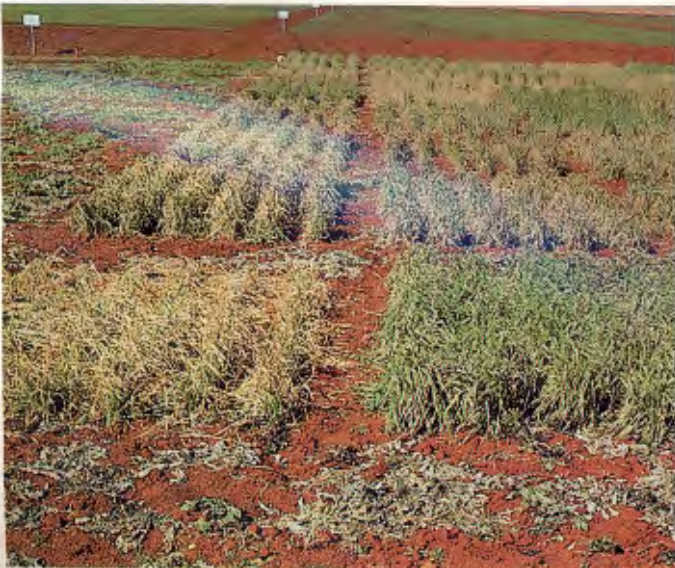


RACHIS

Vol. 5, No. 1

Jan 1986

Barley and Wheat Newsletter



The Center and its Mission

The International Center for Agricultural Research in the Dry Areas (ICARDA) was established in 1977 to undertake research relevant to the needs of developing countries and specifically for the agricultural systems in West Asia and North Africa. The overall objective of the Center is to contribute towards increased agricultural productivity, thereby increasing the availability of food in both rural and urban areas, and thus improving the economic and social well-being of people.

The Center focuses mainly on winter-rainfall areas with 200 to 600 mm annual rainfall. Where appropriate, research also covers environments with monsoon rainfall or irrigation.

ICARDA is a world center for the improvement of barley, lentil, and faba bean; and a regional center for the improvement of wheat, chickpea, farming systems, pasture and forage crops, and livestock. Training agricultural researchers from developing countries is an important component of ICARDA's activities.

ICARDA is one of 13 international research centers receiving support from donors through the Consultative Group on International Agricultural Research (CGIAR). CGIAR, an association of governments, organizations, and private foundations, supports agricultural research worldwide to improve food production in developing countries.

RACHIS

Barley and Wheat Newsletter

Vol. 5, No. 1, Jan 1986

RACHIS—the Barley and Wheat Newsletter—is published by the International Center for Agricultural Research in the Dry Areas (ICARDA). It contains mainly short scientific articles but also includes book reviews and news about training, conferences, and scientists in barley and wheat.

Published half-yearly in January and July, RACHIS can be obtained free by writing to the Distribution Unit, Communications and Documentation Program, ICARDA, P.O. Box 5466, Aleppo, Syria. Contributions to RACHIS should be sent to Dr Habib Ketata.

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COVER

Various stresses affect cereal crops in the ICARDA region. Shown are effects of (clockwise from top left): salinity, drought, diseases, and cold.

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Editorial

With this issue, RACHIS—the Barley and Wheat Newsletter—enters its fifth year of publication. The first issue of RACHIS appeared in November 1982 and was distributed to 400 readers. By the time the second issue appeared in May 1983, the mailing list had grown to 700 addresses. The sharp increase in demand reflected the value of the Newsletter. This, combined with the increasing flow of contributions, led to making RACHIS biannual from 1984. The current mailing list has 1700 addresses from both developing and developed countries.

The concept behind RACHIS was to facilitate quick dissemination of information within the region and beyond. The objective of RACHIS is different from those of refereed journals: it offers a medium for informal exchange of knowledge, particularly to researchers in the ICARDA region. Paradoxically, in the ICARDA region, where over 70% of the cropped area is devoted to barley and wheat, there is no English-language newsletter or journal with resources for quality production and worldwide distribution. Excellent research results are being produced by national programs in the ICARDA region, but much of those results were not being widely disseminated in the past for two major reasons: (i) the researchers hesitated to write in English and so published their work in their national languages, often in publications not distributed widely, and (ii) even when they wrote their articles in English, they often failed to meet the requirements of the established English-language journals. Since ICARDA has a world mandate for barley, and a regional mandate for wheat, it decided to offer RACHIS to the national program researchers in the region in order to bring their work to the attention of the researchers across the world.

RACHIS strives to meet the aforesaid objective by providing a very flexible language option to contributors. Articles written in Arabic and French are translated into English at ICARDA. Those written in English but not meeting acceptable standards are either rewritten or substantially edited by the RACHIS editorial team. We have found that this approach has been successful in stimulating a large number of national program researchers to pull their research results out of their files and publish them in RACHIS. So far RACHIS has published 94 full-length articles and 48 short communications from 25 countries. The other important feature of RACHIS editorial policy is to accept even small pieces of information from young researchers in national programs, which would otherwise remain unknown if they had to wait until a good volume of information became available to qualify for publication in an established journal. Nonetheless, RACHIS has been publishing review articles and full-length articles when these were considered useful to readers by the RACHIS editorial team.

Looking into the past 4 years of RACHIS, ICARDA feels satisfied to note that the Newsletter has been successfully fulfilling its objectives and it is playing a very important role in strengthening cereal research network with the national programs in the region. We invite our colleagues in the ICARDA region and elsewhere in the world to send us their suggestions to improve the services offered by RACHIS.

Research and Production

Combined Analysis of On-Station Yield Trials

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Replicated yield trials form an integral part of a plant breeding program. They provide a way to assess the yield potential of new selections by comparisons with one or more standard (check) varieties and by comparisons with other new selections. The usual procedure is to conduct a number of trials for a given species during a single growing season at a given location, usually an experiment station. The trials are identical in a number of ways. The same experimental design, usually a randomized complete block or a lattice, is used for all trials. The number of checks is the same for all trials and the same varieties are used as checks in each trial. The number of new selections is the same in all trials but a different group of selections is used in each.

There are a number of advantages to this procedure. It provides a uniform system for evaluating the yield potential of a large number of new selections. It also provides the high precision associated with small blocks in relatively small individual trials. There is one primary disadvantage, however. The usual procedure is to analyze the data from each trial separately. This permits the comparison of new selections with the checks and with other new selections in the same trial. It does not, however, permit the comparison of a new selection in one trial with a new selection in a different trial. Further, the experimental error variance is not as well estimated from the individual analyses as it would be from a combined analysis of the data from all trials.

This paper presents a combined analysis of data from several yield trials conducted at the same location in a given year. The purpose of the combined analysis is to provide a single estimate of the experimental error common to all trials, to adjust the means of the new selections for differences from trial to trial, and to present a way

of comparing the adjusted selection means with the checks and with adjusted selection means from different trials. In this paper, consideration will be restricted to a combined analysis of several trials conducted using a randomized complete block (RCB) design.

The combined analysis proceeds through a number of stages:

1. An analysis of variance is conducted on the yields of the checks, using the data from all trials. Adjustment factors for adjusting the selection means for differences among trials are also computed.
2. Analyses of variance of yields of the new selections are conducted for each trial separately. The selection means are also adjusted for trial differences.
3. A pooled estimate of experimental error is computed from entries in the analysis of variance of the checks and the new selections. This variance is then used to compute standard errors for the various types of comparison.

In the development which follows let:

p = number of trials.

r = number of blocks (replicates) per trial.

c = number of check varieties.

v = number of new selections per trial.

x_{ijk} = yield of the k^{th} check in the j^{th} block of the i^{th} trial.

y_{ijk} = yield of the k^{th} new selection in the j^{th} block of the i^{th} trial.

The check yields may be tabulated as shown in Table 1.

The entries in Table 1 are computed as:

$$x_{ij} = \sum_k x_{ijk} = \text{sum for the } j^{\text{th}} \text{ block in the } i^{\text{th}} \text{ trial.}$$

$$x_{i.k} = \sum_j x_{ijk} = \text{sum for the } k^{\text{th}} \text{ check in the } i^{\text{th}} \text{ trial.}$$

(This sum needs not be computed except to check other computations).

$$x_{i.} = \sum_j x_{ij} = \sum_k x_{i.k} = \text{sum of the } i^{\text{th}} \text{ trial.}$$

$$x_{.k} = \sum_i x_{i.k} = \sum_i \sum_j x_{ijk} = \text{sum for the } k^{\text{th}} \text{ check.}$$

$x_{...} = \sum_i x_{i..} = \sum_k x_{..k}$ = grand total of all check yields.

$\bar{x} = x_{...}/prc$ = grand mean of all check yields.

$\bar{x}_{i..} = x_{i..}/rc$ = mean yield of the i^{th} trial.

$a_i = \bar{x}_{i..} - \bar{x}$ = adjustment factor for trial i .

$\bar{x}_{..k} = x_{..k}/pr$ = mean yield of the k^{th} check.

The analysis of variance of the check yields is computed using the entries in Table 1. This is given in Table 2.

Table 1. Yield of check varieties common to several trials.

Trial	Block	Check				Sum	Mean	Adjustment factor
		1	2	...	c			
1	1	x_{111}	x_{112}	...	x_{11c}	$x_{11.}$		
	2	x_{121}	x_{122}	...	x_{12c}	$x_{12.}$		
		
		
	r	x_{1r1}	x_{1r2}	...	x_{1rc}	$x_{1r.}$		
	Sum	$x_{1..1}$	$x_{1..2}$	...	$x_{1..c}$	$x_{1..}$	$\bar{x}_{1..}$	a_1
2	1	x_{211}	x_{212}	...	x_{21c}	$x_{21.}$		
	2	x_{221}	x_{222}	...	x_{22c}	$x_{22.}$		
		
		
	r	x_{2r1}	x_{2r2}	...	x_{2rc}	$x_{2r.}$		
	Sum	$x_{2..1}$	$x_{2..2}$	...	$x_{2..c}$	$x_{2..}$	$\bar{x}_{2..}$	a_2
.			
.			
.			
p	1	x_{p11}	x_{p12}	...	x_{p1c}	$x_{p1.}$		
	2	x_{p21}	x_{p22}	...	x_{p2c}	$x_{p2.}$		
		
		
	r	x_{pr1}	x_{pr2}	...	x_{prc}	$x_{pr.}$		
	Sum	$x_{p..1}$	$x_{p..2}$	...	$x_{p..c}$	$x_{p..}$	$\bar{x}_{p..}$	a_p
Grand sum		$x_{...1}$	$x_{...2}$	...	$x_{...c}$	$x_{...}$		
Mean		$\bar{x}_{...1}$	$\bar{x}_{...2}$	...	$\bar{x}_{...c}$	\bar{x}		

Table 2. Analysis of variance ANOVA of check yields.

