**Table12.** Mean yields of entries selected from the CHTWYT and CWAWSN sown using a single preseeding irrigation in Obregon, Mexico, during the 1998–99 crop cycle.

| Pedigree | Yield (t/ha) | % of Baviacora |
|---|---|---|
| BCN//Sora/*Ae. tauschii* (323) | | |
| CASS94600121S-1Y-2B-1PR-0B-0HTY | 3.838 | 123 |
| BCN//Sora/*Ae. tauschii* (323) | | |
| CASS94Y00121S-1Y-2B-2PR-0B-0HTY | 3.697 | 118 |
| Oasis/Kauz//4*BCN | | |
| CMSS93Y04048M-1M-0Y-0HTY | 3.694 | 118 |
| BCN/RABI//GS/CRA/3/*Ae. tauschii* (895) | | |
| CASS94Y00160S-40Y-7B-1PR-0B-0HTY | 3.660 | 117 |
| HP1716 (Kauz derivative) | 3.618 | 116 |
| BCN//SORA/*Ae. tauschii* (323) | | |
| CASS94Y00121S-1Y-2B-3PR-0B-0HTY | 3.536 | 113 |
| ATTILA/3*BCN | | |
| CMBW90Y4399-0TOPM-1Y-010M-010M-010Y-1M-015Y-0Y-0HTY | 3.518 | 113 |

program. Surprisingly, a number of lines, primarily synthetic derivatives, performed well under moisture stress (Table 12). A possible relationship between drought and late heat tolerance selected under optimally irrigated conditions is indicated. Table 12 shows the performance of these Bacanora derivatives in relation to Bacanora itself. The derivatives yield up to 23 % higher than Bacanora. This relationship needs further examination and will be handled by our physiology program.

## *A sea-water based salinity testing protocol and the performance of a tester set of accumulated wheat germ plasms.*

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Abiotic stresses are static mechanisms that tend to be more durable due to the absence of pathogen influence. Three stresses of significance are heat, drought, and salinity, and all still pose a major challenge. Focusing on salinity with wheat as the main crop, we have accumulated a number of land races and cultivars from global collaborators to form a tester set. We have developed a field-screening protocol using a dilution of sea water as the irrigation source. This setup was initiated in 1996 and initially reported by us in 1997. We are now providing an update after several investigations, particularly after we implemented the use of a well-designed field layout and were able to make projections for discriminating saline-tolerant germ plasm under our conditions at this stage.

The tester set is comprised of 12 bread wheat cultivars and one durum wheat (PBW 34) cultivar. The bread wheat cultivars include land races (Kharchia 65 and Shorawaki); conventional cultivars (KRL 1-4, Lu 26 S, Sakha 8, SNH-9, and WH-157); a wheat cytogenetic-stock parental line (Chinese Spring); an intergeneric hybrid-derivative cultivar (Pasban 90); and the elite bread wheat lines Oasis, Galvez, and Yecora as checks. The test saline regimes were 0, 8.0, 12.0, 16.0, and 20.0 dS/m with observations recorded for leaf area, plant height, days-to-anthesis and physiological maturity, and 1,000-kernel weight.

**Germ plasm details.** Details of the 13 entries included in the tester set are given in Table 13. The durum wheat PBW 34 is a susceptible line, whereas Oasis, Galvez, and Yecora are the three wheat check cultivars. Oasis and Yecora are separated by Oasis in having the *Lr19* gene. Both are dwarf and high-stress levels readily influence this trait. Kharchia and Shorawaki are tolerant but rust susceptible, tall land races from India and Pakistan, respectively. The cultivar Chinese Spring is a line used in intergeneric hybridization primarily because of its superior crossability with alien Triticeae species and is notable for its superior salt tolerance. Chinese Spring is a tall, awnless, facultative winter wheat and susceptible/highly susceptible to leaf/stem rust. Pasban 90, a variety released in Pakistan for irrigated agricultural

