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Development of salt tolerant barley for sustainable agriculture in Kuwait

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SUMMARY – The combined effects of aridity and soil salinity limit the range of crops that can be produced in Kuwait. Fresh water is used to irrigate crops in Kuwait, but this is an expensive approach and research is needed to exploit brackish water resources. Continuous irrigation with brackish water has resulted in widespread salinization of farmlands in Kuwait. Salt-tolerant barley lines selected in this study are valuable in developing efficient agricultural systems for farmlands affected by salinity. Their use in combination with agronomic soil rejuvenation methods will allow the sustainable use of Kuwaiti resources and help bring into production areas considered unfit for cultivation. A wide range of barley genotypes (141) were tested for their responses to fresh and brackish water surface irrigation. The lines included: (i) two control cultivars recommended for their salt tolerant, Gustoe and California Mariout; (ii) a range of modern cultivars; (iii) a range of landrace barleys; (iv) a selection of wild barleys; (v) a selection of salt tolerant mutant lines; and (vi) hybrids. Various agronomic traits were tested, the most important being biomass as barley is used mainly for fodder in Kuwait. The two control genotypes performed well in brackish water as did semi-dwarf, *Ari-e*. mutants. Investigations of root traits showed that short rooted genotypes, had an advantage. Sustainable barley cultivation is feasible in Kuwait by careful consideration of soil type, local ground water, soil rejuvenation, water table control and genotype.

Key words: Kuwait, barley, soil, water, salinity.

Introduction

Kuwait is a desert country and farming takes up less than 17,000 hectares (3% of the land area). Farming is confined to the Abdali region in the North and the Wafra region in the south. Brackish water is used for irrigation in these areas and can lead to rising water tables and secondary soil salinity. In Abdali the use of ground water caused a build up of salts and sodicity (Al-Rashad and Al-Ghawas, 1999). At Wafra salinity increases with increasing depth (Al-Rashed and Al-Senafy, 1995). The combination of aridity and salinity in Kuwait limits the range of crops, nevertheless there is a desire to optimise the use of natural resources.

Barley (*Hordeum vulgare*) is an important forage crop in Kuwait, but the lack of local production necessitates expensive import. The Public Authority for Agriculture and Fish Resources (PAAFR) of Kuwait has surveyed several thousand of hectares with a view of expanding barley cultivation in Kuwait. Barley is also the most drought and salt tolerant of the small grain cereals and included in the list of priority crops in the "Kuwait Greenery National Plan" (KISR, 1996) and in the Agriculture Master Plan of the State of Kuwait (KISR, 1997). The work programme was therefore set up to survey and match soils, water and genotypes for barley cultivation in Kuwait (Al-Meniae, 2003).

Test site, materials and methods

Test site

Following a national soil survey (Omar *et al*., 2001) a barley cultivation test site was selected at Wafra. The Wafra soils are loose and susceptible to wind erosion and a protected site, surrounded on three sides by Tamarix trees, was chosen. The deep rooted trees provided an additional advantage in that they prevented a rise in the water table, a hazard in irrigation schemes.

Soil survey

Physical and chemical properties were evaluated in the field and laboratory using USDA standards. The soil was analysed before and after each field trial. The soil type was defined as Muslan, but importantly was non-saline down to a depth of 100-150 cm. In general the soil was non-gypsiferous, calcareous and non-sodic with a very low clay and organic matter content and with a low water storage capacity. A more detailed soil description is given in Al-Menaie (2003).

Water analysis

Salinity of the ground water at Wafra was measured by electrical conductivity (6.75 dS/m) and classed as S1 (low sodium adsorption ratio) and C4 (high salinity) (Richards, 1954). This brackish water was saturated with Ca and SO_4. The analysis indicated that Al-Wafra water could be used in conjunction with permeable soils and moderately salt tolerant crops such as barley. More details of the water analysis are given in Al-Menaie (2003).

Genotype survey

A wide range of barley germplasm was surveyed for field testing in 1999/2000 and included the groups:

(i) Recommended lines for the regions, ICARDA recommended the salt tolerant cultivars Gustoe and California Mariout.

(ii) Wild barley lines from the "Fertile Crescent" (primary centre of diversity of *H. spontaneum*), previously tested for salt tolerance (Pakniyat *et al*., 1997).

(iii) Semi-dwarf mutant lines, previously assessed for salt tolerance (Forster, 2001).

(iv) Parental lines of genetic mapping populations, including cultivars, breeding lines and landrace material.

In the second field trial (2000/2001) the best and worst lines were re-tested along with F1 hybrids from selected crosses.