Source	df	ss	ms	f
Total	prc-1	SSTOT _c		
Block	pr-1	SSB _c	MSB	
Trial	p-1	SST	MST	F
Block in trial	p(r-1)	SS(B/T)	MSC	F(B/T)
Checks	c-1	SSC	MSC	FC
Error	(pr-1) (c-1)	SSE _c	MSE	

The sums of squares in Table 2 are computed as follows:

First compute a correction term, C_c , as:

$$C_c = x_{...}^2 / prc$$

Then:

$$SSTOT_c = \sum_i \sum_j \sum_k x_{ijk}^2 - C_c$$

$$SSB_c = (1/c) \sum_i \sum_j x_{ij.}^2 - C_c$$

$$SST = (1/rc) \sum_i x_{i..}^2 - C_c$$

$$SS(B/T) = SSB_c - SST$$

$$SSC = (1/pr) \sum_k x_{.k.}^2 - C_c$$

$$SSE_c = SSTOT_c - SSB_c - SSC$$

Mean squares are obtained by dividing the sums of squares by their associated degrees of freedom.

The experimental mean square error, MSE, is used as a divisor in all of the F ratios:

$F_T = MST/MSE$ tests the significance of the differences among trial means.

$F(B/T) = MS(B/T)/MSE$ tests blocks within trials.

$F_C = MSC/MSE$ tests the significance of the differences among check means.

This completes the first stage of the analysis.

In the second stage an analysis of variance of yields of the new selections is computed for each of the trials individually. The data which enter this analysis for an individual trial may be tabulated as shown in Table 3.

Table 3. Yields of the new selections in trial 'i'.

Selection	Block				Sum Σ	Mean \bar{y}_i	Adj. mean \hat{y}_i
	1	2	...	r			
1	y_{i11}	y_{i21}	...	y_{ir1}	$y_{i.1}$	$\bar{y}_{i.1}$	$\hat{y}_{i.1}$
2	y_{i12}	y_{i22}	...	y_{ir2}	$y_{i.2}$	$\bar{y}_{i.2}$	$\hat{y}_{i.2}$
.
.
.
v	y_{i1v}	y_{i2v}	...	y_{irv}	$y_{i.v}$	$\bar{y}_{i.v}$	$\hat{y}_{i.v}$
Sum	$y_{i1.}$	$y_{i2.}$	...	$y_{i.r.}$	$y_{i.}$	$\bar{\bar{y}}_i$	$\hat{\bar{y}}_i$

In Table 3 the entries are:

y_{ijk} = yield of the k^{th} selection in the j^{th} block of the i^{th} trial.

$y_{i.k} = \sum_j y_{ijk}$ = sum for the k^{th} selection in the i^{th} trial.

$y_{ij.} = \sum_k y_{ijk}$ = sum for the j^{th} block in the i^{th} trial.

$y_{i..} = \sum_k y_{i.k} = \sum_j y_{ij.}$ = total yield of all selections in the i^{th} trial.

$\bar{y}_{i.k} = y_{i.k}/r$ = unadjusted mean yield of the k^{th} selection in the i^{th} trial.

$\bar{\bar{y}}_i = y_{i..}/rv$ = unadjusted grand mean for the i^{th} trial.

$\hat{y}_{i.k} = \bar{y}_{i.k} - a_i$ = adjusted mean yield of the k^{th} selection in the i^{th} trial.

$\hat{\bar{y}}_i = \bar{\bar{y}}_i - a_i$ = adjusted grand mean for trial i.

Note: a_i is the adjustment factor for trial i computed in the first phase and shown in Table 1.

Analysis of variance of the yields of new selections in a single trial is illustrated in Table 4. This is the usual analysis for a randomized complete block design.

The sums in squares in Table 4 are computed in the following way: Compute a correction term C_i

$$C_i = y_{i..}^2 / rv$$

Then: $SSTOT_i = \sum_j \sum_k y_{ijk}^2 - C_i$

Table 4. Analysis of variance (ANOVA) of yields of new selections in trial 'i'

Source	df	ss
Total	rv - 1	SSTot _i
Block	r - 1	SSB _i
Selection	v - 1	SSV _i
Error	(r - 1) (v - 1)	SSE _i

$$SSB_i = (1/v) \sum_j y_{ij}^2 - C_i$$

$$SSV_i = (1/r) \sum_k y_{i.k}^2 - C_i$$

$$SSE_i = SSTot_i - SSB_i - SSV_i$$

Note: It is not necessary to compute mean squares and F ratios for these analyses.

The analysis of variance shown in Table 4 is completed for each of the trials. This completes the second stage of the analysis.

The final stage is the computation of the pooled estimate of experimental error and the standard errors for the various comparisons. The pooled experimental error, s_p^2 , is computed from the error sums of squares in the analyses of variance of the checks and of the new selections. This estimate is obtained as $s_p^2 = [SSE_c + \sum_i SSE_i] / [(pr-1)(c-1) + p(r-1)(v-1)]$ with $(pr-1)(c-1) + p(r-1)(v-1)$ degrees of freedom. The pooled estimate is used in computing standard errors, significance tests, and interval estimates.

There are a number of comparisons which may be of interest in the combined analysis. These comparisons and their standard errors are:

1. Difference between adjusted means of new selections in the same trial. The standard error, s_{d1} , is:

$$s_{d1} = \sqrt{2 s_p^2 / r}$$

2. Difference between adjusted means of new selections in different trials, with the standard error, s_{d2} , of:

$$s_{d2} = \sqrt{2(v+1) s_p^2 / rv}$$

3. Difference between check means. The standard error, s_{d3} , of these differences is:

$$s_{d3} = \sqrt{2 s_p^2 / pr}$$

4. Difference between the adjusted mean of a new selection and a check mean, with a standard error, s_{d4} , of:

$$s_{d4} = \sqrt{\frac{s_p^2}{r} \left(1 + \frac{1}{v} + \frac{1}{p}\right)}$$

In most cases it is not necessary to compute two standard errors for comparing adjusted means of new selections. Rather, an average standard error, s_{da} , may be used for this purpose. This average standard error is computed as:

$$s_{da} = \sqrt{(2c+1) s_p^2 / rc}$$

All of the standard errors are computed with $(pr-1)(c-1) + p(r-1)(v-1)$ degrees of freedom.

Numerical Example

In the 1983/84 growing season a number of yield trials were conducted on barley at Tel Hadya. The trials were planted at the normal planting time, and each trial consisted of 24 entries replicated three times in a randomized complete block experimental design. In all of the trials there were three common checks: entry 1 = Rihane 'S', entry 12 = Beecher, and entry 24 = Arabi Abiad. The remaining 21 entries in each trial were new selections, and these differed from trial to trial. Results from four of these trials were selected to illustrate the combined analysis. Yield data for these trials are given in Appendix Table 1.

The first stage in the combined analysis is the analysis of the check yields from all of the trials. These are shown in Table 5.

Note: The adjustment factor is the difference between the trial mean and the grand mean. For example:

$$251.6 = 3380.3 - 3128.7$$

The analysis of variance of the check yields is presented in Table 6.

Appendix Table 1. Yields (kg/ha) from four normally planted advanced yield trials on barley at Tel Hadya in 1984.

Trial 1 Entry	Block			Trial 2 Entry	Block			Trial 3 Entry	Block			Trial 4 Entry	Block		
	I	II	III		I	II	III		I	II	III		I	II	III
1*	2550	4241	3683	1*	3259	3375	3333	1*	3366	3283	3000	1*	2433	2633	3325
2	2433	3833	3750	2	3075	3625	4000	2	3200	3591	2625	2	2108	2200	2983
3	2150	4250	3966	3	3291	3741	3375	3	3141	3233	2958	3	2391	3108	3100
4	2950	3225	3000	4	2941	2750	2533	4	2975	2291	1833	4	2666	2416	3500
5	4125	3925	3733	5	4283	3891	3933	5	3708	2708	2725	5	3250	3333	2741
6	3441	3916	3725	6	2958	3233	3216	6	3950	3383	2316	6	1666	2016	2050
7	3066	3883	3700	7	2875	2791	2758	7	2458	2666	2333	7	2283	3116	3158
8	3433	3725	4366	8	2708	2641	3333	8	2575	2350	2383	8	1450	2108	3183
9	3233	3966	3008	9	2933	2941	2500	9	3583	2900	2833	9	2416	2708	3391
10	3008	2600	2725	10	3425	4041	3600	10	3766	3800	3225	10	2000	2600	2450
11	2766	2708	2808	11	3633	3091	3008	11	2783	2600	2358	11	2358	3000	2600
12*	3500	3375	3000	12*	3633	2866	2658	12*	3058	2875	2250	12*	2833	2283	2250
13	3008	4025	3841	13	3125	2775	2875	13	2500	2983	2483	13	3350	3150	3025
14	3100	4358	3008	14	2941	3491	2883	14	3016	4066	2941	14	2541	3208	3108
15	3541	3383	3300	15	3025	3383	3533	15	3316	2666	2016	15	2416	2816	2050
16	3958	3858	3991	16	3625	3475	3616	16	3300	2158	2383	16	2966	2875	3116
17	3258	3533	3833	17	2958	3525	3575	17	1800	2283	1808	17	2308	2633	2850
18	2491	3508	4050	18	3208	3408	3708	18	3441	2700	3291	18	2791	3858	3291
19	3000	3516	3433	19	4125	4100	3958	19	4008	3075	2683	19	2691	2858	2950
20	4083	3183	3583	20	4175	3616	3283	20	3741	2475	2358	20	3341	3750	3450
21	3958	3458	3316	21	3033	3116	2875	21	3158	3541	2500	21	2033	2883	3441
22	3200	3266	2900	22	3883	3266	3550	22	3016	3166	3266	22	2983	3525	3375
23	2333	2583	2550	23	3491	3000	3091	23	3008	3200	2666	23	2916	3166	3225
24*	3075	3816	3183	24*	3416	3533	3025	24*	3100	3533	2933	24*	3375	3416	3175

* = Check entry.

Table 5. Check yields (kg/ha), means, and adjustment factors for four barley yield trials.

Trial	Block	Check			Total	Mean	Adjusted Factor
		1 Rihane	2 Beecher	3 Arabi Abiad			
1	1	2550	3500	3075	9125	3380.3	251.6
	2	4241	3375	3816	11432		
	3	3683	3000	3183	9866		
	Σ	10474	9875	10074	30423		
2	1	3250	3633	3416	10299	3232.1	103.4
	2	3375	2866	3533	9774		
	3	3333	2658	3025	9016		
	Σ	9958	9157	9974	29089		
3	1	3366	3058	3100	9524	3044.2	-84.5
	2	3283	2875	3533	9691		
	3	3000	2250	2933	8183		
	Σ	9649	8183	9566	27398		
4	1	2433	2833	3375	8641	2858.1	-270.6
	2	2633	2283	3416	8332		
	3	3325	2250	3175	8750		
	Σ	8391	7366	9966	25723		
Total		38472	34581	39580	112633		
Mean		3206.0	2881.8	3298.3		3128.7	

Table 6. Analysis of variance of yields of three standard barley varieties from four yield trials.

