Proceedings of the 5th International Triticale Symposium, Annex
June 30 – July 5, 2002, Radzików, Poland

Saline/Sodic sub-soil on triticale, durum wheat and bread wheat yield under irrigated conditions

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Abstract

Sub-soil (> 30 cm) salinity and sodicity is a growing problem particularly in irrigated agricultural areas with rising water tables, poor water quality and/or deficient soil drainage. There were two objectives in this study; (1) to quantify the effect of sub-soil salinity and sodicity in grain yield of triticale, bread wheat and durum wheat and, (2) to determine if genotypes within and between these three crops interact in a normal soil and one with a saline/sodic sub-soil under irrigated conditions. The soils at the CIMMYT experiment station in Cd. Obregon, Sonora, Mexico were mapped by kriging with GS+ geostatistical software for all chemical properties and soil texture. Using the soil maps, two contrasting areas of the station where identified. One with a saline/sodic sub-soil and the other with a normal soil (no limiting factors). A two year experiment was established with sixteen genotypes that included six bread wheats (1-6), five durum wheats (7-11) and five triticales (12-16) in the two soil types previously identified. The results showed a 10% yield reduction when all sixteen genotypes were averaged in the saline/sodic sub-soil location compared to the one with the normal soil. Average across genotypes all three crops seem to have the same level of tolerance to sub-soil salinity/sodicity. However, there was an interaction among genotypes for tolerance to sub-soil salinity/sodicity within each crop. Seven out of the sixteen (44%) genotypes evaluated were tolerant indicating a high frequency of tolerance to this soil problem in the CIMMYT germplasm. Breeders should be aware of the genotype x soil interaction present in bread wheat, durum wheat and triticale at the research station and insure that their trials are planted in soils that represent their breeding objectives.

Introduction

Soil salinity has been found to reduce wheat yields usually when values of electrical conductivity are above 6 decisiments per meter (dS/m) throughout the root zone. However, there is limited information about the effect of salinity on grain yield of bread wheat, durum and triticale, when present only in the sub-soil (> 30 cm deep). The effect of sodicity is not as well documented as salinity but it is suspected to have an effect on wheat yields, through a reduction in the drainage properties of the soil and a high pH. Soil sodicity is usually measured with one of two indices; one is the sodium absorption ratio (SAR) which give information on the comparative concentrations of Na^{+}, Ca^{2+}, and Mg^{2+} in soil solution and the second one is the exchangable sodium percentage (ESP), which measures the degree to which the exchange complex is saturated with sodium. The critical values for considering a soil sodic is 13 for SAR and 15 for ESP (Brady and Weil, 1996). However, in Australia that uses the same indices, lower critical values are used for the classification of sodic soils.

In a research station that has an emphasis in the selection and evaluation of germplasm, such as CIMMYT's, it is important to identify the areas of the station that cannot express the yield potential of the germplasm under evaluation. However, it is probably more important to establish if there are interactions between the germplasm evaluated and the soil types present in the station. If these interactions exist the breeder has to decide which soil or soils better represent his breeding objectives. Otherwise if he/she is doing selection and evaluation work without any knowledge of the soil limitations he/she may end up selecting for tolerance to a stress which may not be relevant in farmers fields. Worse however, would be if he/she neglects to select within the research station for a stress present in farmers' fields. Thus it is important to identify these interactions and select for the future the soil type that will better represent farmers conditions and breeders objectives. If these interactions are ignored the germplasm identified in the non-representative soil type could potentially be less relevant to the target farmers.

Our objective was to determine the effect of sub-soil salinity and sodicity on the yields of bread wheat, durum wheat and triticale and establish if there were interactions between soil type and crops/genotypes.

Materials and methods

Site

Research was conducted at the CIMMYT experiment station in Cd. Obregon, Sonora, Mexico during 1999-2000 and 2000-2001. A 100-ha section of the station was selected for the study. The field had been soil mapped (one composite soil sample every two hectares) at four depths 0-15, 15-30, 30-60 and 60-90 cm during 1999 (Ortiz-Monasterio, et al. 1999, unpublished). Maps were produced by kriging with GS+ geostatistical software (GDS, 2000). Two sites were chosen from the soil maps that represented contrasting levels of salinity and sodicity below 30 cm depth (Fig. 1).

