1 is simply that variety 1 is more 'salt tolerant' than variety 2 in absolute terms.

The second definition is RELATIVE SALT TOLERANCE, the grain yield or total dry weight of a crop or variety at a specified level of salinity as compared to its yield or dry weight on a non-saline soil. In Figure 2 variety 2 has better RELATIVE SALT TOLERANCE than variety 1. Relative to the yields at non-saline EC(i), variety 2 does not decrease in yield as rapidly as variety 1 as the conductivity increases to saline EC(ii). At the same time, variety 1 has better ABSOLUTE SALT TOLERANCE since its yield is higher at EC(ii).

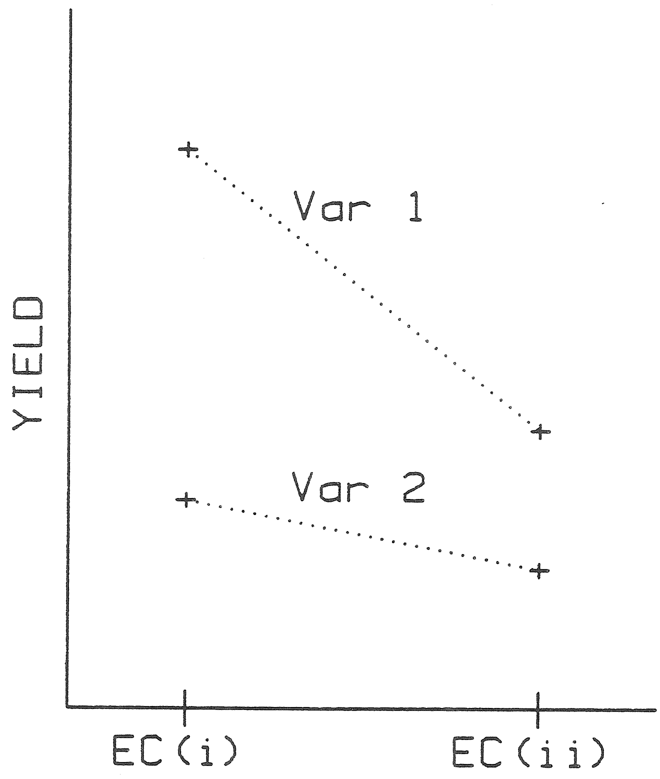


FIGURE 2. RELATIVE SALT TOLERANCE

The experimental plot at Borden was situated to ensure that part of the area was saline and part non-saline. A completely randomized design was used because of extreme soil variability. Forty replications of twenty-two genotypes were grown in 5' rows. There was diversity in the barleys chosen including 2-row varieties, 6-row varieties, local varieties, selections from Europe, Mexico, USA and the mid-east. A reputedly salt tolerant variety, California Mariout, was included.

FIGURE 3. EXPERIMENTAL DESIGN

COMPLETELY RANDOMIZED DESIGN

22 GENOTYPES

40 REPLICATIONS

5′ ROWS

FIGURE 4. GENOTYPES

12 FROM 1981 GUIDE TO FARM PRACTICE

4 FROM 1983 VARIETIES OF GRAIN CROPS

3 FROM USA

1 FROM CZECHOSLOVAKIA

1 FROM MEXICO

1 FROM UNITED ARAB REPUBLIC

The test was seeded May 17 and treflan was incorporated above the seed for green foxtail control. Plots were hand weeded as necessary. During the growing season there was 92 mm of rainfall. At maturity, each row was hand-harvested 2" above ground level and grain and total dry weight yields taken. A 6" soil core was then punched in the stubble of each row. Electrical conductivity was determined on each sample by the saturated paste method at the Saskatchewan Soil Testing Laboratory.