Source	df	ANOVA		
		ss	ms	F
Total	35	7,120,515.6		
Block	11	3,078,454.9		
Trial	3	1,389,312.3	463,104.1	3.52*
Block in trial	8	1,689,142.6	211,142.8	1.60
Variety	2	1,148,820.7	574,410.4	4.37*
Error	22	2,893,240.0	131,510.9	

* Significant at 5%.

Note that the check variety means are significantly different. Similarly, there are significant differences, on average, from trial to trial. Adjustment of selection means for differences from trial to trial would appear to be worthwhile.

The next step in the combined analysis is the analysis of variance of yields of new selections and

the adjustment of mean yields for each of the separate yield trials. Yields from one of these trials are given, as an example, in Table 7. The analysis of variance of the yields from this trial, as well as the analyses of new *selection yields* from the other three trials, are shown in Table 8.

Having completed the analysis of variance of the checks and of the new selections, the pooled estimate, s_p^2 , of the experimental error variance may now be computed.

$$s_p^2 = \left[\text{SSE}_c + \sum_i \text{SSE}_i \right] / \left[(pr-1)(c-1) + p(r-1)(v-1) \right] =$$

$$\frac{[2,893,240.0 + 7,854,180.5 + 3,454,808.8 + 5,979,186.7 + 4,569,376.4]}{[(4 \times 3 - 1)(3-1) + 4(3-1)(21-1)]} =$$

$$(24,750,792.4)/182 = 135,993.4; 182 \text{ d.f.}$$

The standard errors for the several types of comparisons may now be computed:

1. Difference between adjusted means of new selections in the same trial:

Table 7. Yields of new selections in Trial 1 of a barley yield trial at Tel Hadya in 1984.

Entry	Block			Total	Mean \bar{y}	Adjusted mean, \hat{y}^1
	I	II	III			
2	2433	3833	3750	10016	3338.7	3087.1
3	2150	4250	3966	10366	3455.3	3203.7
4	2950	3225	3000	9175	3058.3	2806.7
5	4125	3925	3733	11783	3927.7	3676.1
6	3441	3916	3725	11082	3694.0	3442.4
7	3066	3883	3700	10649	3549.7	3298.1
8	3433	3725	4366	11524	3841.3	3589.7
9	3233	3966	3008	10207	3402.3	3150.7
10	3008	2600	2725	8333	2777.7	2526.1
11	2766	2708	2808	8282	2760.7	2509.1
13	3008	4025	3841	10874	3624.7	3373.1
14	3100	4358	3008	10466	3488.7	3237.1
15	3541	3383	3300	10224	3408.0	3156.4
16	3958	3858	3991	11807	3935.7	3684.1
17	3258	3533	3833	10624	3541.3	3289.7
18	2491	3508	4050	10049	3349.7	3098.1
19	3000	3516	3433	9949	3316.3	3064.7
20	4083	3183	3583	10849	3616.3	3364.7
21	3958	3458	3316	10732	3577.3	3325.7
22	3200	3266	2900	9366	3122.0	2870.4
23	2333	2583	2550	7466	2488.7	2237.1
Total	66535	74702	72586	213823	3394.0	3142.4

1. $\hat{y} = \bar{y} = (\text{adjustment factor}) = \bar{y} - 251.6$

Table 8. Analysis of variance of yields of new barley selections from four yield trials.

Source	df	ANOVA Sum of squares			
		Trial 1	Trial 2	Trial 3	Trial 4
Total	62	18,150,595.0	11,543,816.8	18,976,010.9	16,506,525.5
Block	2	1,710,983.5	5,866.5	3,779,342.0	2,790,591.6
Selection	20	8,585,431.0	8,083,141.5	9,217,482.2	9,146,557.5
Error	40	7,854,180.5	3,454,808.8	5,974,186.7	4,569,376.4

$$s_{d1} = \sqrt{2 \frac{s_p^2}{r}} = \sqrt{(2) (135,993.4)/3} = 301.10$$

2. Difference between adjusted means of new selections in different trials:

$$s_{d2} = \sqrt{2(v+1) \frac{s_p^2}{rv}} = \sqrt{2(21+1) (135,993.4)/(3)(21)} = 308.19$$

3. Difference between check means:

$$s_{d3} = \sqrt{2 \frac{s_p^2}{pr}} = \sqrt{(2) (135,993.4)/(4) (3)} = 150.55$$

4. Difference between an adjusted mean of a new selection and a check mean:

$$s_{d4} = \frac{s_p^2}{r} \left(1 + \frac{1}{v} + \frac{1}{p}\right) = (135,993.4/3) \left(1 + \frac{1}{21} + \frac{1}{4}\right) = 242.53$$

5. Average standard error of difference between adjusted new selection means:

$$s_A = (2c+1) \frac{s_p^2}{rc} = (2 \times 3 + 1)(135,993.4)/(3)(3) = 325.23$$

Table 9. Adjusted mean yields (kg/ha) of new selections of barley in four yield trials at Tel Hadya in 1984.

	Trial 1 Adjusted mean	Trial 2 Adjusted mean	Trial 3 Adjusted mean	Trial 4 Adjusted mean
2	3087.1	2 3463.3b	2 3223.2	2 2700.9
3	3203.7	3 3365.6b	3 3195.2	3 3136.4
4	2806.7	4 2971.3	4 2450.8	4 3131.2
5	3676.7ab	5 3932.3abc	5 3131.5	5 3378.6b
6	3442.4b	6 3032.3	6 3300.8b	6 2181.3
7	3298.1b	7 2704.6	7 2570.2	7 3122.9
8	3589.7b	8 2790.6	8 2520.5	8 2517.6
9	3150.7	9 2687.9	9 3189.8	9 3108.9
10	2526.1	10 3585.3b	10 3681.5a	10 2620.6
11	2509.1	11 3140.6	11 2664.8	11 2923.3
13	3373.1b	13 2821.6	13 2739.8	13 3445.6b
14	3237.1	14 3001.6	14 3425.5b	14 3222.9
15	3156.4	15 3210.3	15 2750.5	15 2697.9
16	3684.1ab	16 3468.6b	16 2698.2	16 3256.3
17	3289.7b	17 3249.3	17 2048.2	17 2867.6
18	3098.1	18 3337.9b	18 3228.5	18 3583.9b
19	3064.7	19 3957.6abc	19 3339.8b	19 3103.6
20	3364.7b	20 3587.9b	20 2942.5	20 3784.3abc
21	3325.7b	21 2904.6	21 3150.8	21 3056.3
22	2870.1	22 3462.9b	22 3233.8	22 3564.9b
23	2237.1	23 3090.6	23 3042.5	23 3372.9b
Adjusted factor	251.6	103.4	-84.5	-270.6

a = significantly higher than Rihane with mean yield = 3206.0

b = significantly higher than Beecher with mean yield = 2881.8

c = significantly higher than Arabi Abiad with mean yield = 3298.3

LSI (5%) = 452.2

The least significant increase, LSI, (one-sided LSD) may be computed for determining which of the adjusted new selection means significantly outyield the checks. For this example:

$$LSI = t_a s_{d4}$$

where:

t_a is the one-sided t at the a probability level.

For a 5% LSI: $t_a = t_{0.05(182)} = 1.645$

$$\text{and } LSI = (1.645)(242.53) = 398.96$$

The mean yields of the checks and the adjusted means of the new selections in the four yield trials may be summarized as shown in Table 9.

On considering the results summarized in Table 9 it is seen that 28 of the new selections, after adjustment for differences among trials, outyielded the check variety, Beecher. Of these, 6 outyielded the check variety, Rihane's, while only 3 of the 84 new selections had significantly greater yield than Arabi Abiad.

Barley Improvement for Different Uses in Dry Areas in Cyprus

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Barley (*Hordeum vulgare* L.) is considered among the crops most adapted to dry areas, and in Cyprus long ago it was considered the safest grain crop in low-rainfall areas (Anonymous 1937). In a more recent study conducted at 27 environments, the yield of Athenais barley was consistently higher than that of wheat varieties (Hadjichristodoulou 1974). The mean yield of Athenais was 3.2 t/ha, 75% higher than that of Pitic 62 aestivum wheat and 98% higher than that of Kyperounda durum wheat. New high-yielding varieties of cereals were released recently in Cyprus but barley continues to be considered as better adapted to rainfed areas than wheat. Barley occupies 90% of the total area sown with grain cereals.

In Cyprus, barley is used for grain production, for hay production, and for grazing. A program was initiated in 1967 at the Agricultural Research Institute (ARI) aiming at improving barley varieties for different uses.

Grain Production

Traditionally, barley is grown to feed livestock, mainly sheep, goats, and pigs. In the past and until about 30 years ago, farmers used barley for bread making in years of drought when wheat production was insufficient. There are no reports on using barley for malting purposes.

The old local varieties, Mavrokritharon, Paphitico, and Hexasticho were replaced during the 1950s by Athenais variety, an introduction from Greece. Recently a new high-yielding variety, Roho, outyielded Athenais by 15.6% and was released under the local name Kantara (Hadjichristodoulou *et al.* 1980). The main methods used to improve grain yield were:

a) Pure-line selection in commercial varieties: At the initiation of the barley breeding program, an intensive evaluation of pure-line progenies of single plants selected from Athenais and Sel. B-55-22 varieties was conducted over several years. Though some differences were found between selections and their mother variety, none of the new lines was good enough to be released.

b) Introduction: In cooperation with international centers (such as FAO, CIMMYT, and ICARDA) and national programs, a large number of lines was introduced and tested in the special program which screens for high yield and consistency of performance. Lines are first tested in nurseries, the most promising of which are promoted to Series A trials (1-2 replications, 1-2 locations, plot size of 4 m²) for the first yield evaluation. The most promising are promoted to Series B, C, D, and E in which the number of replications gradually increases to six, number of locations to three, and plot size to 11 m². Through this program, the variety Kantara with 15.6% higher grain yield than Athenais was released (Hadjichristodoulou *et al.* 1980). The success of introduction in selecting promising material depends to a great extent on the availability of suitable genetic material for the agroclimatic conditions of the country. The role of international centers such as ICARDA in making such material available is very important. In fact, the procedure followed by ICARDA in selecting promising lines, based on information collected from the region, has increased the availability of suitable germplasm to the national program.

c) Hybridization: Around 300-400 new crosses are made each year among selected parents which, either performed well under dryland conditions or possessed certain desirable genes for important traits such as earliness, lodging resistance, disease resistance, tillering capacity, and large spikes. The most promising lines available at present, which slightly outyield Kantara, resulted from the crossing program and involve crosses of Athenais with the early Swedish variety Mari.

d) Mutation breeding: In the framework of a research contract between ARI and IAEA (International Atomic Energy Agency) for the period 1970-80, aiming at improving protein content of barley, lines were evaluated for yield also. In most cases yields were equal or lower than those of the mother variety. However, from a population of Attiki barley treated with different doses of fast neutrons, a line (M-Att-73-337-1) was selected which possessed similar protein content, earliness, plant height, 1000-grain weight, and volume weight to the mother variety but 10% higher grain yield (means of six trials over two seasons 1979-80). This line was subsequently tested in 10 trials over 3 years and yielded equal to the recently released Kantara, but 11% higher than Attiki.