Over 140 genotypes were tested over two seasons. Two treatments were applied: fresh water irrigated and ground water irrigated, applied at the surface. It was important that these treatments did not overlap and were separated 1.5 m in a split plot experimental design. In the first year 141 genotypes were tested. Seed were sown in parallel rows with one replicate per genotype occupying 1.25 m of a row in a bed. Each replicate row consisted of 5 seed spaced at 25 cm intervals. Each treatment plot was composed of 3 beds, and each bed consisted of all (randomised) genotypes. After harvest salt was flushed from the soil with fresh water. The second field trial consisted of 54 entries.

Data were collected on: plant weight, number of seed/spike, number of seed/plant, spike weight, survival, number of tillers, height of main stem and tillers.

Results

Because of the large data sets (>10,000 data points), only an overview is presented here. Over all yields in brackish water were reduced by about 50%, but there were strong genotype and genotype x treatment interactions for all traits in both trials. Table 1 gives a summary of the first trial results, because biomass was considered the most important trait for Kuwait, the genotypes have been ranked according to plant weight. Relative performance was calculated as:

$$\frac{\text{Control} - \text{Stress}}{\text{Control}} \times 100$$

Table 1. First year overall rankings for relative performance of the top 10 and worst 10 genotypes arranged according to plant weight

Genotypes†	Plant weight	No. of seed/spike	No. of seed/plant	Spike weight	Survival	No. of spikes	No. of tillers	Height of the main stem	Mean height of tillers	Overall ranking
Golden Promise[3]	1	58	20	10	16	31	38	107	18	3
Tab 37[2]	2	108	120	94	108	85	67	92	49	95
Ari-e.228[3]	3	40	16	24	77	35	43	115	61	16
Ari-e.1[3]	4	53	22	46	110	25	26	105	56	29
Ari-e.156[3]	5	70	38	40	3	41	37	82	104	19
Tab 45[2]	6	22	99	9	141	116	107	90	112	84
Foma[3]	7	49	27	39	39	62	64	73	71	22
Gustoe[1]	8	44	15	53	137	29	36	117	82	47
Maythorpe[4]	9	23	10	14	61	26	30	61	37	2
California Mariot[1]	10	28	13	33	105	44	48	87	119	37
I-15[2]	132	111	85	8	94	78	74	72	52	89
T-20[2]	133	59	71	132	100	76	72	140	140	130
Gadot[2]	134	69	116	106	40	121	119	52	121	126
I-6[2]	135	99	48	67	22	22	14	129	128	73
NL 5/1[2]	136	79	82	122	23	86	86	35	31	80
T-17[2]	137	133	134	65	15	118	112	66	93	124
NL 5/2[2]	138	45	55	126	73	74	81	78	43	92
I-1[2]	139	120	64	83	34	24	25	119	103	91
T-7[2]	140	86	94	125	26	95	93	125	115	128
I-2[2]	141	68	124	72	78	125	125	123	125	137

†[1]Recommended, [2]wild, [3]mutant ,[4]parental genotype.

Similar results were obtained in Year 2 with Golden Promise, *Ari-e*.228, Foma, Gustoe and Maythorpe being in the top 10 in terms of overall relative performance (California Mariout was just outside the top 10, twelfth), and with the worst all being wild barley lines (Al-Menaie, 2003).

Discussion

Taking both years into account, promising genotypes could be identified for fresh and brackish water irrigation in Kuwait, Table 2.

Table 2. Promising genotypes for biomass production†

Fresh water irrigation	Brackish water irrigation
Gustoe[1]	Gustoe[1]
California Mariout[1]	California Mariout[1]
Derkado[4]	Golden Promise[3]
Bonus[4]	Derkado[4]
Maythorpe[4]	ER/Apm[4]
26-35[2]	*Ari-e*.228[3]
7-168[2]	B83-12/21/5[4]
ER/Apm[4]	*Ari-e*.156[3]
NM6/5[2]	Bonus[4]
22-30[2]	Foma[4]

†[1]Recommended, [2]wild, [3]mutant ,[4]parental genotype.