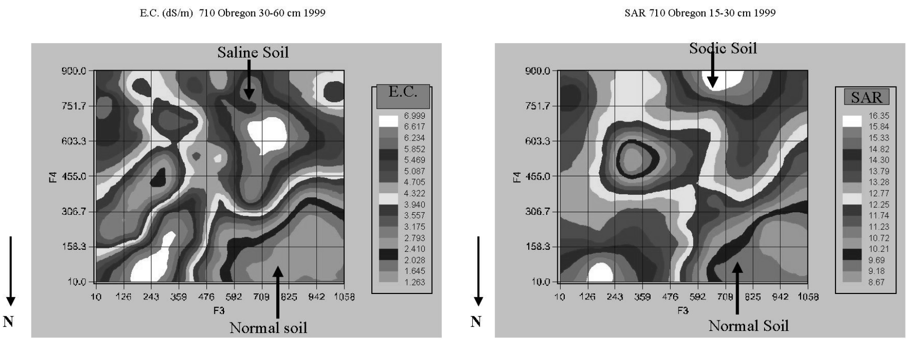

Fig. 1. Soil maps for salinity and sodicity below 30 cm of depth in 100-ha of CIMMYT's research station in Block 710 in Cd. Obregon, Sonora, Mexico. The arrows indicate the area without soil limitations (normal soil) and the areas with salinity and sodicity problems (saline and sodic soil)

The two experiments that were planted within a give year where managed exactly the same way with the objective of minimizing any management effects that could confound the soil (location) effect. Thus the two experiments that were planted the same year in the two contrasting soils had the same land preparation, planting date, seed density, fertilization, number and timing of irrigations, weed and disease control. All experiments were planted within the optimum planting date for the area. Plot size was four beds (80 cm apart) equivalent to 3.2 m wide and 5 m long. The harvest area was the central three meters of the central two beds equivalent to 4.8 m^2. The plots were harvested by hand and threshed in a Pullman thresher.

The experimental design used was a randomized complete block design (RCBD) over locations (the two soil types) and years with sixteen genotypes and four replications.

The genotypes included six bread wheats (1-6), five durum wheats (7-11) and five triticales (12-16).

1. Super Seri
2. Bacanora T88
3. Rayon F89
4. Pfau/Weaver
5. Kambara
6. Tarachi F01
7. Altar C84
8. Atil C00
9. SN Turk
10. Aconchi C89
11. Rafi C9
12. FAHAD_5
13. POLLMER_3/3/RONDO/BANT_5//ANOAS_2
14. POLLMER_2.1.1
15. 274/320//BGL/3/MUSX/LYNX/4/RHINO_9/5/ARDI_1/TOPO 1419
16. LIRA/BUL/4/2*T4466/3/K760/DP//X77-387-1/5/LIRON

Data Analysis

The analysis of the data was done using the statistical program SAS, applying the procedure PROC MIXED (SAS 1991). The variables; genotype, soil (location) and the interaction soil x genotype were consider as fixed effects in the model, while year, replications and all their interactions were considered random. If any of the variance components resulted in zero variance, this component was removed to have a more parsimonious model. The means and significance of the genotype and soil x genotype interaction was obtained with the LSMEANS / PDIFF procedure.

Results

The effect of the saline/sodic sub-soil was evaluated by calculating a salinity/sodicity tolerance index. This index was the relative yield of the plots under the saline/sodic soil divided by the yield of the plots in the normal soil (without soil limitations). The closer the value is to one the more tolerant is the genotype to salinity. This index represents then the grain yield achieved with respect to the non-limiting soil. Averaged over genotypes and years the site with salinity/sodicity problems in the sub-soil (> 30 cm) had a 10% yield reduction (7018 vs 6327 kg/ha) with respect to the site without limiting sub-soil factors (Table 1). Fig. 2 shows the different gentoypes evaluated using the salinity/sodicity tolerance index. The genotype that has one or more stars [significance at 0.05 (*), 0.01 (**) and 0.001 (***) respectively] on top of the bar indicates that it is susceptible to salinity. While the genotypes that have an NS (non-significant) represent the tolerant genotypes to salinity/sodicity, since the yield difference between the saline/sodic subsoil and the soil without sub-soil limiting factors were not statistically significant. That means that the bread wheat cultivars Rayon F89 and Tarachi F01 are tolerant to salinity/sodicity while the rest of the bread wheat genotypes were susceptible to salinity. In the durum wheat group Altar, Atil and SN Turk were tolerant and Aconchi and Rafi were susceptible. In the triticale group, Pollmer 2.1.1 and the cross with Pollmer were both tolerant to salinity and the rest were susceptible. The fact that some genotypes change their yield in both soil types (the susceptible ones), while others maintain their yield in both soil types (the tolerant ones) indicates that there is an interaction between genotypes in the two soil types evaluated.

When looking at the average of the genotypes within a crop, there is no difference between crops in terms of their average tolerance to a saline/sodic sub-soil. In contrast when we look within a crop we find in all three crops genotypes that are tolerant and susceptible.

