Vol. 21 IDESIA (Chile) Julio - Diciembre 2003 N°2

Bread, durum and sinthetic hexaploid wheats in saline and non-saline soils.

Acevedo, E.[a]*, Silva, P.[a], Fraga, H.[b], Pargas, R.[b], Ortiz, M.[a] and Mujeeb-Kazi, A.[c]

Abstract

IDESIA (Chile) Vol. 21 N° 2, 2003

The genetic improvement of resistanse to salinity is becoming increasingly important as marginal soils are incorporated to agriculture. The work reported in this paper evaluated the intra and interspecific variability in yield responses to soil salinity of four Triticum groups: synthetic hexaploid wheat (T. turgidum x Aegilops tauschii), bread wheat (T. aestivum L.), durum wheat (T. turgidum L.) and bread wheat from a salinity resistance reference group. The yield potential of these genotypes was measured and the salinity resistance per se was calculated. The wheat material was grown in five environments (2 locations and 3 years) variably affected by soil salinity. The mean grain yield of the nursery ranged from 1821 to 5876 kg ha-1. The bread, durum and the salinity reference set groups of genotypes had significantly higher yield. The genotypes of the synthetic hexaploid group were late flowering, had high stature, low number of grains per ear and low harvest index, which resulted high yield stability but low grain yield. The best adapted genetic material was found in the bread wheat and the reference set groups. The salinity reference set had the highest grain and biomass yield in the lowest yielding environment. The synthetic and bread wheats groups did not have variability in biomass in this environment while the variability for both, biomass and grain yield was null in the durum wheat group. The soil salinity resistance was analyzed using a resistance index (Bidinger *et al.*, 1987a; 1987b). The bread wheats, including those in the soil salinity resistance group had the higher yield potential and soil salinity resistance.

Keywords: soil salinity, hexaploid and tetraploid wheats, synthetic hexaploids, grain yield.

Acevedo E.; P. Silva.; H. Fraga.; R. Pargas.; M. Ortiz & A. Mujeeb-Kazi. 2003 Trigos harineros, duros y sintéticos hexaploides en suelos salinos y no salinos. IDESIA (Chile) 21 (2): 75-88

Resumen

El mejoramiento genético de la resistencia a la salinidad se está incrementando en forma importante a medida que los suelos marginales son incorporados a la agricultura. En el presente trabajo se evaluó la variabilidd intra e interespecífica a las respuestas de producción a la salinidad del suelo de cuatro grupos de Triticum: trigo sintético hexaplide (T. turgidum x Aegilops (tauschii)), trigo (harinero) (aestivum L.), trigos duro (Durum T. turgidum L.) y trigo harinero de un grupo resistente a la salinidad. El potencial de rendimiento de esos genotipos fue medido y su resistencia a la salinidad. El material del trigo se desarrolló en cinco ambientes (2 localidades durante 3 años) afectados por salinidad variable del suelo. La principal cosecha de grano varió de 1.821 a 5.876 kilogramos ha-1. El trigo harinero, el duro y el grupo de genotipos resistentes a la salinidad tuvieron una producción significativamente más alta. Los genotipos de los grupos hexaploides sintéticos fueron de floración tardía, de mayor altura, bajo número de granos por espiga, bajo índice de cosecha, la que resultó en una alta estabilidad del rendimiento pero bajo rendimiento en grano. Los trigos harineros del grupo resistente a la salinidad presentó los granos más grandes y la producción de biomasa fue la más baja. El sintético y los grupos de los trigos harineros no tenían variabilidad en biomasa en este ambiente mientras que la variabilidad para la de ambos, de biomasa y producción en grano fue nula en el grupo de trigo Durum. La resistencia a la salinidad del suelo fue analizada usando un índice de resistencia (Bidinger *et al.*, 1987a; 1987b). Los trigos harineros, incluyendo aquellos del grupo de resistencia a la salinidad del suelo tuvieron el potencial de producción y la resistencia más alta a la salinidad del suelo.

Palabras claves: Salinidad de suelo, trigos, hexaploides y tetraploides, hexaploides sintéticos, producción del grano.

---

[a] Laboratorio de Relación Suelo-Agua-Planta. Facultad de Ciencias Agronómicas. Universidad de Chile. Casilla1004. Santiago, Chile.
[b] Universidad Autónoma de Baja California Sur. Apdo. Postal 19-B. La Paz B.C.S., México.
[c] CIMMYT, Lisboa 27, Col. Juárez, Apdo. Postal 6-641,06600, México D.F., México.
*Corresponding author. Tel.: 56-02-6785816; Fax: 56-02-6785858; e-mail: eacevedo@abello.dic.uchile.cl

INTRODUCTION

Soil salinity is an important agricultural problem in many areas, particulary in arid zones irrigated with low quality water. Winter cereals are affected by excess soil salinity, cell elongation is reduced leading to a decreased leaf area and ions accumulate in the leaf tissues with consequent toxic effects. Wheat usually shows early senescence and srivelled grains resulting from toxic salt effects (Wyn Jones and Gorham, 1991), there also abortion of distal spikelets leading to reduced grain yield (Grieve *et al.*,1992). The number of spike bearing tillers is also drastically reduced (Maas and Grieve, 1990; Maass *et al.*, 1994).