Genotypes from all four groups possessed useful traits and some interesting contrasts were

revealed between the best genotypes in fresh water irrigation compared to brackish. For example four of the top ten lines in the brackish treatment carry semi-dwarf alleles at the *Ari-e*. locus (Golden Promise, B83012/21/5, *Ari-e*.228 and *Ari-e.*156). The salt tolerance of these lines has been noted in previous studies (Forster, 2001; Pakniyat *et al*., 1997a,b). Furthermore, studies by Al-Menaie (2003) showed that *Ari-e*. genotypes had short roots and this may have an additional advantage at Wafra in not penetrating into the saline soil zone at 100-150 cm depth. There has been no breeding of barley for Kuwait and the potential for improvement is great. Traditional breeding (crossing the best with the best) is one route forward as recommended cultivars, California Mariout and Gustoe, showed good performances. These two cultivars have been crossed together and doubled haploids (DHs) have been produced from the F_1 for further studies. Landrace and wild barley genotypes, as in other studies (Ceccarrelli *et al*., 1998; Ellis *et al*., 2000; Forster *et al*., 2004), were also identified for breeding and genetic studies of abiotic stress tolerance. Selected genotypes have been crossed onto California Mariout and Gustoe and DH lines produced. These populations have been developed to study the genetics controls of performance as well as to initiate a barely breeding programme in Kuwait.

Irrigation with brackish water is of concern. In this study we found that brackish water irrigation had positive and negative effects on soil properties, but analysis after each trial showed that soil rejuvenation was possible by flushing out salts with fresh water. The site benefited from the presence of tamarix trees in maintaining the level of the water table and reducing wind damage. The work demonstrates that barley production can be expanded in Kuwait, but an integrated approach is necessary in matching soils, water, genotype and ecology.

References

Al-Meniae, H.S. (2003). *Matching soil, water and genotype for barley cultivation in Kuwait*. PhD Thesis, University of Reading, UK.

Al-Rashad, M. and Al-Ghawas, S. (1999). *Optimum use of ground water for sustainable irrigation in Al-Abdally farms*. Kuwait Institute for Scientific Research, WH 009C, Final Report, KISR 5554.

Al-Rashed, M. and Al-Sanafy, M.N. (1995). *Ground water impact on inorganic contamination of soil in Wafra farms*. Kuwait Institute for Scientific Research, WH 005K, Final Report, KISR 4643.

Ceccarreli, S., Grando, S. and Impiglia, A. (1998). Choice of selection strategy in breeding barley for stress environments. *Euphytica*, 103: 307-318.

Ellis, R.P., Forster, B.P., Robinson, D., Handley, L.L., Gordon, D.C., Russell, J.R. and Powell, W. (2000). Wild barley: A source of genes for crop improvement in the 21st century? *J. Exp. Bot.*, 51: 9-17.

Forster, B.P. (2001). Mutation genetics of salt tolerance in barley: An assessment of Golden Promise and other semi-dwarf mutants. *Euphytica*, 120: 317-328.

Forster, B.P., Ellis, R.P., Moir, J., Talamè, V., Sanguineti, M.C., Tuberosa, R., This, D., Teulat-Merah, B., Ahmed, I., Mariy, S.A.E.E., Bahri, H., El Ouahabi, M., Zoumarou-Wallis, N., El-Fellah, M., Ben Salem (2004). Genotype and phenotype associations with drought tolerance in barley tested in North Africa. *Ann. Appl. Biol.*, 144 (in press).

KISR (1996). *National Greenery Plan*. Kuwait Institute for Scientific Research, Report 4938.

KISR (1997). *Agricultural Master Plan of the State of Kuwait (1995-2015). Plan Overview*. Prepared by Kuwait Institute for Scientific Research, Arid Land Agriculture Department/Food Resources Division.

Omar, S.A.S., Misak, R., King, P., Shahid, S.A., Abo-Rizg, H., Grealish, G. and Roy, W. (2001). Mapping the vegetation of Kuwait through reconnaissance soil survey. *J. Arid Environ.*, 48: 341-355.

Pakniyat, H., Handley, L.L., Thomas, W.T.B., Connolly, T., Macaulay, M., Caligari, P.D.S., Forster, B.P. (1997a). Comparison of shoot dry weight, Na^+ content and $\delta^{13}C$ values of *ari-e* and other semi-dwarf barley mutants under salt stress. *Euphytica*, 94: 7-14.

Pakniyat, H., Thomas, W.T.B., Caligari, P.D.S. and Forster, B.P. (1997b). Comparison of salt tolerance of *GPert* and non-*GPert* barleys. *Plant Breed.*, 116: 189-191.

Pakniyat, H., Powell, W., Baird, E., Handley, L.L., Robinson, D., Scrimgeour, C.M., Nevo, E., Caligari, P.D.S. and Forster, B.P. (1997). AFLP variation in wild barley (*Hordeum spontaneum* C. Koch) with reference to salt tolerance and associated ecogeography. *Genome*, 40: 332-341.

Richards, L.A. (1954). *Diagnosis and improvement of saline and alkali soils*. USDA Handbook, No. 60.