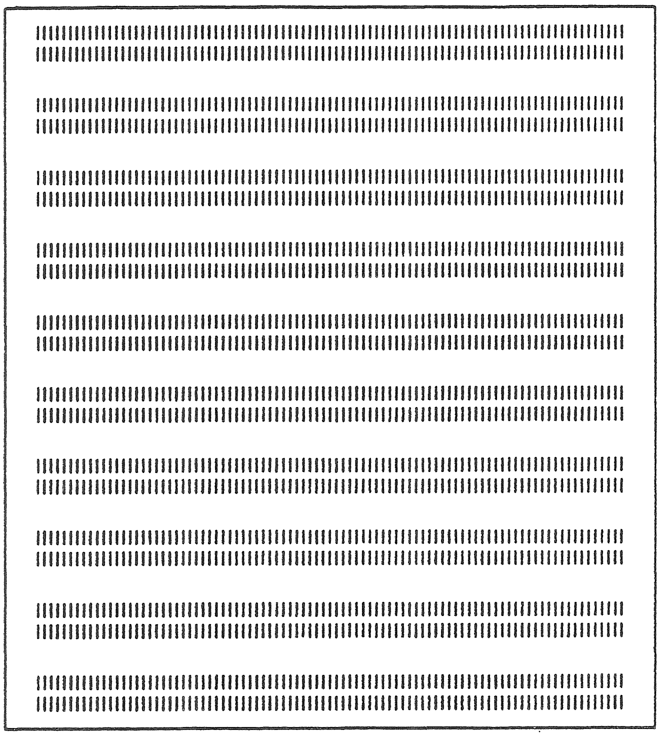
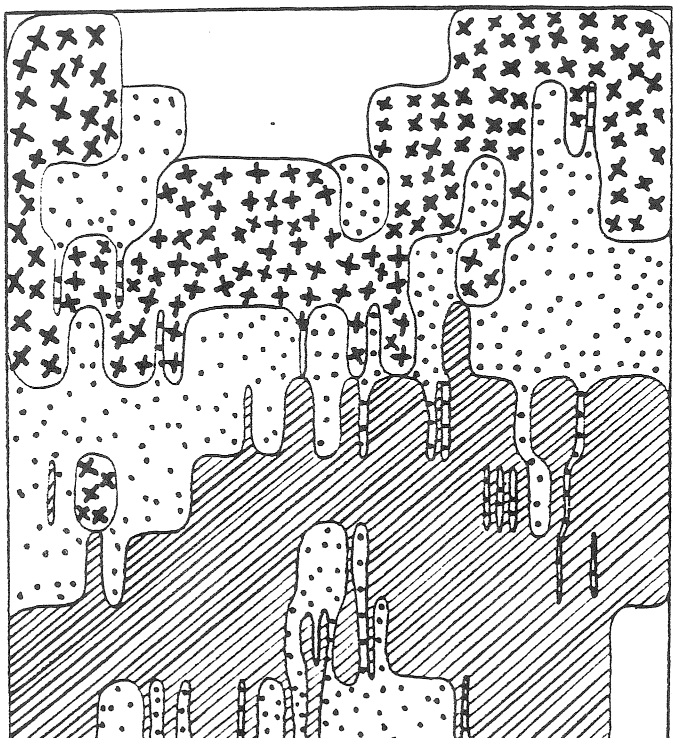


FIGURE 5. EXPERIMENTAL FIELD PLAN

| REPRESENTS ONE 5' ROW

FIGURE 6. SALINITY CONTOUR MAP



Measurements of grain yield and total dry weight of each genotype were taken over a wide range of conductivity values.