Grain yield of bread wheat (hexaploid) is reduced to 50% of its potential when the electrical conductivity of the soil saturation extract (Ece) reaches 13 dS m^{-1} (Ayers and Westcot, 1985). The soil salinity threshold at wich bread wheat (hexaploid) starts decreasing grain yield is highers (8,6 dS m^{-1}) than in the tetraploid durum wheat (5,9 dS m^{-1}). Bread wheat has a higher resistance to salinity (Maas, 1986). Furthermore, durum wheat decreases its grain yield at a higher rate than bread wheat with increasing soil salinity.

Genetic improvement has not been highly succesful in improving grain yield under salinity stress. One reason may be that the genetic variability for this trait in the genetic pool being used by breeders is low (Wyn Jones and Gorham,1991) or it may be that not enough attention is being given to the salinity resistance *per se* in wheat improvement programs.

Direct selection for grain yield under stress does not guarantee the stress resistance of the genotypes in as much as the yield under stress depends on the yield potential, phenology and the stress resistance *per se* of the genotype (Acevedo *et al.*,1998).

The stress resistance per se of genotype is seldom evaluated. Usually yield under stress is reported where yield potential, crop phenology and stress resistance are confounded (Acevedo, 1991). To avoid these confounding effects, Bidinger *et al.* (1987a, 1987b) proposed a stress response index which allows the estimation of the salinity resistance *per se* of the genotype.

Aegilops tauschii (syn. *Aegilops squarrosa* auct. non L.), diploid, is a wild relative of wheat, donor of the D genome (Mac-Fadden and Sears, 1946). *Ae tauschii* grows wild in Asia (Appels and Lagudah, 1990) existing a high diversity in natural populations of the species. This diversity has not been introgressed into modern bread wheat and by so doing it may increase the wheat resistance to environmental stresses. The genome of *Ae. tauschii* is homologous to the D genome of modern hexaploid wheat and genetically normal recombinants are obtained when the species is crossed to bread wheat directly or when its synthetic hexaploid (*Triticum turgidum* x *Ae. tauschii*) is utilized (Mujeeb-Kazi *et al.*, 1996).

Several authors agree that genes located in the D genome confer salinity tolerance to hexaploid wheat by reducing Na^+ accumulation in the leaf tissue (Shah *et al.*, 1987, Gorham *et al.*, 1987) and increasing discrimination in favor of K^+ (Schachtman *et al.*, 1991).

With a different perspective, it has been suggested that selection for high yield potential could be the best strategy to increase wheat yield under soil salinity stress owing to the heterogeneity of salt distribution in the soil. Wheat would grow and yield best in the soil zones with lower soil salinity. Higer grain yield can be obtained in these zones with genotypes having an higher yield potential (Richard *et al.*,1987).

In this work we evaluate the intra and inter-specific variability in response to soil salinity of four *Triticum* groups: synthetic hexaploids (*T. turgidum* x *Ae. tauschii*), bread wheat (*T. aestivum* L.), durum wheat (*T. turgidum* L.) and a spring bread wheat group reputed to have high yield under salinity stress. We measured the yield potential, the yield under salinity stress and evaluated the salinity resistance of the genotypes in each group.

2. MATERIALS AND METHODS

2.1 Field experiments

A nursery of forty wheat genotypes (Table 1), each one classed into one of four groups, was assembled: nine entries of synthetics hexaploids plus Altar, the durum wheat used in the crossed with Ae. tauschii conformed the synthetic group; ten entries of bread wheat, eleven entries of durum wheat and ten entries of the salinity reference set conformed the other groups. All the entries were suggested by CIMMYT wheat breeders for this experiment. The various groups will be referred to as synthetics, bread wheats, durum wheat and reference set.