**Table 13.** Details of the tester set of wheat germ plasm accumulated and used in the study.

| Species/Cultivar | | Country and/or Source | Additional details |
|---|---|---|---|
| *T. turgidum* cv. PBW34 | | India (Dhaliwal) | Durum wheat |
| *T. aestivum* cvs. | Kharchia 65 | | |
| | Shorawaki | India (K.N. Singh) | Land race |
| | | Pakistan (N.I. Hashmi) | Land race |
| *T. aestivum* cv. Chinese Spring | | USA (E.R. Sears) | |
| *T. aestivum* cv. Pasban 90 | | Pakistan/CIMMYT, (M. Hussain and Mujeeb-Kazi) | *Th. distichum* derivative |
| *T. aestivum* cvs. | KRL 1-4 | India (K.N. Singh) | Kharchia derivative |
| | Lu 26-S | Pakistan (R.H. Qureshi) | Lu 26 selection |
| | Sakha 8 | Egypt (A.M. Mousa) | |
| | SNH-9 | India (M. Younus) | |
| | WH-157 | India (M. Younus) | |
| *T. aestivum* cvs. | Galvez | CIMMYT (Wheat Bank) | |
| | Oasis | CIMMYT (Wheat Bank) | With *Lr19* |
| | Yecora | CIMMYT (Wheat Bank) | |

areas plus saline sodic soils, is an intergeneric derivative with the pedigree Inia66/*Th. distichum*//Inia 66/3/ Genaro81. The cultivars KRL 1-4, SNH-9, WH-157, Lu 26S, and Sakah 8 originate from India, Pakistan, and Egypt.

Seeds of the above lines are maintained by the wheat wide crosses program in CIMMYT, and 10-g samples can be provided to researchers upon request to the second author of this article.

**Field screening using sea-water dilutions.** The germ plasm screening of the tester lines for salinity was conducted under field conditions in La Paz, Baja California Sur, Mexico. Sea water in close proximity to this field site was trucked in and stored in 1,200-liter dark Nalgene containers. Mixing sea water with normal field-site irrigation water provided the desired EC levels of 8, 12, 16, and 20 dS/m, representing treatments T2 to T5. The control nonsaline treatment T1 (1.5 dS/m) utilized well water as the irrigation source.

Field plots measured 3 $m^2$ and were separated from each other by 1 m on all sides by black plastic line dividers. Each plot was flood-irrigated individually according to its treatment category with 200 liters twice a week. The electrical conductivity (EC) of each irrigated plot was measured and, if necessary, precisely adjusted. Soil samples were taken randomly from two places in each plot after 24 hours for EC analysis. The established extraction procedures included measuring the fresh soil weight, drying samples at room temperature, taking 100-g samples/plot, extracting salts from the 100-g plot sample with 30 ml distilled water, and reading the EC level of the filtrate an Orion® conductivity meter. Plots were fertilized with urea once a week up to 8 weeks after germination in each plot. Each entry was planted in four rows, 4-m long and 15 cm apart, and replicated in triplicate in a lattice design.

**Results and establishing criteria to discriminate the tolerance of the entries.** Salinity levels from 10 dS/m and above are considered by researchers as being unsuitable for wheat, and if cultivars grow well then these are assumed to possess tolerance to such elevated EC levels. Hence, a good cutoff point in screening may be at about 12.0 to 12.5 dS/m. At this level, some reductions in measured traits should appear. These reductions will become more pronounced as the EC levels are increased further.

In our test, significant reductions were initiated in the cultivars at 12.5 dS/m, became pronounced at 16.5, and reached a maximum at 20.5 dS/m, where 50 % reductions across all traits were widespread. Shorawaki and Kharchia exhibited reductions between 20 to 35 % at 20.5 dS/m and were the least affected, indicating their superior tolerance. They were unaffected at 12.5 dS/m.