Forage Barley

The dry climate of Cyprus limits the choice of species for forage production to satisfy the needs of ruminants during late summer and early winter, when there is shortage of roughage in the fields. Barley has been used for hay production either in pure stand or in mixture with legumes because it gives the highest dry-matter yield, 109% higher than the legume forage crops (vetches and peas) and 50% higher than other cereals (Hadjichristodoulou 1973). Recently, new oats and triticale lines were selected which give similar dry-matter yield as barley. Long-term screening of varieties resulted in selection of barley varieties Morocco 628 and 48 Alger for their high dry-matter yield (Hadjichristodoulou 1976). Morocco 628 has smooth awns, making it more suitable than rough-awned varieties for hay production. Improved hooded types were developed by crossing genotypes having high dry-matter yield with hooded cultivars (Hadjichristodoulou 1985a).

Under conditions of early fast growth in November/December and in fertile soils, barley suffers from lodging if the amount and distribution of rainfall is favorable. Under such conditions, farmers graze the crop and the regrowth is harvested in May for grain production. Studies on such dual-purpose barley showed that under ordinary rainfed conditions grain yield is reduced by 33% and straw yield by 40% if the crop is grazed at tillering stage (Hadjichristodoulou 1983). These studies also indicated that high grain-yielding lines could be used as basic material for selecting dual-purpose varieties. This finding greatly facilitates breeding for dual-purpose barley as most countries have on-going breeding programs for grain production. The aim should be to select dual-purpose varieties which produce relatively high yields of dry matter at grazing with minimum adverse effects on grain yield.

Pasture Barley

All cultivated barley varieties, used either for grain or hay production, have no grain shattering and grain yield losses at harvesting are minimum. Furthermore, animals grazing the stubble can pick up whole or part of the spikes, thus limiting the chances of self-regenerating barley crops. In contrast, the wild relative of cultivated barley (*Hordeum spontaneum*) is protected from biotic and nonbiotic enemies, because of its self-regenerating mechanisms, namely brittle rachis, which enable

shattering of grains at maturity, and long flat grains on which a small portion of the rough awn is firmly attached. These mechanisms enable the seeds to enter the soil and protect them from grazing animals.

These properties of *H. spontaneum* are being used at ARI to develop self-regenerating barley in order to establish permanent pastures in marginal lands, stony fields, and hilly areas, where implements and tractors cannot be used for sowing each year. The need for such a crop arose after varieties of traditional pasture crops such as medics, clovers, and *Lolium* species failed to establish themselves in the dry climate of Cyprus. In contrast, *H. spontaneum* thrives well in these areas. In special studies conducted by the Forage and Pasture Crop Improvement Program of ARI in hilly pasture lands, the dry matter of barley was 67% higher than that of the mixture of medics and loliums (ARI Annual Report 1981). Similar results were published in the 1982 and 1983 Annual Reports. The quality of barley pasture at the tillering stage (grazing stage) is excellent, with protein content of dry matter around 28%.

The above considerations prompted the initiation of a breeding program aiming at developing special self-reseeding pasture types of barley in order to improve vegetation of the natural pastures in Cyprus estimated to occupy around 160,000 ha, 17% of the total area of Cyprus (Jones *et al.* 1958). Selected forage types of barley were crossed with several selections of *H. spontaneum* and the material is now at the F₂ generation. Selection for resistance to grazing and high forage-yielding pasture genotypes will be made using animal grazing. The frequency of such genotypes is expected to increase with time, while unsuitable genotypes will be eliminated by animal grazing. Ceccarelli and Mekni (1985) suggested the use of *H. spontaneum* in breeding for grain barley in the low-rainfall areas. *H. spontaneum* crosses very easily with *H. vulgare*, and the brittle rachis character is controlled by dominant genes (Nilan 1964). This process, of almost natural selection operating on the segregating populations, may be aided by using male sterility facilitated recurrent selection methods, developed at the Montana State University, USA. Within natural populations of *H. spontaneum*, several leafy plants were selected which appear to have originated from natural outcrosses of *H. spontaneum* with *H. vulgare*. Their seed and spike types resemble more the wild than the cultivated barley.

Consistency of Performance

Breeding for specific conditions in the dry areas of Cyprus is meaningless, because of the significant variation in climatic conditions with year and location. Therefore, efforts were deviated to breeding for stable varieties with consistency of high performance under the diverse growing conditions. Such varieties were identified not only in barley, but also in wheat and other crops and were released for cultivation.

In order to increase the efficiency of breeding and screening for consistency of performance, two approaches are being followed:

a) Screening of lines for yield at several locations and over 3-4 seasons: Only the most promising lines are retained each year. Common checks (the best available varieties) are used for valid comparisons among trials and years. Before releasing a variety, its yield and consistency of performance are compared using regression analysis.

b) Identification of selection criteria to be used in segregating populations and in nurseries: This is done by critical evaluation of all available data from trials and by special studies. As a result of these studies it was decided to select for optimum heading date, high and uniform tillering, stability of tiller number per unit area (high plasticity of tiller number per plant), stability of height, stability of 1000-grain weight or slow leaf senescence, disease tolerance or resistance, and long awns (Hadjichristodoulou 1981, 1985b, 1986).

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Agronomic Traits Contributing to Drought Tolerance in Huskless Barley

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Genetic variation has been demonstrated in several species for drought-related traits. However, no efficient screening method has been developed and the association between these traits and plant productivity under stress has not been clearly established. It was suggested that no single drought-resistance factor is a good indicator of plant productivity under drought stress (Blum 1978; Sammons *et al.* 1979). Therefore, it may be necessary to identify a number of agronomic or physiologic traits which can be used in screening for drought tolerance.

The present study is aimed at determining the genetic variability for several traits in barley germplasm and identifying some of these traits which could contribute to drought tolerance.

Materials and Methods

The material under study consisted of 201 diverse accessions from the world collection of barley, being maintained by the Germplasm Collection, Conservation, and Evaluation Unit at All India Coordinated Barley Improvement Project, IARI, Regional Station, Karnal. The experiment was conducted in a randomized complete block design with three replications. Each entry was

sown in 2 m long rows, spaced 30 cm apart. No irrigation was given in the season. Recommended cultural practices were adopted. Five plants were selected randomly from each plot for recordings on: root and shoot lengths, 60 days after sowing; third-leaf area; plant height (excluding-awns); awn length; tillers/plant; days to 75% flowering; days to 75% maturity; spike length (excluding awns); 1000-kernel weight; and grain yield/plant.

Coefficient of variability, heritability in the broad sense, and correlation coefficients for the various characters were computed following Hanson *et al.* (1956) and Dewey and Lu (1959).

Results and Discussion

Differences among the accessions were significant for all characters with the exception of tillers/plant and days to maturity (Table 1). Means, ranges, and coefficients of variation for all traits are given in Table 2. The difference between phenotypic and genotypic coefficients of variation was highest for tillers/plant followed by grain yield/plant, leaf area, and root and shoot length.

Heritability estimates were highest for plant height (0.56), followed by 1000-kernel weight (0.53), spike length (0.49), shoot length (0.37), and awn length (0.36); and lowest for tillers/plant (0.01) and root length (0.09).

Traits such as 1000-kernel weight and spike and shoot lengths, which are less influenced by the environment, have better scope for improvement. On the other hand, other traits such as tillers/plant and root length are highly influenced by nongenetic factors and may not be easily improved by selection in droughty environments.

Table 1. Analysis of variance for yield and yield components in huskless barley.

Source	DF	Mean sum of square										
		Root length (cm)	Shoot length (cm)	Leaf area (cm)	Plant height (cm)	Awn length (cm)	Tillers/plant	Days to flowering	Days to maturity	Spike length (cm)	1000-kernel weight (g)	Grain/plant (g)
Replication	2	179.47**	95.85**	0.25	22.40	1.23	339.81**	9.4	222.80**	1.65	0.34	0.13
Strains	200	5.67**	9.50**	5.96**	116.79**	4.37**	15.50	45.86**	6.44	1.96**	45.62**	42.27*
Error	400	4.70	4.36	3.79	33.17	2.0	15.14	22.64	5.33	0.65	13.99	27.29

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

Table 2. Range, mean, and coefficient of variability for grain yield and other traits in huskless barley.

Character	Range	Mean	±	SE	CV (%)	
					Phenotypic	Genotypic
Root length (cm)	7.40-16.25	11.83	±	2.16	19.24	5.87
Shoot length (cm)	6.60-17.75	10.95	±	2.08	24.04	14.63
Leaf area (cm ²)	3.68-13.05	6.74	±	1.94	32.89	15.50
Plant height (cm)	46.80-91.10	64.59	±	5.75	13.40	10.01
Awn length (cm)	7.30-21.80	10.93	±	1.42	16.38	9.88
Tillers/plant	6.50-22.10	12.52	±	3.89	31.25	3.41
Days to 75% flowering	80.00-104.50	93.69	±	4.75	6.25	3.64
Days to 75% maturity	123.00-132.50	126.46	±	2.10	1.92	0.59
Spike length (cm)	5.50-10.95	7.81	±	0.81	14.62	10.35
1000-kernel weight (g)	23.00-49.60	33.12	±	3.74	16.48	12.00
Grain yield/ plant (g)	6.67-32.00	15.31	±	5.22	38.52	17.88

A study of correlations among all traits both at the genotypic and phenotypic levels showed that grain yield/plant is tightly associated with 1000-kernel weight, days to flowering, and shoot length, demonstrating that barley lines with large kernels, early flowering, and relatively taller plants are desirable in droughty environments. Higher grain yield/plant was also associated with shorter spikes and smaller leaf area.

It is concluded that: (1) tremendous variation exists among the accessions for all traits, demonstrating the actual potential for improving barley for the following traits: 1000-kernel weight, spike length, and shoot length; (2) large kernels, short spikes, medium to tall plants, early flowering, and small leaf area may be useful attributes that can be used as selection criteria in droughty environments.

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A Single Lodging Index for Barley

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The use of fertilizers and irrigation tends to increase lodging which can cause yield losses of 12-66% depending upon the degree of lodging, stage of occurrence, and subsequent weather conditions (Day 1957). Previous research studies have shown root system (Howard and Howard 1912), plant height (Bhide and Bhalerao 1925), breaking strength (Albrecht 1908), diameter of culm (Brady 1934), tillering (Welton 1928), length of lowest internode (Atkins 1938), number of nodes/shoot (Malkani and Vaidya 1956), and length of ear head (Welton 1928) to be associated with lodging. These traits were, therefore, recommended as lodging indices. However, there is no unanimity over the importance and usefulness of these various indices. Vaidya and Mahabalram (1982, 1984) have suggested the use of shoot x height/root (SH/R) and breaking strength/height x mothershoot (Br/HM), as lodging indices for barley. However, the development of two equally important indices may not be desirable in varietal screening, particularly if these indices are closely correlated. The present study included 109 barley entries which were evaluated for lodging and lodging-related traits. The material was characterized by sizeable variation as cv values were 29% for shoot weight (S), 32.5% for root weight (R), 20.2% for mothershoot weight (M), 11.8% for height (H), and 27.7% for breaking strength (Br). Experimental observations were recorded as described by Vaidya and Mahabalram (1982).