The nursery was planted at two locations: a) La Paz, Baja California Sur, México (24°09'N,110°20' W, 16 m.a.s.1), having a loamy sand soil (ECe=3.5 dS m^{-1}, pH=8.0) irrigated with a high salinity water (Ecw≅ 3.0 dS m^{-1}, pH≅ 7.5), and b) Obregon, Sonora, México (27°48'N,109°92'W, 38 m.a.s.1.) with a clay loam soil (ECe= 0.7 dS m^{-1}, pH=8.0) and good quality irrigation water (ECe= 0.3 dS m^{-1}, pH=8.3). The genotypes were planted in five row plots (0.2 m between rows) 3.5 m in length (3.5 m^2 $plot^{-1}$) using an RCB field design with 4 replicates in La Paz and 3 replicates in Obregon. The tree central rows 2.5 m in length (1.5 m^2) were harvested for yield and yield components.

2.2 Field observations

The following orbservations were made: plant height (to the tip of the ear, awns included); emergence date; anthesis (yellow anthers, DC 70, Zadoks *et al.*, 1974); physiological maturity, taken as the moment of complete yellowing of the spike (Hanft and Hych, 1982); biomass, grain yield, grain weigh. The harvest index, the number of spikes m^{-2}, grains per unit area were calculated. The Na^+ and K^+ concentration of the flag leaf was measured in samples taken at anthesis at La Paz in the 92/93 season. The analysis was done in the Soils and Plant Nutrition Laboratory at El Batan, CIMMYT, México.

2.3 Statistical analyses

The results were analysed using either a single or combined ANOVA and groups were compared using contrasts (Scheffe method). Stability analysis were done by regressing genotypic yield on an environmental index for grain yield (Finlay and Wilkinson, 1963; Eberhart and Rusell, 1966).

The stress resistance index (DRI) was calculated as a residual by expressing yield under stress (Ys) as a function of yield potential (Yp), flowering date (FL) and correcting for experimental error (e) (Bidinger *et al.*, 1987a; 1987b), such that,

$$Ys = a + b\,Yp + cFL + DRI + e \quad (1)$$

The lower yielding environment (La Paz, 92/93) was used as Ys. Yield potential and days to flowering were obtained from Obregon 93/94 where the highest yield was obtained. The DRI is defined as the difference between actual Ys and the estimated Y^s using equation 1 expressed in units of standard error of Y^s units, Then:

i) If $\frac{|Ys - Y\hat{}s|}{\sigma} \leq 1$, DRI = 0

ii) If $\frac{|Ys - Y\hat{}s|}{\sigma} > 1$, DRI = $\frac{|Ys - Y\hat{}s|}{\sigma}$

When DRI = 0, the yield under stress was well estimated by the yield potential and flowering date. A value of DRI greater than 1.0 indicates that the genotype is either resistant (positive) or susceptible (negative) to the stress.

All the statistical analysis were done using the MSTATC-C software (Michigan State University, 1988).

3. RESULTS AND DISCUSSION.

3.1 Environmental characteristics.

The electrical conductivity of the soil saturation extract at La Paz varied between 1.8 and 3.8 dS m^{-1} (Table 2). The salinity problem in La Paz was induced by the irrigation water which had ECw values between 2.6 and 3.5 dS m^{-1}.

The environmental index used in this paper is the nursery mean yield in each environment (Table 3) which varied from 1,805 kg ha^{-1} (La Paz, 92/93) to 5,787 kg ha^{-1} (Obregon, 93/94).

The values of the soil saturation extract at La Paz are below the soil salinity threshold causing grain yield reduction in wheat (5.9 dS m^{-1} for durum wheat and 8.6 dS m^{-1} for bread wheat) (Maas, 1986). Even during the most sensitive growing stage to salinity (germination and seedling stages) the wheat crop can tolerate 4 to 5 dS m^{-1} (Ayers and Westcot, 1985; Richards, 1983).

The irrigation water doubles its concentration at field capacity, and it doubles again as the soil water content decreases towards permanent wilting point (Hanson *et al.*, 1993). On the average, the effective EC of soil water is approximately three times higher than that of free water. Severe salinity problems are reported with an ECw of 3 dS m^{-1} (Ayers and Westcot, 1985). Therefore, the genotypes planted at La Paz experienced salinity problems while when planted in Obregon they did not experience salinity.

3.2 Analysis among groups.

The stability analysis indicated that the synthetics were the lower yielding group across environments. This group had the highest yield stability and lowest potential yield (Fig.1). The salinity reference set of genotypes had the highest yield stability among the improved entries and the durum wheat group had the lowest yield stability. Durum wheats had the highest yield potential but they decreased their grain yield faster when the quality of the environment decreased (Fig. 1). They had the highest sensitivity to the salinity stress, in agreement with results reported by Mass (1986).

The biomass production was similar among groups in the favorable environment (Table 4). The durum wheat group had the lowest biomass production in the stressed environments and the reference set the highest (Table 6).

3.3 Highest yielding environment

The genetically improved entries (bread wheat, durum wheat and reference set) had the highest grain yield in the most favourable environment. The three groups had similar grain yield in this environment as well as similar yield components and harvest index (Table 4). There were no differences in biomass production among groups in this environment.