TABLE 1. RANGE OF CONDUCTIVITIES

GENOTYPE	MS/CM	MS/CM
ABEE	0.5	22.6
ARGYLE	0.8	19.8
ATLAS	0.9	23.9
BEACON	0.6	22.3
BETZES	3.9	25.0
BONANZA	0.5	22.0
CAL. MARIOUT	0.7	22.3
CI 11609	1.7	27.6
CI 3552	0.7	22.5
CI 7503	0.9	21.9
CONQUEST	2.0	22.0
DIAMOND	0.8	25.9
ELROSE	2.1	24.2
FAIRFIELD	0.8	23.7
HARRINGTON	0.7	22.5
HECTOR	1.6	25.1
JOHNSTON	2.3	21.7
KLAGES	0.9	23.7
KLONDIKE	0.6	21.8
MELVIN	0.5	21.9
STEPTOE	1.3	24.2
SUMMIT	0.9	23.8

In total there were 57 zero-grain yield values and 26 zero-total dry weight values which were eliminated before proceeding with regression analysis. These values tended to skew the regressions somewhat since for any one genotype there were from zero to six zero-yield values and from zero to three zero-dry weight values. Even without the zero values, observations were still taken from a wide range of conductivity due to the large number of replications.

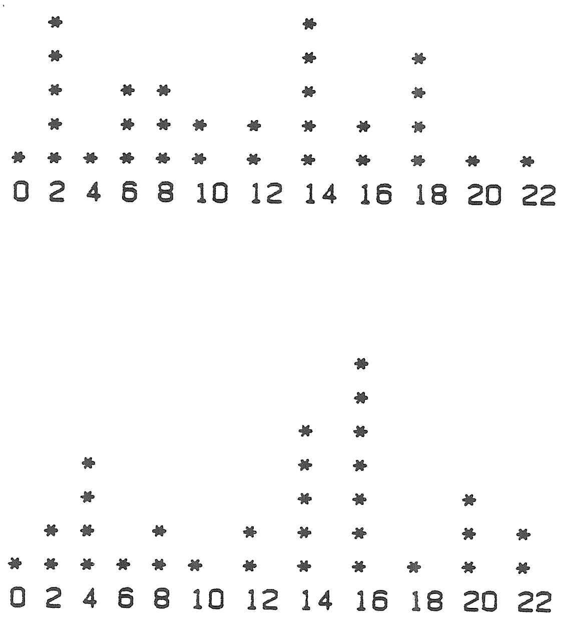


FIGURE 7. EC HISTOGRAMS FOR TWO GENOTYPES

Regression analyses indicated that grain yield and total dry weight of each genotype decreased linearly with increasing conductivity. In three

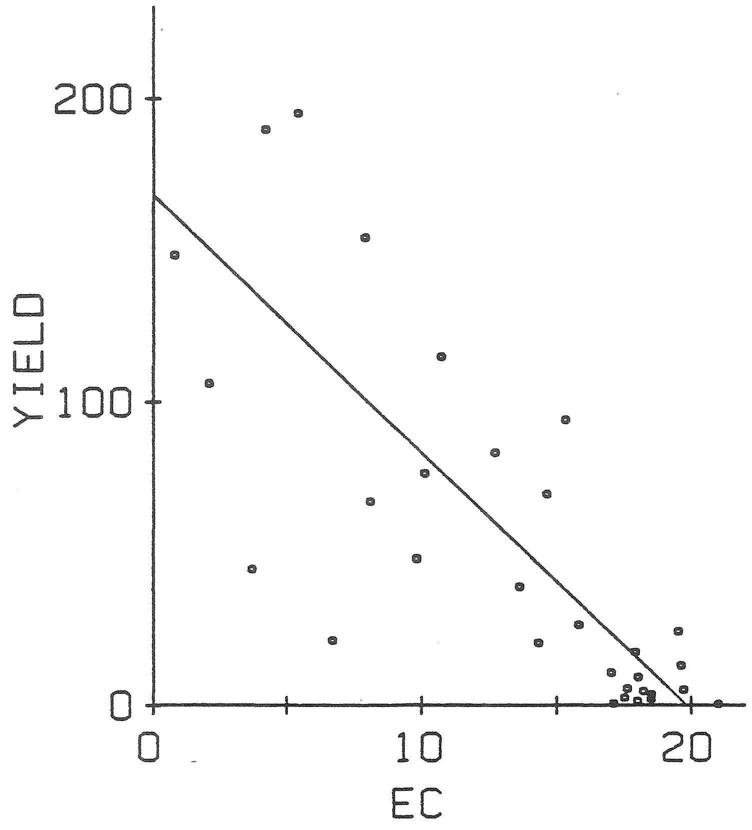


FIGURE 8. REGRESSION OF GRAIN YIELD ON ELECTRICAL CONDUCTIVITY (VARIETY 1)