Correlations among various traits or indices are shown in Table 1. It is seen that all indices have correlations with lodging of approximately similar magnitude. The significant correlation between SH/R and Br/HM tends to indicate a certain redundancy if both are simultaneously used to describe lodging. However, the compound ratio SH^3M/BrR gave slightly higher correlation with lodging, suggesting that such a ratio can be used as a single index in screening barley varieties for lodging resistance.

Table 1. Coefficient of simple correlation (r) between different characters.

Character being correlated	r
Lodging and SH/R	+0.594**
Lodging and Br/HM	-0.613**
Lodging and SHM/BrR	+0.545**
Lodging and SH^2M/BrR	+0.612**
Lodging and SH^2M/BrR^2	+0.547**
Lodging and SH^2M/Br^2R	+0.572**
Lodging and SH^3M/BrR	+0.663**
Lodging and SH^4M/BrR	+0.572**
SH/R and Br/HM	-0.639**
SH^3M/BrR and SH/R	+0.539**
SH^3M/BrR and Br/HM	-0.568**

**Significant at the 1% level.

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Combining Ability of Diaraland Genotypes of Barley¹

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In a successful hybridization program, parents are selected on the basis of their adaptability and combining ability. This study examines the combining ability of Diaraland adapted genotypes for yield and its components through a diallel cross analysis.

Materials and Methods

The experimental material comprised four indigenous lines from Diaraland (DR-46, DHB-4, DR-56, and DR-32) and four well adapted Indian barley varieties (Ratna, Jyoti, Vijaya, and RS-6) as parental lines and all possible 28 F₁s, which were raised in three randomized complete blocks at the experimental farm of the barley research unit (ICAR), B.R.D. Postgraduate College, Deoria, India, during rabi 1979/80. Plot size was 3 m x 0.3 m with 10 cm between rows. The experiment was sown on 14 November 1979. Ten competitive plants were selected from each entry in each replication to collect data on tillers/plant, ear

length (cm), grains/ear, spikelets/ear, 1000-grain weight (g), and grain yield/plant (g). Genetic analysis was carried out following the Griffing (1956) method-2, model-I.

Results and Discussion

Analysis of variance for the design of experiment showed significant differences for the various traits. Analysis of variance for combining ability along with variance components are presented in Table 1. General combining ability variances were highly significant for all characters. A comparison of relative magnitude of estimates of general and specific combining ability variances revealed predominance of additive gene action for tillers/plant, ear length, grains/ear, spikelets/ear, 1000-grain weight, and grain yield/plant. The magnitude of gca and sca variances does not provide a clear picture of the proportion of additive and nonadditive type of genotypic variation. Therefore, σ^2_g , σ^2_S , and σ^2_A were estimated for all characters using expected mean squares given by Griffing (1956). This indicated that additive and nonadditive variations were equally important for tillers/plant, ear length, grains/ear, spikelets/ear, 1000-grain weight, and grain yield/plant.

The gca estimates of parents and sca effects of F₁s were computed for all traits. Among the parents DR-56 and DR-32 were the best general

Table 1. Analysis of variance for general and specific combining ability in the F₁ generation.

Source of variation	df	Mean sum of squares					
		Tillers/ plant	Ear length (cm)	Grains/ ear	Spikelets/ ear	1000- grain weight (g)	Grain yield/ plant (g)
sca	7	12.242**	2.794**	179.040**	29.247**	36.742**	110.358**
sca	28	3.022**	0.758**	50.679**	5.487**	12.697**	19.812*
Error	70	0.665	0.063	5.158	0.241	0.097	3.018
σ^2_g		0.922	0.204	12.736	2.376	3.304	9.055
σ^2_g or σ^2_D		3.022	0.758	51.679	5.487	12.697	19.812
σ^2_A		1.844	0.408	25.472	4.752	4.608	18.110

* Significant at 5%; ** Significant at 1%.

¹ Based on Ph.D. thesis submitted by first author to Gorakhpur University.

combiners for tillers/plant while Ratna, Jyoti, Vijaya, and DHB-4 were poor combiners. Seven cross combinations namely Jyoti x RS-6, Jyoti x DR-56, Jyoti x DR32, Vijaya x RS-6, Vijaya x DR-56, DR-46 x DHB-4, and DR-56 x DR32 showed highly significant positive sca effects.

For ear length, the parent DR-56 contributed increased ear length to its hybrids as shown by highly significant positive gca effects for this trait. Seven crosses (Ratna x Jyoti, Jyoti x DHB-4, Vijaya x DR-56, RS-6 x DR-56, RS-6 x DR-32, DR-46 x DR-56, and DR-46 x DHB-4) showed highly significant positive sca effects, while the crosses Ratna x DHB-4, Jyoti x Vijaya, Jyoti x RS-6, Vijaya x DR-32, RS-6 x DR-46, DR-46 x DR-32, and DHB-4 x DR-56 showed highly significant negative sca effects for ear length.

The parents, DR-56, DR-32, and Vijaya were the best general combiners for grains/ear. Significant positive sca effects were observed for 13 crosses namely Ratna x DR-32, Jyoti x DHB-4, Jyoti x DR-56, Jyoti x DR-32, Vijaya x RS-6, Vijaya x DR-46, Vijaya x DR-56, RS-6 x DHB-4, RS-6 x DR-32, RS-6 x DR-56, DR-46 x DHB-4, DHB-4 x DR-32, and DR-56 x DR-32.

Three parents viz. Vijaya, DR-56, and DR-32 showed significant positive gca effects and others possessed significant negative gca effects for spikelets/ear. Four crosses namely Ratna x DR-32, Vijaya x DR-56, RS-6 x DHB-4, and DHB-4 x DR-32 exhibited highly significant positive sca effects while crosses Jyoti x DR-46, Jyoti x DR-32, and DR-56 x DR-32 had significant and positive effects.

The best general combiners for 1000-grain weight were DHB-4, RS-6, and Jyoti. Highly significant positive sca effects were obtained for Jyoti x RS-6, Jyoti x DHB-4, Vijaya x RS-6, Vijaya x DR-56, DR-46 x DHB-4, DR-46 x DR-56, DR-46 x DR-32, DHB-4 x DR-56, and DHB-4 x DR-32.

The parents DR-56, DHB-4, DR-46, and DR-32 were good general combiners for grain yield/plant with highly significant positive gca effects. The best cross combinations having highly significant positive sca effects were Jyoti x RS-6, Jyoti x DHB-4, Jyoti x DR-56, Jyoti x DR-32, Vijaya x RS-6, Vijaya x DR-46, Vijaya x DR-56, RS-6 x DHB-4, DR-46 x DHB-4, and DHB-4 x DR-32.

This study revealed predominance of additive gene action in the expression of tillers/plant, ear length, grains/ear, spikelets/ear, 1000-grain weight, and grain yield/plant, although nonadditive gene action is also involved. These

findings are in agreement with those of Upadhyaya and Rasmusson (1967); Arevallo *et al.* (1974); and Verma and Gulati (1976) for tillers/plant, grains/ear, and grain yield/plant, and Verma (1978); Singh *et al.* (1980); and Sharma (1978) for ear length, spikelets/ear, and 1000-grain weight.

It is concluded that DR-56, DR-32, DR-46, and DHB-4 could be selected as parents for hybridization programs aiming at improving grain yield of barley under Diaraland conditions.

Because larger seeds are more appreciated in the market, the improvement of seed size should be given high priority in barley breeding programs. This study showed that RS-6 is a good combiner for this trait and thus would be a desirable parent for a hybridization program aimed at improving barley in India.

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*Original not seen.

Malting Barley as a Potential Crop for Irrigated Areas in the Middle East

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The most important criteria of barley for malt potential are the hot water extract and the saccharifying activity (the capacity to convert starch to simple sugars). From the aspect of laboratory testing of barley genotypes, kernel size, plump kernel distribution, protein content, and diastatic power of the barley itself (i.e. before malting) give a good indication of its malting potential, and can be tested by simple equipment. The plump kernel test requires a 100 g sample, which limits its use to generations later than F₃, but it is nondestructive and the sample can be planted after testing. The percentage of plump kernels in a barley sample is an indication of the starch content and potential hot water extract of the malted barley. A high correlation ($r=0.92$) exists between the 1000-kernel weight of barley and the percentage of kernel size which itself is a very stable varietal characteristic with an average coefficient of correlation between locations of over 0.8. Diastatic power of barley gives an indication of the enzyme

activity of the final malt, and is also a stable varietal characteristic, with a between-location correlation coefficient of 0.85. Protein content should be fairly low for malting purposes, about 11.5-12.5% (N x 6.25 dry basis) is ideal. High protein content is associated with low hot water extract, since if the protein is high, the starch content will be correspondingly lower. On the other hand if the protein is too low the enzyme activity is also likely to be lower, which affects the power of the malt to convert starch to fermentable sugars. Protein content is not a stable varietal characteristic in barley, and is affected to a greater degree by the environment (soil and weather conditions) than the genetic makeup.

At the ICARDA cereal quality laboratory early generation barley is first visually screened for general kernel appearance, and then the 1000-kernel weight is determined. Only genotypes with yellow or white aleurone are considered for malting quality, since blue, purple, and black aleurone types are not favored by the malting industry. Only genotypes with high 1000-kernel weight are recommended for further testing. These genotypes are tested for plump kernel count in F₄ and later generations, using European Normal Sortierung sieves of 2.8, 2.5, and 2.2 mm slotted openings. Genotypes which have plump kernel counts of over 75% (through 2.5 mm screen), and small kernels of less than 6% (through 2.2 mm screen) are tested for diastatic potential. There is a negative

Table 1. Barley genotypes with high yield and malting potential.