The within group analysis indicated that in the high yielding environment there was no variability for biomass or grain yield within durum wheats and within the sintetycs.

The genotypes with the highest yield in the most favourable environment were 38 (Q 19 which is an Australian wheat with high yield potential), 21 (bread wheat), 36 (Sakha 8, bread wheat from the reference set), 1 (Altar, durum wheat) and 14 (bread wheat) (Table 5).

The syntetic group had the lowest grain yield, being about half when compared to the other groups. This was due to a lower number of grains per spike and a higher stature which led to a lower harvest index. The synthetics were late in flowering and maturing, with a low grain production rate, possessing all the traits of genotypes which have not been submitted to genetic improvement (Evans and Dunstone, 1970).

Rees *et al.*, (1994) had found high genetic variability in biomass within a different population of syntetic. The bread wheats, either from the bread wheat group or the reference set, had genetic variability for these traits.

3.4 Lowest yielding environment

The synthetic group had the lowest grain yield in the lowest yielding environment. The highest grain yield in this environment was obtained by the bread wheat and the reference set groups. The reference set group had the highest biomass yield; the lowest biomass yielding group being the durum wheat (Table 6). There was no within group variability for biomas or grain yield in the durum wheat group under salinity stress. There was within group grain yield variability for all the other three groups but the salinity reference set was the only one to have within group variability for biomass under the high stress conditions.

The low yield of synthetic group was also related to a low number of spikes per unit area, low number of spikes of grain per spike and a low harvest index.

The five genotypes attaining the highest grain yield in this lowest yielding environment were:21 (bread wheat, 2,810 kg ha^{-1}); 36 (Sakha 8, bread wheat from the reference set, 2,613 kg ha^{-1}), 33 (Kharchia, bread wheat from the reference set, 2,560 kg ha^{-1}), 15 (Kauz, bread wheat, 2,593 kg ha^{-1}) and 37 (Shorawaki, bread wheat, 2,450 kg ha^{-1}).

Genotypes 15, 21 and 36 attaining the highest grain yield in this lowest yielding environment, also had high yield potential (Table 5) but not all high yield potential genotypes had high yield under salinity stress as suggested by Richards *et al.*,(1987). Indeed, genotypes 33 and 37 did not have high yield potential but were among the higher yielding under salinity stress.

3.5 Effect of flowering date on yield under salinity stress.

Grain yield was negatively correlated to days to anthesis in the La Paz 92/93 environment ($r= -0.687, P\leq 0.001$) when the 40 genotypes of the nursery were considered. There was no correlation of grain yield with flowering date within the bread wheat and reference set groups which had the highest yielding genotypes in the highly stressed environment. The bread wheat entries were mid flowering, they flower either a bit earlier than the mean anthesis date (15, 21, 33) or a bit late (36, 37) when compared to the 40 genotypes of the nursery.

3.6 Resistance to salinity

Grain yield was highly and positively correlated ($r= 0.769, P\leq 0.001$) to DRI across the 40 *Triticum* genotypes at the poorest yielding environment (Table 7). The following genotypes were found to have a DRI above 1.0, i.e. to be resistant to salinity: 15 (Kauz, bread wheat),21 (bread wheat), 32 (Candeal, bread wheat of the reference set), 33 (Kharchia, bread wheat of the reference set), 36 (Sakha 8, bread wheat of the reference set), 37 (Shorawaki, bread wheat of the reference set). No genotype from the synthetic and/or the durum wheat group was found resistant to salinity.

The DRI (Bidinger *et al.*, 1987b allowed an estimation of the salinity resistance *per se* of each genotype. The DRI value is independent of yield potential and escape (measured as days to flowering). The genotypes having high yield under salinity stress were all improved bread wheats. Entry 32 was resistant to salinity according to DRI but whith low yield potential (2,803 kg ha-1) and its yield under salinity stress was also low. A genotype to be high yielding under salinity stress appears to require a moderate to high yield potential besides a high DRI. This is the case for genotypes 36, 37, 15, 21 and 33.

The high correlation between DRI and yield under salinity stress indicates that salinity resistance has a strong influence in the yield under stress. On the average, DRI explained about 60% of the yield under stress, the rest being explained by yield potential and days to anthesis. Different genotypes, however, may have different combinations of these three factors contributing to yield under stress.

3.7. Sodium concentration in flag leaves

Table 8 shows the concentration of Na^+, K^+ and K^+/Na^+ ratio for the four groups of entries. The three groups having the D genome did not show significant differences in the leaf concentration of Na^+, K^+, or in the K^+/Na^+ ratio. There was within group variability for Na^+ concentration in the synthetic group but not in the bread wheat and reference set group. There was also genetic variability within the durum group for Na^+ concentration in the flag leaf. Variability within groups was also found for K^+ concentration in the synthetics, bread wheat and reference set groups, and in K^+/Na^+ in the synthetics, durum wheat and reference set.