cases a slightly better fit was obtained with a quadratic function. For simplification of subsequent analyses it was assumed that the response to increasing salinity was best described by a linear function.

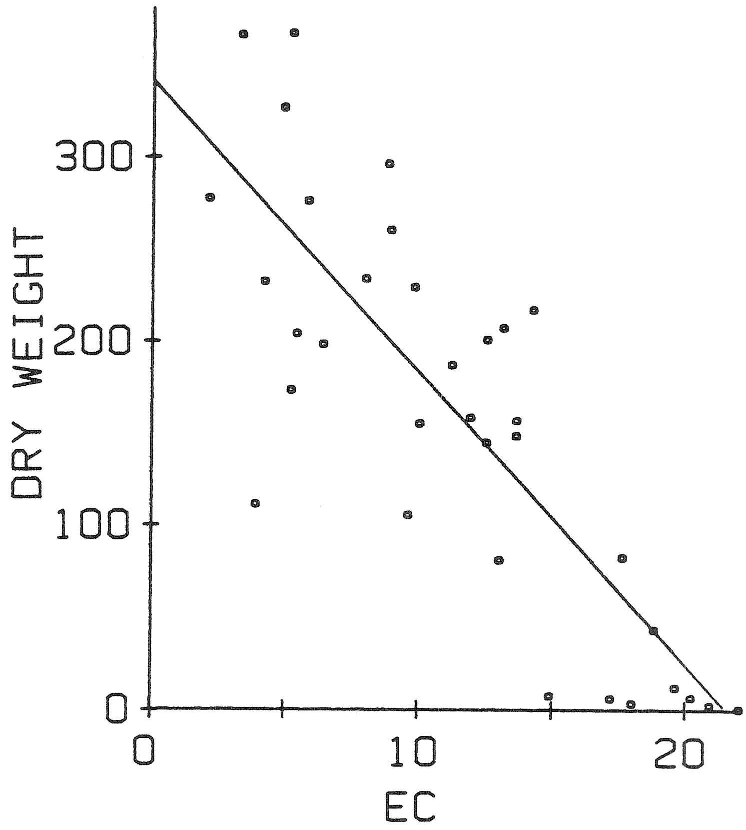


FIGURE 9. REGRESSION OF TOTAL DRY WEIGHT ON ELECTRICAL CONDUCTIVITY (VARIETY 2)

Use of a completely randomized design made it possible to test for homogeneity of the regression coefficients (the slopes) by a method outlined in Steel and Torrie (1980), p. 420-422. This F-test showed that the slopes of the regression lines differed significantly among genotypes. It was also noted that the y-intercepts and slopes of the regression lines were highly correlated (-.982 for grain yield and -.971 for total dry weight).

TABLE 2. CORRELATION BETWEEN Y-INTERCEPTS AND SLOPES FOR GRAIN YIELD

	Y-INTERCEPT	SLOPE
ABEE	209.61	-10.462
ARGYLE	213.75	-10.038
ATLAS	113.71	-5.940
BEACON	139.75	-6.323
BETZES	189.93	-9.724
BONANZA	195.87	-8.826
CAL. MARIOUT	93.28	-4.873
CI 11609	190.28	-9.845
CI 3552	104.70	-5.818
CI 7503	144.96	-7.499
CONQUEST	242.09	-11.942
DIAMOND	219.31	-10.375
ELROSE	169.03	-8.061
FAIRFIELD	168.04	-8.481
HARRINGTON	239.76	-11.334
HECTOR	193.09	-9.956
JOHNSTON	260.29	-12.879
KLAGES	188.83	-9.324
KLONDIKE	241.40	-12.261
MELVIN	216.60	-9.991
STEPTOE	200.85	-10.454
SUMMIT	221.73	-10.836