Pedigree	Yield (kg/ha)	Plump kernel count (% over 2.5 mm)	1000-kernel weight (g)	Protein (%)	Diastatic power units
NIL 1615	3490	76.6	40.1	9.8	206
M64-76/BON/JO/YORK/3/M5/GALT/ /AS46/4/HJ34-80/ASTRIX	4020	77.0	36.3	8.0	195
CMSWB 77A-0164-2AP-2AP- QAP PITAO/CAM/AVT/RM150814/POR /DS/APROL 3/CM 67/DWG*2/ICB 78- 0013-10AP-3AP-4AP-QAP	3430	78.4	47.0	11.3	188
MARIS DINGO/DEIR ALLA 106 ICB 78-0052-10AP-1AP-1AP-QAP	3470	76.0	45.5	10.8	183
WEISEL BURGER/AHOR 1303-61 ICB 77-0432-1AP-2AP-2AP-2AP-QAP	3500	90.2	46.7	10.8	187
ALGER/UNION 385-2-2/ KRASNORDORSKY CMB77A-1267-4AP- OSK-1AP-1AP-1AP-QAP	3850	98.8	47.0	10.9	230

correlation between plump kernel count and diastatic power. This differs between groups of selections taken from the same parental lines, and has ranged between -0.6 and -0.9 for the material tested at ICARDA. However, it is possible to find genotypes which carry the combination of plump kernels and high diastatic potential, and Table 1 shows some genotypes which combine both these characteristics with high grain yield under rainfed conditions in the medium-rainfall area.

Under irrigation, combined with good fertilizer management these lines would likely yield even higher, and the use of nitrogenous fertilizer would assure a satisfactory protein content.

The Mediterranean region countries annually import about 150,000 tonnes of malt or malting barley. A further 4-5 million tonnes of barley are imported, some of which is also used for malting.

Both malting barley and malt are expensive commodities; the price of malting barley is usually around 150-180 US \$/tonne. The climatic conditions prevailing in northern Syria, and the Orontes Valley during the maturation season are ideally suited to produce clean, bright grain, free from weather damage. Introduction of good malting quality cultivars, grown under these weather conditions coupled with irrigation and fertilizer management, could provide Syrian farmers with an alternative crop which would have a high export value. Malting barley is preferable to durum wheat, since climatic conditions favorable to produce high yields often result in durum wheat with lower protein content and vitreous kernel percentage, which are not desirable for industrial purposes. Meanwhile, the same conditions result in lower protein and high plump kernel count in barley, both of which are assets to malting quality.

A Method to Screen F_2 Populations for Barley Stripe Disease (Helminthosporium gramineum)

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Barley stripe, caused by (*Helminthosporium gramineum* (*Pyrenophora graminea*), is an important seed-borne disease prevalent in most barley-growing countries of North Africa and the Middle East (Bayaa *et al.* 1978; Boulif 1981; El-Ahmed *et al.* 1981; Kamel 1981; Sharp 1984). The disease can be controlled by seed treatment, but an effective seed multiplication system for barley involving such a treatment is absent in most of these countries. Therefore, the best means of controlling this disease is through breeding disease-resistant cultivars. To achieve this, it is necessary to avail effective selection for disease resistance in segregating populations, preferably starting at the F_2 .

Satisfactory infection levels have been achieved through artificial inoculation, using the sandwich method (Houston and Oswald 1948) or by inoculating the florets (Suneson 1950). However, these methods

are only feasible for a few crosses, and in order to handle a greater number, as usually available in breeding programs, a new method for infecting large numbers of F_1 plants should be developed, to allow selection at F_2 .

Therefore, an experiment was conducted with both F_1 plants and pure lines to see if large numbers of plants could naturally be infected. A few methods of artificial inoculation were also employed. Thus a technique has been developed to allow natural infection to occur during all stages of spike development.

Materials and Methods

1. Collection of spreader for *H. gramineum*
Infected heads with mature grains were collected from plants of the susceptible line U. Sask. 1766/Api from Beja during the 1981/82 season. Seeds were stored for planting next season.

2. Planting of F_1 nursery
In 1982/83, an F_1 nursery of 129 crosses consisting of 20-30 plants of each cross was planted at Beja (two rows x 1.5 m) and the infected seeds (spreader) were grown in two rows around each plot of this nursery to permit natural infection. Seeds of each of Roho, a resistant cultivar, and Ky63-1294, a susceptible one, were also planted with the F_1 nursery and surrounded by the same spreader, to compare the efficiency of natural versus artificial inoculations.

3. Inoculation

The F₁ plants were subjected to natural infection. For Roho and Ky63-1294, 30 spikes each at the same stage of development were tagged 2-3 days after pollination and then divided into three equal groups. The spikes of the first two groups were inoculated artificially by cutting and removing the upper third of the glumes and then spraying with a spore suspension of *H. gramineum* collected from leaves of the spreader plants. The heads of the first group were then covered by glycine bags while in the second group heads were left uncovered. The heads of the third group remained under natural infection. All heads of the three groups as well as those of the F₁ nursery were harvested in late May 1983.

4. Planting of F₂ nursery

Only 48 crosses were then planted as F₂s in early December 1983 at Beja and El-Kef, Tunisia. One hundred seeds of each of Roho and Ky63-1294 were planted early December in a nursery at INRAT, Ariana, Tunisia.

The total number of plants showing disease symptoms was counted during January and February for the above two lines, whereas the incidence of the disease in F₂s was scored in late March.

Results and Discussion

At Beja in the 1982/83 season, most of the spreader

plants around the F₁ nursery developed stripe symptoms with profuse sporulation on the leaves. This provided a source of continuous inoculum for infecting the plants at all stages of head development.

Teviotdale and Hall (1976) reported that the low temperature (6-12°C) for 28 days during germination of the infected seeds, is the key factor affecting symptom development of this disease. In this study although the soil temperature was not measured, the prevailing air temperature during December 1983 and January 1984 at Beja and El-Kef (Table 1) seemed favorable for symptom development.

Results for the variety Ky63-1294 show that 46.7 and 45.5% of the germinated plants showed stripe symptoms, resulting from natural and artificial inoculation (uncovered spikes), respectively (Table 2). Under natural infection, Roho showed no symptoms and under artificial inoculation it showed a very low percentage of infection. Moreover, for Ky63-1294, infection was reduced by 38.9% when artificially inoculated spikes were covered by glycine bags. This may be due to the effect of high temperature on spore germination and/or the infection process inside the bags, or because of the protection of florets from further infection during the later stages of head development.

The F₂ populations arising from F₁ plants showed different reactions to stripe disease. Out of 48 F₂

Table 1. Average temperature (°C) during December 83, and January and February 84, at Beja and El-Kef.

Location	December 83		January 84		February 84	
	Min.	Max.	Min.	Max.	Min.	Max.
Beja	5.8	15.9	4	14	3.8	13.8
El-Kef	3.3	13.4	1.5	12.5	1.7	12

Table 2. Incidence of stripe disease in naturally and artificially inoculated plants, under Ariana conditions, Tunisia, 83/84.

Variety or cross and pedigree	Natural infection	Artificial inoculation	
		Covered spikes	Uncovered spikes
Ky63-1294			
Total tested plants	90	72	66
Striped plants (%)	46.7	27.8	45.5
Roho			
Total tested plants	95	96	85
Striped plants (%)	0	2.1	4.7

populations, 10 showed a high incidence, 17 moderate, and the remaining were free. This allowed an effective selection for resistance between and within families at both Beja and El-Kef stations (Table 3).

These results show that the level of natural infection, when the source of inoculum is abundant, is not maximal but very similar to that of artificial inoculation when the florets are uncovered.

Moreover, the level of natural infection in the F₂ plants is not maximal but the presence of striped plants in these populations as well as the use of spreader around and inside the populations will ensure reasonably high infection to allow further selection in the following generations. Consequently, by reaching the stage of advanced generations, a high percentage of susceptible plants will be eliminated.

Since the infection of florets can occur at any stage of spike development from boot to the soft dough stage (Teviotdale and Hall 1976), and because of the great variation in heading time between and within families, the natural floret infection was proposed as a method to provide continuous release and dissemination of spores of *H. gramineum* which could ensure infection in the different stages of spike development. This method is easy to use, practical, and does not induce the spores into the florets, thus avoiding breaking the probable

Table 3. Incidence of barley stripe disease in some crosses of the Tunisian F₂ population planted at El-Kef and Beja, Tunisia, during 1983/84.

*Crosses free from stripe disease:

HP 119-7/3/Api/CM67//1454
 Mari/CM67//weah
 VDC1/Minn 126/CM67
 Bco. Mr/Arizona 5908/Aths
 CI 7207/011i/Arizona 5908/Aths

*Crosses with moderate incidence of stripe disease:

Beecher/Arizona 5908/Aths
 Beecher/3/Nopal//Api/CM67
 Arizona 5908/Aths//Dickson 628
 Arizona 5908/Aths/3/11012.2/ Impala/Birence
 Arizona 5908/Aths/3/As46/Giza 120//1106/Giza 118

*Crosses with high incidence of stripe disease:

Ky63-1294/Minn480/Gva
 Api/CM67/4/MEH 111.4/3/Apm/Dwarf 21/Por/IB65
 CN 100/0623/Fun/2*Fun/3/Tra/4/10925-1/5/Heines
 standard

morphological and/or mechanical resistance in some genotypes.

However, to be more efficient, spreader varieties should represent early, medium, and late types, and should preferably be tall varieties, and collected from different sites to ensure a wide spectrum of virulences.

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Survey of Fungal Diseases of Barley in North and Central Jordan

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Barley production has been confined to northern and central regions of Jordan. In 1983 the area cultivated to barley was 48654 ha all of which are grown in rainfed areas (Anonymous 1984).

Yield of barley in Jordan is among the lowest in the world, with an average of 400 kg/ha a year (Anonymous 1984). Unimproved cultivars, prevalence of hot dry weather, erratic rainfall, poor soil moisture conservation, poor seed-bed preparation, and lack of nutrients are major contributors to low yields. Heavy infection by diseases and lack of control measures also contribute to reducing yield. Diseases which attack barley in Jordan have been reported by Vestal (1954), Qasem (1970), Show *et al.* (1979), and Mamluk *et al.* (1984). This study is the first attempt in Jordan to assess such diseases on a local cultivar, Deir Alla 106, and to identify methods of their control.

Materials and Methods

In 1984/1985 an experiment was conducted at northern and central regions of Jordan which, respectively, occupy 43 and 38% of the total area under barley cultivation (Anonymous 1984). These regions represent different environmental conditions, particularly with respect to average rainfall which exceeds 350 mm, in the northern region and is only around 250 mm in the central region (Anonymous 1985).

Field inspection and sample collection were conducted in 20 locations in the barley-growing region. Disease evaluation was made at the growing stage (10 May) when all spikes are out of sheath, according to the growth stage key described by large (1954) and Anonymous (1976).

Disease incidence has been recorded as percentage of infected plants in the field. The sampling unit was 100 plants checked in each field in the laboratory, depending on the disease evaluation. The plants or leaves checked were collected from 10

different points selected at random on two diagonals of the field.

Severity of rust diseases was recorded as percentage of leaf area affected by each rust according to the scale of Peterson *et al.* (1948) and Loegering (1959). Severity of foliar diseases, other than rusts, was based on the percentage leaf area affected by the pathogen using the scales described by James (1971) and Saari and Prescott (1975).

Diseases were tentatively diagnosed in the field. Isolation and identification of the causal agents were performed in the laboratory. Identification was determined according to the characters of species reported by Barnett and Hunter (1972), Anonymous (1981), and Mathre (1982).