The data confirm previous results (Shah *et al.*, 1987) with a high Na^+ concentration in durum wheat which does not have D genome. On the contrary they show a higher K+/Na^+ discrimination in the hexaploid wheats.

The sodium concentration of the flag leaf was negatively correlated to above ground biomass ($r= -0.601$, $n= 40$, $P\leq 0.001$) in the 92/93 environment of La Paz while the K^+/Na^+ was positively correlated to biomass yield ($r= 0.42$, $n= 40$, $P\leq 0.007$). The DRI was negatively correlated to Na^+ concentration in the flag leaf ($r= -0.467$, $n= 40$, $P\leq 0.002$).

The lowest Na_+ concentration of the flag leaf is an important mechanism of salinity resistance, explained about 22% of the salinity resistance in wheat.

5. CONCLUSION

The synthetic group of genotypes had the characteristics of non improved wheat material, low grain yield, low number of grains per spike, high stature, low harvest index and low grain production rate. They had low grain yield and high stability. Furthermore, they had low genetic variability in the parameters studied. They had, however, a high K^+/Na^+ ratio, equal to the other hexaploid wheaths.

The improved genotypes had higher grain yield with the reference set being most stable. The hexaploids had the higher grain yield under stress and the higher salinity resistance.

A high yield potential appears to be a important trait to achieve high yield under salinity stress, but alone it does not imply high yield under such conditions. Salinity resistance measured with the DRI index is correlated to grain yield under stress which in turn is negatively correlated to Na^+ concentration in the flag leaf at anthesis.

Table 1
Genotypes used in this study.

N°	Group	Origen of the seed	Name	Cross/Pedigree
1	III	W-4 BV-91	Altar	
2	II	BV-91	Opata	
3	III	BV-91	Aconchi	
4	IV	BV-91	Oasis	
5	I	W-13 BV-91		CHEN"S"/Ae. tauschii (168*) CIGM 87.2755-IB-OPR-OB
6	I	W-14 BV-91		CNDO/R143//ENTE"S"/MEXI"S"/3 Ae. tauschii (221*) CIGM86.953-IM-M-OB-OPR-OB
7	I	W-40 BV-91		PBW114/ Ae. tauscchii OB-OPR-OB
8	I	W-73 BV-91		68111/RGB//WARD RESEL/3/STIL"S"/4/ Ae. tauschii (164*) CIGM88.1161-OB
9	I	W-75 BV-91		DOY 1/ Ae. tauschii (188*) CIGM88.1175-OB

N°	Group	Origen of the seed	Name	Cross/Pedigree
10	I	W-80 BV-91		CPT/GEDIZ"S"/3/GOD"S"//JO"S"/CR"S"/4/ Ae. tauschii (196*) CIGM88.1186-OB
11	I	W-82 BV-91		CPT/GEDI"Z"/3/GOO"S"//JO"S"/CR"S"/4/ Ae. tauschii (205*) CIGM88.1192-OB
12	I	W-84 BV-91		CPT/GEDIZ"S"/3/GOO"S"//JO"S"/CR"S"/4/ Ae. tauschii (208*) CIGM88.1194-OB
13	I	W-124 BV-91		DOYI/ Ae. tauschii (488*) CIGM88.1353-OB
14	II	S-2 MV-91		BUC/FL K^+//MYNA/VUL CH 91575-28Y-OM-OY-1M-OY
15	II	S-6 MV-91	Kauz	
16	II	S-9 MV-91	Tui	
17	II	S-13 MV-91		SPB/BOW//SPB CM96547-AG-OY-OM-OY-6M-ORES
18	II	S-15 MV-91		CO79"2"/PRL//CHIL CM92354-61Y-OM-OY-1M-ORES
19	II	S-18 MV-91		F12.71/COC//BAU/3/BAU CM96251-Y-OY-OM-OY-4M-ORES
20	II	S-20 MV-91		CNO79/PRL//CIL"S" CM92313-25M-OY-OM-3Y-OB
21	II	S-23 MV-91		SERI"3"//BUC"S" CRG-68-H-6Y-3B-OY
22	II	S-35 MV-91		BUC/BJY//PRL CM95521-BY-OH-OSY-3M-ORES
23	III	EPC 393		CHEN/RBC11HUI/TUB CD68653-A-9Y-4B-2Y-IB-OY-OAB-OREC
24	III	EPC 304		TCHO"S"/MORUS//SILVER CD80739-A-IM-OYRC-OM-7REC-OPA
25	III	EPC 188		MEH"S"/PEN//STINT"S" CD74548-A-2Y-020H-OAP-OTR-1M-OREL
26	III	EPC 288		SRN/GOTE"S" CD74059-2Y-020H-IY-IM-2YRC-2B-OREC
27	III	EPC 222		QFN/RILL"S" CD69426-10B-4Y-2B-5YRC-2B-OREC
28	III	EPC 105		CHEN"S"/RISSA"S"/4/FUJA"S"/CIT71/CIT71/CII/3/SHWA"S" CD83227-B-2M-OYRC-OM-15REC-OPA
29	III	EPC 229		EUPODA CD75150-A-IY-BM-IY-IM-4YRC-2M-OREC