CORRELATION -.982

TABLE 3. CORRELATION BETWEEN Y-INTERCEPTS AND SLOPES FOR TOTAL DRY WEIGHT

	Y-INTERCEPT	SLOPE
ABEE	392.85	-18.850
ARGYLE	422.46	-19.172
ATLAS	227.85	-11.339
BEACON	265.49	-12.088
BETZES	350.32	-17.309
BONANZA	378.04	-15.780
CAL. MARIOUT	206.42	-10.663
CI 11609	348.56	-17.078
CI 3552	236.98	-12.369
CI 7503	308.42	-15.577
CONQUEST	446.32	-21.253
DIAMOND	393.71	-18.450
ELROSE	340.82	-15.830
FAIRFIELD	324.78	-15.899
HARRINGTON	456.13	-21.182
HECTOR	398.74	-20.375
JOHNSTON	494.29	-23.301
KLAGES	415.62	-20.131
KLONDIKE	442.68	-22.098
MELVIN	372.43	-16.281
STEPTOE	347.74	-17.571
SUMMIT	430.37	-20.321

CORRELATION -.971

The next step was to understand the meaning of the very high negative correlation between y-intercepts and slopes. Mathematically, a set of lines with a perfect correlation between y-intercepts and slopes intersect at a common point. To determine whether or not this set of regression lines intersected at a common point on the salinity scale, a procedure called linear calibration was used (Snedecor and Cochran 1967, p. 159-160). Instead of making a prediction of grain yield or total dry weight based on conductivity, this procedure did the reverse. The question asked was; when grain yield or total dry weight of these genotypes equalled zero, at what conductivity did this occur?

Linear calibration gave point estimates of conductivity where grain yield and total dry weight equalled zero, and confidence intervals for these point estimates. The point estimates fell within a very narrow range of conductivities, 18.0 to 22.2 mS/cm for grain yield and 19.2 to 23.9 mS/cm for total dry weight. The mean point estimate for grain yield was 20.2 mS/cm and 20.8 mS/cm for total dry weight. In all cases the confidence intervals overlapped.