Results and Discussion

To obtain information on the incidence and severity of the prevalent diseases, average of separate assessments has been calculated for each region (Table 1). For convenience, the figures quoted in the Table for disease incidence are the average percentages of diseased plants in all inspected locations of each region. Figures of disease severity represent the average percentages of leaf area affected by the disease on assessed leaves of all locations in the region. Figures in parentheses are the range of infections.

The study revealed that all inspected fields of barley were infected with one or more fungal diseases. Eleven fungal diseases were found (Table 1). Black stem rust was the most severe disease recorded, followed by leaf scald. Next in importance came brown rust, powdery mildew, and yellow rust, while leaf stripe, blotch diseases, and smuts were present at relatively lower levels.

The ratio of north: central infection differs markedly for the diseases recorded. For black stem and yellow rusts it is approximately 3:2, and similarly for brown rust and smuts, while leaf scald and powdery mildew exhibited a ratio of approximately 2:1 which could significantly reduce yield of barley in the northern region. This difference in disease incidence can be correlated with the prevailing rainfall in the region. Such rainfall levels are more conducive to disease development. This is in agreement with the findings of Mamluk *et al.* (1984) on diseases of vegetables.

Certain new disease records have been reported on barley; namely septoria leaf blotch and net blotch.

Table 1. Incidence and severity of barley diseases in northern and central regions of Jordan in 1984/1985.

Disease	Causal organism	Number of infected fields		Average and range of disease incidence		Average of disease severity	
		North	Central	North	Central	North	Central
Black stem rust	<i>Puccinia graminis</i> Pers.	10	10	33.4 (13-100)	24.5 (4-100)	20.6	13.5
Brown rust	<i>Puccinia hordei</i> Otth.	10	8	18.2 (5-100)	16.6 (2-92)	15.1	14.8
Yellow rust	<i>Puccinia striiformis</i> West.	3	2	9.7 (7-31)	6.5 (4-9)	10.5	5.1
Covered smut	<i>Ustilago hordei</i> (Pers.) Lagerh.	3	5	1.3 (0-2)	1.4 (0-2)		
Loose smut	<i>Ustilago nuda</i> (Jens.) Rostr.	2	2	1 (0-1)	1 (0-1)		
Leaf scald	<i>Rhynchosporium secalis</i> (Oud.) Davis.	10	9	21.8 (3-42)	11.3 (2-26)	25.7	12.2
Powdery mildew	<i>Erysiphe graminis</i> DC.	7	5	15.5 (2-51)	8.5 (2-37)	13.4	7.6
Spot blotch	<i>Helminthosporium sativum</i> Pam.	3	1	6 (4-9)	2	10.5	8.7
Leaf stripe	<i>Helminthosporium gramineum</i> Rabh.	2	0	3.5 (2-5)	0	7.25	
Septoria leaf blotch	<i>Septoria passerinii</i> Sacc.	4	1	1.25 (1-2)	1	5	2
Net blotch	<i>Pyrenophora teres</i> Drechs.	2	0	2 (1-3)	0	5	

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- Three Wheat Resistance Genes, H5, H11, and H13, Effective against the Hessian Fly Mayetiola destructor (Say) in Morocco¹**
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- Hessian fly, *Mayetiola destructor* (Say), is the major insect pest of wheat in Morocco. Its damage to wheat may cause total loss of the crop (Anonym 1939). Its occurrence has been observed in all of the wheat-growing areas (Durand 1967; Elbouhssini 1981; Hatchett *et al.* 1984). Hessian fly also attacks barley, although the damage to barley is usually not severe (Anonym 1939). Since the use of insecticides and cultural practices are incompatible with the farming practices in Morocco, the use of resistant wheat varieties appears to be the only practical method for controlling this pest.
- The objective of this study was to evaluate the known Hessian fly-resistance genes in wheats for resistance to Hessian fly in Morocco, and determine whether any of the sources may be of value in breeding for resistance. Thirty-eight common wheats from the USA carrying all of the known resistance genes (Marquillo-Kawvale, H1H2, H3, H5, H6, H7H8, H9, H9H10, H10, H11, H12, and H13 plus 'Newton' and 'Bennett' as susceptible checks) were evaluated in both field and greenhouse tests. The wheats were evaluated at four field locations (Guiche, Marchouch, Sidi Kacem, and Sidi el Aidi), which were known to have high populations of the fly. Seeds were planted in 1 m rows (one entry per row) in the fall of 1984. Data were obtained from 63 entries at each location. The variables measured were the number of susceptible plants (stunted with dark blue-green leaves) and the

¹ Cooperative research of the MidAmerica International Agricultural Consortium (MIAC), University of Nebraska, Moroccan Dryland Farming Project, USAID Project No. 608-0136, the National Institute of Agronomy Research (INRA), Rabat, Morocco, Departments of Agronomy and Entomology, Kansas State University, and the US Department of Agriculture, Agricultural Research Service. Contribution No. 86-93-T from the Kansas Agricultural Experiment Station.

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Table 1. Summary of reaction of resistance genes in wheats to Hessian fly in Morocco, field tests¹, MIAC-INRA Project.

Resistance genes	Total no. of entries	Total no. of plants sampled	\bar{X} percent plants susceptible	\bar{X} no. of larvae per susceptible plant
Susceptible checks	32	1331	84.6	3.9
Marquillo-Kawvale	28	1238	75.7	3.6
H1H2	4	123	62.8	3.2
H3	24	959	75.1	3.3
H5	20	888	2.5	1.2
H6	28	1132	78.3	3.5
H7H8	8	345	34.9	2.5
H9	8	317	46.7	1.7
H10	8	344	81.8	3.6
H9H10	4	182	83.7	3.4
H11	4	173	3.0	0.8
H13	84	3074	4.8	1.3

¹ Sidi el Aidi, Guiche, Marchouch, and Sidi Kacem.

Table 2. Reaction of resistance genes in wheats to Hessian fly in Morocco. Greenhouse test - INRA, Department of Plant Pathology and Entomology, Rabat. MIAC-INRA Project.

Resistance genes	No. of entries	Total no. of plants	% plants susceptible	\bar{X} no. of larvae per susceptible plant
Susceptible checks	17	269	87.0	5.0
Marquillo-Kawvale	2	32	81.3	6.3
H1H2	1	20	85.0	2.8
H3	2	29	72.4	5.0
H5	2	25	0.0	0.0
H6	3	47	70.2	4.8
H7H8	1	14	14.3	1.0
H9	1	16	18.8	0.7
H10	1	17	82.4	6.3
H11	1	13	0.0	0.0
H12	1	17	64.7	3.3
H13	21	338	1.2	5.5

number of larvae per susceptible plant. The resistant plants were dissected and observed for the presence of dead larvae to verify resistance.

The greenhouse test consisted of 25 entries, also representing the known resistance genes and Newton as the susceptible check. The method of testing was similar to that described by Cartwright and LaHue (1944). As in the field test, the percentage of susceptible plants and larval density was estimated. Also, resistant plants were dissected and observed for the presence of dead larvae to confirm resistance.

Results of the field tests (Table 1) corroborated those of the greenhouse test (Table 2) in showing that wheats having the H5, H11, and H13 genes were highly resistant. In field tests, the mean percentages of susceptible plants for H5, H11, and H13 genes were 2.5, 3.0, and 4.8, respectively, and the mean numbers of larvae per susceptible plant were 1.2, 0.8, and 1.3, respectively, both of which were significantly different ($P < 0.05$) from the susceptible checks. Several dead first-instar larvae were recorded on the resistant plants carrying these genes, an indication of their high level of

antibiosis. In the greenhouse test only a few H13 plants were susceptible (1.2%), whereas all H5 and H11 plants showed complete resistance.

Wheats having H7H8 and H9 resistance genes were moderately resistant. The mean percentages of susceptible plants for H7H8 and H9 genes were 34.9 and 46.7 in the field and 14.3 and 18.8 in the greenhouse, respectively. They also had a lower number of larvae per susceptible plant, 2.5 and 1.7 in the field and 1.0 and 0.7 in the greenhouse.

Results of these tests indicated that only H5, H11, and H13 resistance genes would be effective in breeding wheats for resistance to Hessian fly in Morocco. These genes are now being incorporated into Moroccan bread and durum wheats.

Difference in the reaction of some genes at different locations was also detected. This indicates that the frequency of virulence in fly populations may differ at each location. Thus, additional sources of resistance will be needed to protect against possible development of virulent biotypes.

Effect of Leaf Rust on Grain Yield and Kernel Weight of Spring Wheat

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Widespread use of disease resistant/tolerant varieties of wheat in the wheat-growing countries of the world has been of enormous benefit in reducing losses, improving yield, and stabilizing production over the past 50 years. However, the danger of losses from disease epidemics in wheat varieties will continue to persist due to comparatively shorter life of resistant commercial varieties grown in Pakistan. When a high-yielding variety with good rust resistance is released to farmers, it outyields the existing varieties and therefore spreads soon over a large area to the exclusion of most of the other varieties. The changes of a new race of rust to appear at this juncture cannot be eliminated. If a new race of rust appears, the crop of the entire area (sown under such one variety) becomes susceptible. In years of favorable weather for the development of rust, an epidemic occurs and a disaster can result (Borlaug 1978). Consequently in the absence of resistant varieties, only those susceptible varieties should be recommended which suffer less in the

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epiphytotic conditions in the experimental plots, because the losses in such varieties during epidemic years under ordinary farm conditions would be much less.

Sambroski and Peturson (1960) reported 12 - 28% reduction in grain yield of resistant wheat varieties under epiphytotic conditions. Planned experiments of several workers (Peturson *et al.* 1948; Aujla *et al.* 1976; Akhtar *et al.* 1980) have indicated significant decrease in yield of susceptible varieties due to leaf rust. These losses mainly occurred due to reduction in kernel weight (Peturson *et al.* 1945); Forsyth and Peturson 1958; Aujla *et al.* 1976).

According to Peturson *et al.* (1945) the stage of development reached by the plants before rust becomes severe determines whether reduced kernel production or reduced kernel weight is responsible for the major reduction in grain yield. Sambroski and Peturson (1960) reported that when leaf rust is severe at a very early stage of plant development, reduced kernel production becomes an important factor in reducing the yield of a susceptible variety. The present investigation was undertaken to determine the extent of losses in grain yield under artificial infection by leaf rust.

Materials and Methods

Leaf rust reaction of the wheat varieties included in the experiment was observed for more than 1 year;

Table 1. Extent and pattern of leaf rust development on 10 wheat varieties, 1982/83.