N°	Group	Origen of the seed	Name	Cross/Pedigree
30	III	EPC367		ALTAR 84//BOY"S"/YAV"S" CD 72562-Q-2Y-OM-OYREC-3M-OREC
31	III	EPC 355		ALLA"S"/SRN3/CHEN"S"//CIT71/CII CD 83671-F-1M-OYRC-OM-9REC-OPM
32	IV		Candeal	
33	IV		Kharchia 65	
34	IV		KRL 1-4	
35	IV		Lu 26-S	
36	IV		Sakha 8	
37	IV		Shorawaki	
38	IV		Q19	
39	IV		SNH9	
40	IV		WH-157	

I = Synthetic
II = Bread wheat
III = Durum wheat
IV = Reference set

* Ae. taushii accession number in wide cross programs working collection

Table 2
Soil and water parameters at La Paz.

Year	Month	Soil pH	Soil EC(dS m^{-1})	Water pH	Water EC (dS m^{-1})
1991	December	8.0	3.8		
1992	February	8.3	2,3	7.3	3.2
	March	7.8	1.8	7.5	3.0
	April	7.4	1.9	7.2	3.5
	December			8.1	3.2
1993	January			7.9	3.2
	February			8.0	2.6
	March			7.3	2.8
	April			8.2	2.9

Table 3
Environmental index at the various year x locations combinations.

Environment	Location	Year	Yield (kg ha^{-1})
1	La Paz	91 / 92	2,493.4
2	La Paz	92 / 93	1,805.1
3	La Paz	93 / 94	4,769.5
4	Obregón	92 / 93	4,402.5
5	Obregón	93/ 94	5,787.6

Table 4
Mean yield and yield parameters for various groups of genotypes at the highest yielding environment (Obregón 93/94).

Parameter	Synthetic n=9	Bread wheat n=10	Durum wheat n=11	Reference set n=10
Biomass (kg ha^{-1})	13,886.7 a	16,216.8 a	16,587.2 a	15200,7 a
Yield (kg ha^{-1})	3,353.5 b	6,801.6 a	6,914.5 a	6080,8 a
Yield index	0.25 b	0.43 a	0.42 a	0,4 ab
Spikes m^{-2}	255.2 a	323.4 a	290.6 a	352,7 a
DW 1000 grains (g)	37.8 a	40.0 a	39.0 a	41,4 a
Grains $spike^{-1}$	36.9 b	54.6 ab	62.7 a	44,6 ab
GPR (g ha^{-1} day^{-1})	81.3	140.0	138.9	128,1
Height (cm)	127.4 a	90.9 b	94.6 b	93,8 b

($P \leq 0.05$)

Table 5
Genotypes with higher yield in highest yielding environment (Obregón 93/94).

Genotype	Group	Yield (kg ha^{-1})
38	Reference	9,292
21	Bread	7,840
36	Reference	7,827
1	Durum	7,807
14	Bread	7,711

Table 6
Yield and yield parameters for various groups of genotypes at the lowest yielding environment (La Paz 92/93).

Parameter	Synthetic n=9	Bread wheat n=10	Durum wheat n=11	Reference set n=10
Biomass (kg ha^{-1})	5,429.9 ab	6,532.9ab	4,765.0 b	6,750.1 a
Yield (kg ha^{-1})	1,063.3 b	2,237.5a	1,734.9 ab	2,184.7 a
Yield index	0.19 b	0.34a	0.37 a	0.33 a
Spikes m^{-2}	184.9 b	199.1ab	145.6 b	249.6 a
DW 1000 grains (g)	42.8 a	37.8b	43.2 a	35.6 c
Grains $spikes^{-1}$	14.0 b	30.7a	28.7 a	26.4 a
GPR (g ha^{-1} day^{-1})	32.9	69.8	54.6	66.8
Height (cm)	71.6 a	62.9b	65.3 ab	69.4 ab

(P= 0.05)

Table 7
Correlation of DRI with yield and yield components.