Oasis, Yecora, and PBW 34 had maximum reductions in leaf area (50 %), which confirmed their salinity sensitivity. A height reduction of 15 % was observed at 12.5 dS/m for each cultivar, which translated to between 20 to 30 % at 20.5 dS/m. The reductions for the two land races, even though around 25 %, was acceptable because the reduced height adequately supports its plant habit, and a beneficial biomass/harvest index could be realized. The height of Chinese Spring was unaffected at 12.5 dS/m, was reduced 12 % at 16.5 dS/m, and reduced nearly 20 % at T5. This trend was the same as observed for the two other land races, Kharchia and Shorawaki. In general, high saline concentrations induced earliness and physiological maturity for all cultivars except for Chinese Spring, Shorawaki, and Kharchia. This characteristic may influence grain-filling quality and yield. Reductions in grain yield and 1,000-kernel weight across treatments and cultivars followed a similar trend as observed for the traits above they were between 15 and 20 % were at 12.5 dS/m for the check cultivars Yecora, Galvez, and PBW 34; whereas the three superior entries Kharchia, Shorawaki, and Chinese Spring exhibited this reduction at the highest salinity test level of 20.5 dS/m.

In general, all the tester entries reported to be salt tolerant were indeed so at the 12.5 dS/m EC level. The performance of the checks showed highly pronounced reductions at this level. The best lines performed well and demonstrated reduction trait levels observed for the checks at 12.5 only at the highest EC level of 20.5 dS/m. We suggest that a level of 12.5 dS/m may be ideal for future field screening of germ plasm and breeding populations.

The above germ plasms also are being tested under controlled conditions in hydroponics (50 mM NaCl) in order to determine their K:Na discrimination trends.

**Conclusions.** 1. The evaluation of the tester-set that we accumulated from different locations may provide information that will facilitate the development of a common ground, from which inferences relative to salinity tolerance can be made by its global testing.

2. Promising lines identified by colleagues could be added to this tester set, with new sets possessing reasonable number of entries made available for evaluations.

3. Breeding populations could be screened initially at 12.5 dS/m and then tested stringently under in vitro conditions and at higher EC levels for comparisons with the best three wheats identified at this stage (Chinese Spring, Kharchia, and Shorawaki).

4. The most superior entries in the current set in addition to Kharchia 65, Shorawaki, and Chinese Spring are WH-157 and KRL 1-4 based upon their performance at 12.5 and 20.5 dS/m

## *Identification of four bread cultivars tolerant to salinity following sea-water field evaluations as varietal candidates for Baja California, Mexico*

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Several elite bread wheat lines from CIMMYT's bread wheat program were screened under in vitro conditions in an MS medium supplemented with NaCl levels of 50, 100, 150, and 200 mM. Seed of the lines were soaked in distilled water for 24 hours and the embryos excised and plated in the above medium. The control had no NaCl. After 50 % germination in the controls, further growth was allowed for 10 days, and then a final germination count and seedling height were recorded. The seedling performance was estimated similarly to the mutation-breeding radiosensitivity determinations for estimating $LD_{50}$ levels. Using this as a basis, and also observing other phenology parameters, we identified a few lines that showed a minimum degree of growth reduction at a NaCl level equal to 12.5 dS/m EC, a level that we have proposed allows selection of tolerant lines.

With the in vitro selections made and some promising lines identified, we advanced this germ plasm for field tests using sea-water dilutions of 12.5 dS/m, following the experimental design, observation, and inference protocols identical to those described in the preceding article. The germ plasms evaluated included four promising lines from the in vitro tests, the tolerant land races Kharchia and Shorawaki, and the susceptible durum wheat PBW 34 (Table 14).

**Table 14.** Salt-tolerant bread wheat comprising the elite nursery.

| Name | Pedigree | Cross number |
|---|---|---|
| Cochimi | Seri *3//BUC 'S' | CRG 68 |
| Mepuchi | BUC/BJY//PRL | CM95521 |
| Pericu | CHIL/PRL | CM92803 |
| Calafia | PFAU//ALD/PVN/3/Myna/VUL | CM91926 |
| PBW 34 | *Triticum turgidum* | |
| Kharchia 65 | *Triticum aestivum* | Land race |
| Shorawaki | *Triticum aestivum* | Land race |