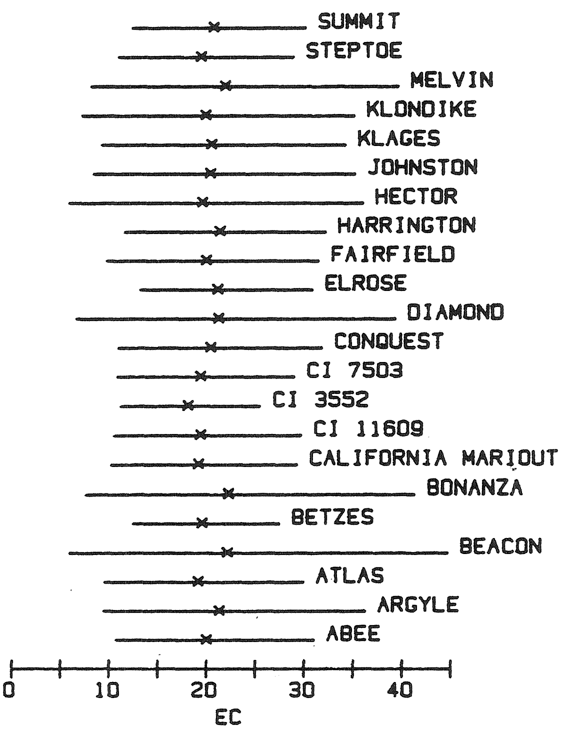


FIGURE 10. POINT ESTIMATES (X) OF CONDUCTIVITY AND CONFIDENCE INTERVALS (—) WHEN GRAIN YIELD = 0

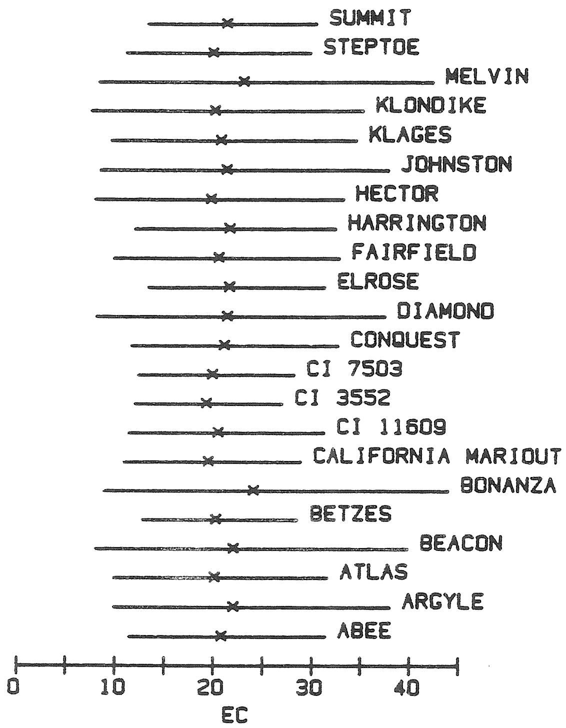


FIGURE 11. POINT ESTIMATES (X) OF CONDUCTIVITY AND CONFIDENCE INTERVALS (—) WHEN TOTAL DRY WEIGHT = 0

A picture of the responses of these barley genotypes started to emerge. In summary, grain yield and total dry weight of each genotype decreased linearly with increasing conductivity, the slopes of the regression lines differed significantly among genotypes and were highly correlated with estimated grain yield and total dry weight at zero conductivity. The estimates of conductivity at which grain yield or dry weight reached zero fell within a narrow range.