DRI versus	La Paz 92/93	Obregón 93/94
Yield (kg ha^{-1})	0.769 ***	0.000
Spikes m^{-2}	0.545 ***	0.155
DW 1000 grains	- 0.397 *	0.010
Grains $spikes^{-1}$	0.467 **	-0.036

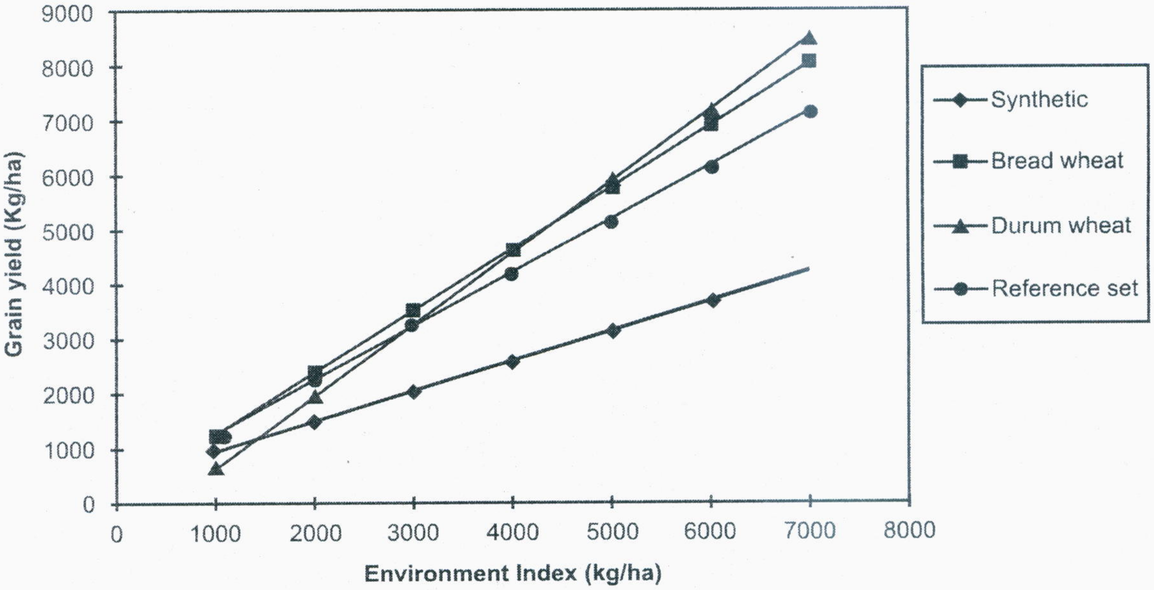
* = $P \leq 0.05$
** = $P \leq 0.01$
*** = $P \leq 0.001$

Table 8
K+ and Na+ concentration in the flag leaf at anthesis of the various Triticum groups (La Paz 92/93).

Parameters	Synthetic n=9	Bread wheat n=10	Durum wheat n=11	Reference set n=10
K^+	28,497.8 a	20,860.0 b	18,534.8 b	22,235.0 b
Na^+	999.0 b	482.0 b	5,803.7a	436.0 b
K^+/ Na^+	67.7 a	43.2 a	3.8 b	74.3 a

($P \leq 0.05$)

Figura 1
Yield stability of Triticum groups



REFERENCES

ACEVEDO, E. 1991. Morphophysiological traits of adaptation of cereals to Mediterranean environments. *In* Acevedo, E., E. Fereres, C. Giménez and J. Srivastava (ed.), Improvement and management of winter cereals under temperature, drought and salinity stresses. Proceeding of the International Symposium October, 1987, Cordova, Spain. Proceedings of the ICARDA-INIA Symposium, Córdova, Spain, pp. 85-96.

ACEVEDO, E., H. SILVA Y P. SILVA. 1998. Tendencias actuales de la Investigación en la resistencia al estrés hídrico de las plantas cultivadas. Bol. Téc. Fac. Cs. Agrarias y Forestales, Universidad de Chile 49:1-28.

APPELS, R. AND E. LAGUDAH. 1990. Manipulation of chromosomal segments from wild wheat for the improvement of bread wheat. Aust. J. Plant Physiol . 17: 253-266.

AYERS, R.S. AND D. W. WESTCOT. 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper N°29.27 p. Food and Agriculture Organization of the United Nations. Roma, Italy.

BIDINGER, F. R., V. MAHALAKSHMI AND G.D. RAO.1987a Assessment of drought resistance in Pearl Millet (*Pennisetum americanum* (L.) Leeke). I Factors affecting yield under stress. Aust. J. Agric. Res.38:37-48.