Table 1. Grain yield of Bread Wheat, Durum Wheat and Triticale averaged over two years in two contrasting soil types (normal and saline/sodic sub-soil)

	Genotype	Normal Soil (kg/ha)	Saline/Sodic Soil (kg/ha)	Diff.(kg/ha)
1	Super Seri	6735	5553	1182 ***
2	Bacanora	6891	5868	1023 **
3	Rayon	6387	6108	279 ns
4	PFAU/WEAVER	6837	5928	908 **
5	Kambara	6910	6130	780 **
6	Tarachi	6456	5913	543 ns
	Bread Wheat (Average)	6703	5917	786
7	Altar	6909	6562	347 ns
8	Atil	7495	6898	597 ns
9	SN Turk	7197	6818	379 ns
10	Aconchi	7027	6238	789 **
11	Rafi	7328	6686	642 *
	Durum Wheat (Average)	7191	6641	551
12	FAHAD_5	7704	6464	1241 **
13	Pollmer_3/3/Rondo/Bant..	6749	6165	584 ns
14	Pollmer 2.1.1	7244	7081	163 ns
15	274/320//BGL/3/MUSX..	7357	6632	725 *
16	LIRA/BUL/4/2*T4466..	7069	6186	883 **
	Triticale (Average)	7225	6506	719
	Grand Mean	7018	6327	692 *

Significant at 0.05 (*), 0.01 (**), 0.001 (***) and not significant (ns)

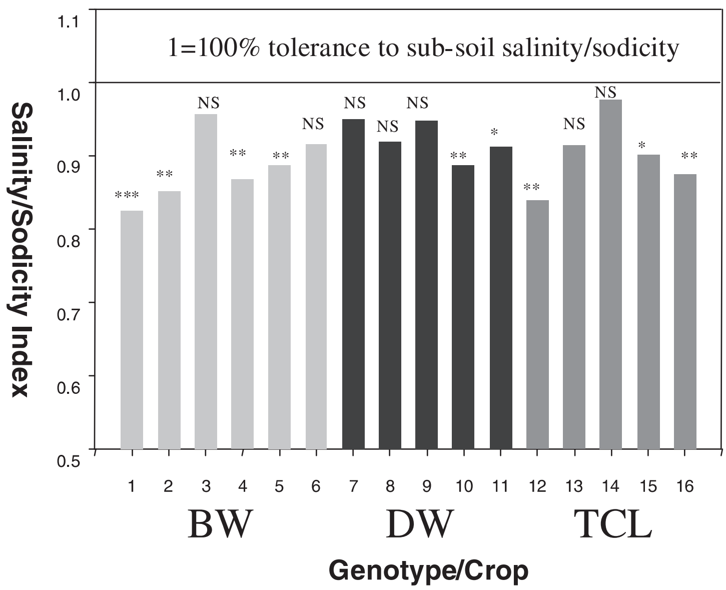

Fig. 2. Salinity/Sodicity tolerance index of sixteen genotypes of bread wheat, durum wheat and triticale. The genotypes with a number closer to one are more tolerant to sub-soil salinity/sodicity

Conclusions

The variation for sub-soil salinity/sodicity tolerance was larger within crops rather than between crops. Although a limited number of genotypes were used in this study to represent bread wheat durum wheat and triticale, based on this sample no one crop appeared to be more tolerant to sub-soil salinity/sodicity on the average. The only bread wheat genotypes that was tolerant to sub-soil salinity/sodicity besides Rayon F89 was Tarachi, which is a cross between the cultivar Seri and Rayon, suggesting that Rayon F89 may be a source of tolerance to sub-soil salinity in bread wheat. Similarly in triticale the only other genotype that was tolerant to sub-soil salinity/sodicity besides Pollmer 2.1.1 was a cross that included Pollmer, suggesting again that Pollmer may be a source of tolerance to sub-soil salinity/sodicity in triticale. In the case of durum wheat all the genotypes that had Altar C84 present in the cross were also tolerant. In addition the durum entry SN Turk was also tolerant to sub-soil salinity/sodicity although Altar C84 was not present in the cross.

Establishing yield trials in the saline/sodic sub-soils of the station will result in an average yield reduction of 10% with respect to the non-limiting soils of the station. Of more interest however, is the fact that there is a genotype by soil type interaction. Although these interactions are not of a cross over type, characterizing the interaction helps identify the genotypes that are more stable across soil types which could in turn be related to wide adaptation. Therefore, it is important that breeders are aware of the soil characteristics where they establish their trails to insure that they are doing so in areas that represent their breeding objectives.

References

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