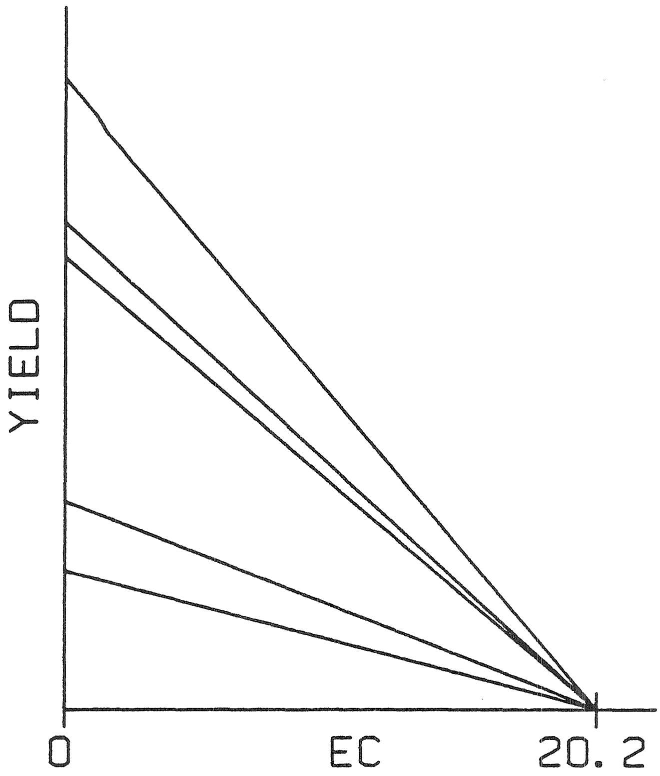


FIGURE 12. STYLIZED RESPONSE OF GRAIN YIELD TO INCREASING CONDUCTIVITY FOR FIVE BARLEY GENOTYPES

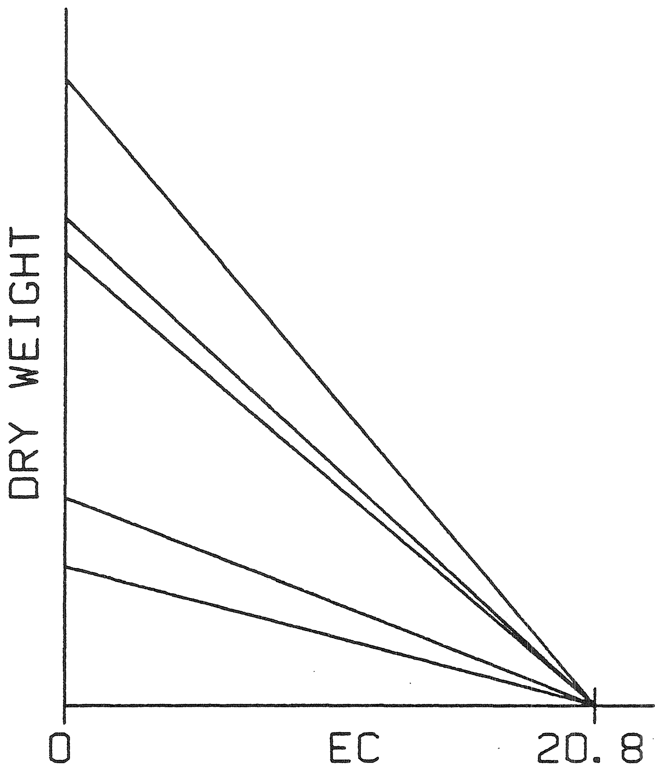


FIGURE 13. STYLIZED RESPONSE OF TOTAL DRY WT TO INCREASING CONDUCTIVITY FOR FIVE BARLEY GENOTYPES

The genotypes with steeper slopes yielded higher over the entire range of conductivity values. With respect to the first definition ABSOLUTE SALT TOLERANCE, the genotype with the steepest slope is the most 'salt tolerant'. However, labelling it 'salt tolerant' when its yield (grain and biomass) under increasing stress (described by the slope) is almost perfectly correlated with its yield in a non-saline environment (the y-intercept) is questionable.

To look at the responses to increased salinity on a relative basis, each regression equation was divided by its y-intercept. In each case, the y-intercept divided by the y-intercept equalled 1. For each genotype the slope divided by the y-intercept gave close numerical values for both grain yield and total dry weight.

TABLE 4, SLOPES/Y-INTERCEPTS FOR GRAIN YIELD AND TOTAL DRY WEIGHT

	YIELD	DRY WEIGHT
	SLOPE/Y-INT.	SLOPE/Y-INT.
ABEE	-.050	-.048
ARGYLE	-.047	-.045
ATLAS	-.052	-.050
BEACON	-.045	-.046
BETZES	-.051	-.049
BONANZA	-.045	-.042
CAL. MARIOUT	-.052	-.052
CI 11609	-.052	-.049
CI 3552	-.056	-.052
CI 7503	-.052	-.051
CONQUEST	-.049	-.048
DIAMOND	-.047	-.047
ELROSE	-.048	-.046
FAIRFIELD	-.050	-.049
HARRINGTON	-.047	-.046
HECTOR	-.052	-.051
JOHNSTON	-.049	-.047
KLAGES	-.049	-.048
KLONDIKE	-.051	-.050
MELVIN	-.046	-.044
STEPTOE	-.052	-.051
SUMMIT	-.049	-.047

Using the mean of the slope/y-intercept values the result is one equation for the regression of relative grain yield of barley on conductivity (Y'=1-.049x) and one equation for the regression of relative total dry weight of barley on conductivity (Y'=1-.048x).