BIDINGER, F. R., V. MAHALAKSHMI AND G.D. RAO. 1987b Assessment of drought resistance in Pearl Millet (*Pennisetum americanum* (L.) Leeke). II Estimation of genotype response to stress. Aust. J. Agric. Res. 38:49-59.

EBERHART, S. AND W. RUSELL. 1966. Stability parameters for comparing varieties. Crop Sci . 6:36-40.

EVANS, L. AND R. DUNSTONE. 1970. Some physiological aspects of evolution in wheat. Aust. J. Biol. Sci. 23:725-741.

FINLAY, K. W. AND G. N. WILKINSON. 1963. The analysis of adaptation in a plant-breeding programme. Aust. J. Agric. Res. 14:742-754.

GORHAM, J., C. HARDY, R. WYN JONES, L. JOPPA AND C. LAW. 1987. Chromosomal location of a K+/Na+ discrimination character in the D genome of wheat. Theor. Appl. Genet. 74:584-588.

GRIEVE, C., S. LESCH, L. FRANCOIS AND E. MASS. 1992. Analysis of main spike yield components in salt-stressed wheat. Crop Sci. 32:697-703.

HANFT, J. M. AND R.D. WYCH. 1982. Visual indicators of physiological maturity of hard red spring wheat. Crop Sci. 22: 584-587.

HANSON, B., S.R. GRATTAN and A. FULTON. 1993. Agricultural salinity and drainage: A Handbook for water managers. 141p. University of California Irrigation Program. University of California. Davis, USA

MAAS, E. 1986. Salt tolerance of plants. Appl. Agric. Res. 1 (1):12-26.

MAAS, E. And C. GRIEVE. 1990. spike and leaf developement in salt stressed wheat. Crop Sci. 30:1309-1313.

MAAS, E., S. LESCH, L. FRANCOIS and C. GRIEVE. 1994. Tiller developement in salt-stressed wheat. Crop Sci. 34:1594-1603.

MUJEEB-KAZI, A., V. ROSAS and S. ROLDAN. 1996. Conservation of the genetic variation of *Triticum tauschii* (Coss.) Schmalh., (*Aegilops squarrosa* auct. non L.) in syntetic hexaploid wheats (*T. turgidum* L. S. lat. x *T. tauschii*; 2n = 6x = 42, AABBDD). Genet. Res. Crop Evol. 43:129-134.

MCFADDEN, E.S. and E.R. SEARS. 1946. The origin of *Triticum spelta* and its free-threshing hexaploid relatives. J. Hered. 37: 81-89; 107-116.

MICHIGAN STATE UNIVERSITY. 1998. MSTAT-C. A software program for the design, management and analysis of agronomic research experiments. Michigan, U.S.A.

REES, D., L. RUIS IBARRA, E. ACEVEDO, A. MUJEEB-KAZI and R.L. VILLAREAL. 1994. Photosynthetic characteristics of syntetics bread wheats. Wheat Special Report N°28. CYMMIT. México.

RICHARDS, R.A. 1983. Schould selection for yield in saline regions be made on saline or non saline soils?. Euphytica 32:431-438.

RICHARDS, R.A., C.W. DENETT, C.O. QUALSET, E. EPSTEIN, J.D. NORLYN and M.D. WINSLOW. 1987. Variation for yield of grain and biomass in wheat, barley, and triticale in a salt affected field. Field Crops Res. 15:277-287.

SAYRE, K. D., E. ACEVEDO and R.B. AUSTIN. 1995. Carbon isotope discrimination and grain yield of three bread wheat germplasm group grown at different levels of water stress. Field Crops Res. 41:45-54.

SCHACHTMAN, D.P., R. MUNNS and M.I. WHITECROSS. 1991.Variation and sodium exclusion and salt tolerance in *Triticum tauschii*. Crop Sci. 31:992-997.

SHAH, S.H., J. GORHAM, B.P. FORSTER and R.G. WYN JONES. 1987. Salt tolerance in the Triticeae: The attribution of the D genome to cation selectivity in hexaploid wheat. J. Exp. Bot. 38:254-269.

WYN JONES, R.G. and J. GORHAM. 1991. Pysiological effects of salinity: scope for genetic improvement. *In* Acevedo, E., E. Fereres, C. Giménez and J. Srivastava (ed.) Improvement and management of winter cereals under temperature, drought and salinity stresses. Proceeding of the International Symposium October, 1987, Cordova, Spain. Proceedings of the ICARDA-INIA Symposium, Córdova, Spain. pp. 177-201.

ZADOKS, J.C., T.T. CHANG and C.F. KONZAK. 1974. A decimal code for the growth stages of cereals. Weed Res. 14: 415-421.

(Fecha de recepción: 29 agosto 2004; Fecha de aceptación: 23 septiembre 2003)