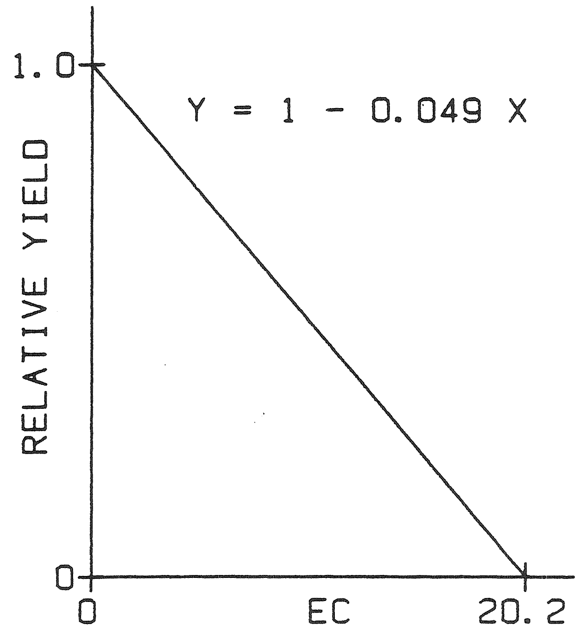


FIGURE 14. REGRESSION OF RELATIVE GRAIN YIELD OF BARLEY ON ELECTRICAL CONDUCTIVITY

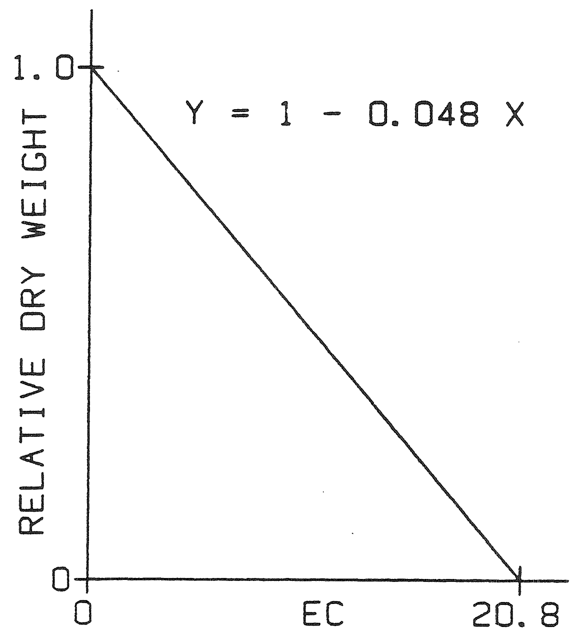


FIGURE 15. REGRESSION OF RELATIVE TOTAL DRY WT OF BARLEY ON ELECTRICAL CONDUCTIVITY

On a relative basis, genotypes with steep slopes responded the same as those with flat slopes. There is, therefore, no basis to say that genotypes with flatter slopes have better RELATIVE SALT TOLERANCE.

In conclusion, the response of these barley genotypes to increasing salinity was highly correlated with their original productivity under non-saline conditions. In relative terms, each genotype responded similarly while in absolute terms the highest yielders remained the highest yielders under increasing salt stress.

This interpretation of the data indicates that genetic variability for salt tolerance within the species of barley is very limited. This suggests that selection for salt tolerance is not likely to be successful.

In answer to the question 'which variety of barley is the most SALT TOLERANT', this data gives us some confidence in saying 'the one that yields the highest in a cropping area or on a particular farm will also be the most SALT TOLERANT under those conditions'.

References

Steel, R.G.D., and J.H. Torrie, Principles and Procedures of Statistics, McGraw-Hill, New York, 1980.

Snedecor, G.W., and W.G. Cochran, Statistical Methods, 6th ed., Iowa State University Press, Ames, Iowa, 1967.