Variety	Treatment	Intensity of leaf rust infection				
		Mar 13	Mar 22	Apr 3	Apr 14	Apr 24
Highly susceptible						
SA-42	Sprayed	5S	0	0	0	0
	Unsprayed	5S	40S	100S	100S	
Punjab-76	Sprayed	TS	0	0	0	0
	Unsprayed	TS	25S	60S	80S	
Susceptible						
Barani-79	Sprayed	5S	0	0	0	0
	Unsprayed	5S	20S	40S	40S	
SA-75	Sprayed	TS	0	0	0	0
	Unsprayed	TS	10S	20S	25S	
Pothowar	Sprayed	TS	0	0	0	0
	Unsprayed	TS	10S	25S	25S	
Moderately susceptible						
Nacozeni	Sprayed	TMS	0	0	0	0
	Unsprayed	TMS	10MS	20MS	25MS	
CB-132	Sprayed	TMS	0	0	0	0
	Unsprayed	TMS	10MS	20MS	20MS	
V-1283	Sprayed	TMS	0	0	0	0
	Unsprayed	TMS	10MS	25MS	25MS	
Moderately resistant/ resistant						
CB-95	Sprayed	TMR	0	0	0	0
	Unsprayed	TMR	5MR	10MR	10MR	
Pak-81	Sprayed	0	0	0	0	0
	Unsprayed	0	0	0	0	0

these were accordingly grouped into highly susceptible (SA42 and Pb76), susceptible (B79, SA75, and Pothowar), moderately susceptible (Nacozeni, CB+132, and V1283), and moderately resistant/resistant (CB-95 and Pak-81). These varieties were planted on 25 November 1982 in a split block design replicated three times in plots each measuring 3 m x 1 m with varieties in "main plots" and fungicide sprays in "subplots." The experiment was fertilized with 84-84-0 kg/ha of N, P₂O₅, and K₂O at seeding. To create the leaf rust epidemics the border rows of the experimental area were planted with a mixture of susceptible varieties and were artificially inoculated with the mixture of leaf rust races on 13 February 1984. The rust-free plots were established by spraying Bayleton-25 at 1235 g/ha at a stage when pustules of leaf rust had appeared in the plots. The Bayleton spray was repeated after 10 days of the first spray. Infection type was recorded for

each variety from 13 March to 14 April 1983. The leaf rust incidence was estimated according to the Modified Cobb Scale (Leogering 1959). At maturity, 1 m² area was harvested from every plot and data were recorded on grain yield and 1000-kernel weight and analyzed according to statistical procedures described by LeClerge *et al.* (1966).

Results and Discussion

The extent and pattern of leaf rust development under unsprayed and sprayed conditions and the coefficient of rust infection of the test varieties are summarized in Tables 1 and 2. Results for 1000-kernel weight and grain yield are presented in Tables 3 and 4, respectively.

Leaf rust inoculum developed late in the growing season, but its subsequent development on highly susceptible varieties was rapid and reached the

Table 2. Coefficient of infection for leaf rust in sprayed and unsprayed treatments at WRI, Faisalabad, 1982/83.

Variety	Coefficient infection	
	Sprayed	Unsprayed
Highly susceptible		
SA-42	5.0	100
Punjab-76	1.0	80
Susceptible		
Barani-79	5.0	40
SA-75	1.0	25
Pothowar	1.0	25
Moderately susceptible		
Nacozari	0.8	20
V-1283	0.8	20
CB-132	0.8	16
Moderately resistant/ resistant		
CB-95	0.4	4
Pak-81	0.0	0

levels of 100 and 80% on SA-42 and Punjab-76 (highly susceptible), respectively. In case of susceptible varieties (Barani-79, SA-75, and Pothowar) it may be seen that they carried comparatively low infection in inoculated plots, from 10S to 40S. Intensity of rust incidence in moderately susceptible varieties (Nacozari, CB-132, and V-1283) did not exceed 25MS.

There were significant effects on grain yield due to varieties, treatments, and their interaction. The resistant varieties Pak-81 and CB-95 yielded significantly better than all other varieties (Table 4).

On an average basis sprayed plots yielded significantly more than rusted or unsprayed plots (4680 vs 3704 kg/ha). Highly susceptible varieties SA-42 (100S) and Punjab-76 (80S) suffered grain yield losses of 50.2 and 46.1%, respectively. Reduction in grain yield of Barani-79, SA-75, and Pothowar was 21.2, 18.8, and 26.2%, respectively. Varieties showing moderate susceptibility to leaf rust recorded decrease in grain yield of 20.5 and 18.9%, and Pothowar suffered appreciable reduction of 22.08% in kernel weight and 26.2% in grain yield. This demonstrated the ability of leaf rust to cause important damage even when present at only a moderate infection level. Small reductions as observed in

Table 3. 1000-kernel weight of test varieties in sprayed and unsprayed treatments, 1982/83.

Variety	1000-kernel weight (g)		Yield loss (%)
	Sprayed	Unsprayed	
Highly susceptible			
SA-42	38.8	24.4	37
Punjab-76	35.5	21.1	41
Susceptible			
Pothowar	30.8	24.0	22
SA-75	36.8	31.4	15
Barani-79	27.7	22.6	18
Moderately susceptible			
Nacozari	39.7	32.6	18
CB-132	39.9	34.5	14
V-1283	37.6	34.0	10
Resistant/ moderately resistant			
CB-95	41.2	38.8	6
Pak-81	40.0	39.2	2

	Varieties (V)	Treatments (T)	V x T
LSD 0.05	0.651	0.942	0.87
LSD 0.01	0.892	2.174	1.19

V-1283, SA-75, and CB-132 would remain undetected or in the lower proportions under field conditions. In the absence of resistant varieties, such varieties having less reduction in yield should be recommended for general cultivation. They seem to possess a certain degree of field tolerance.

Varieties showing moderately susceptible reaction to leaf rust showed decrease of 10-21% in yield. Considerable reduction in grain yield of moderately susceptible/highly susceptible varieties has also been reported by Peterson *et al.* (1945), Forsyth and Peterson (1958), and Rowell (1973). On the other hand, losses in grain yield of resistant varieties CB-95 and Pak-81 were only 4 and 2%, respectively. Sambroski and Peterson (1960) reported 12-28% loss in yield of resistant varieties in epidemic conditions. However, our observations do not agree with their findings which could be attributed to the variation

Table 4. Effect of leaf rust on grain yield of wheat varieties at the Wheat Research Institute, Faisalabad, Pakistan, 1982/83.

Variety	Yield (kg/ha)		Yield loss (%)
	Sprayed	Unsprayed	
Highly susceptible			
SA-42	3930	1953	50
Punjab-76	4833	2603	46
Susceptible			
Pothowar	4376	3226	26
Barani-79	4490	3536	21
SA-75	4423	3590	19
Moderately susceptible			
CB-132	5110	4143	19
Nacozari	4730	4093	14
V-1283	4476	4036	10
Moderately resistant/ resistant			
CB-95	5043	4823	4
Pak-81	5230	5166	1
Mean	4664.1	3716.9	

	Varieties (V)	Treatments (T)	V x T
	LSD 0.05	94.71	5.11	107.22
LSD 0.01	285.05	31.06	652.39

in the material used as well as the time, level, and duration of infection. Similarly, highly significant differences were recorded among varieties, treatments, and their interaction for grain weight of HS, S, MS, and MR/R varieties (Table 4).

In view of the appreciable losses suffered by the susceptible varieties in the present study, it would be most desirable to make resistant varieties available to wheat growers in Pakistan and elsewhere.

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Evaluation of Wheat Germplasm for Salt Tolerance

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Germplasm of crop plants has a considerable genetic plasticity (Shannon 1978) and the importance of making germplasm collections and their utilization has been generally recognized (Frankel 1970; Konzak and Dietz 1969; Krull and Borlaug 1970; Holcomb *et al.* 1977). Modern varieties have narrow genetic base and adapt poorly to adverse environments such as salinity (Manning 1955). However, the endemic genotypes from similar environments may provide basic germplasm for breeding salt-tolerant varieties with acceptable yield potential (Frankel 1970).

Table 1. Characteristics of salt-tolerant accessions with their original locations and habitats, 1977-79, Pakistan.

Accession No.	Location	Altitude (m)	Growth habit	Type of habitat of sample
4	Chingali	640	Erect	Mixed population from lodged crop
11	Dandar	600	do	
77	Chamtalai	1140	do	mixed population
92	Al-puray	1550	do	Dry field
107	Malikpur	860	do	Loamy clay soil, somewhat sloppy
109	Malikpur	860	do	do
119	Behrain	1500	do	Mixed population irrigated with highly saline water
124	Borlai		do	Sandy loam soil
140	Turen Kuzhu	1680	do	do
396	Reshum	1980	do	Sandy loam soil
398	Reshum	1980	do	do
578	Gobar	2930	do	Sandy soil
716	Mirdin	2920	do	do
788	Rabat	2600	do	Loamy soil
829	Shandsa desh	1890	do	do

This paper reports the results obtained from a study on evaluation of primitive wheat germplasm for salinity stress.

Materials and Methods

The endemic wheats collected during the 1976 Netherlands/Pakistan Expedition were screened for salt tolerance. The original wheat collections which comprised the composite populations have been used to develop pure lines. Details of the locations along with growth habit of the promising accessions are given in Table 1. These selections were further tested and evaluated during 1977/78 and 1978/79. Thirty-seven single-plant selections were grown in artificially salinized cemented field basins (6 x 6 x 1 m) at NIAB. The soil of the basins was saline sodic=pH 9.0, EC 15.9 mmhos/cm at 25°C and ESP 48.5. The desired salt level was achieved by irrigating the field basins with tubewell water (saline sodic), containing TSS=35, HCO₃=17.5, Ca⁺⁺ + Mg⁺⁺ = 4.8, Na⁺ = 30.2 meq/l, SAR = 19.5

Simultaneously these single-plant selections were grown as control under normal field conditions where pH=7.5, EC=1.9 mmhos/cm at 25°C and ESP 12.0. The control field was irrigated with canal water with the following characteristics: TSS=2.9, HCO₃=0.75, and Ca⁺⁺+Mg⁺⁺=1.95, Na⁺=0.95 meq/l, and SAR =0.97.

The single-plant selections were grown in the ear-to-row fashion in 3 m long rows with 30 x 15 cm spacings. The experiment was laid out in a randomized complete block design with four replications. At maturity, data on plant height and productive tillers/plant were recorded. Ten plants/replication were randomly selected for recording various observations. Data on various spike characters were recorded in the laboratory using the main tiller from each plant. The data were statistically analyzed and coefficients of correlation were computed among various plant attributes from the crop grown at both normal and saline fields.

Results and Discussion

The correlation coefficients between various characters both under normal and saline conditions are presented in Table 2. Plant height showed a negative correlation with number of grains/spike and yield/plant in both environments.

Number of productive tillers/plant did not show any association with other characters at either fields. Spike length showed a significant positive correlation with number of spikelets/spike under both the growing conditions. The association of spike length with other characters was not so conspicuous. Number of spikelets/spike showed significant negative correlation with spike fertility under salt stress

Table 2. Coefficients of correlation among various characters of pure lines developed from primitive wheats under normal and saline sodic conditions, 1977-79, Pakistan.

Character	Productive tillers/plant	Spike length (cm)	Spikelets/spike	Spike fertility	Grains/spike	1000-grain weight (g)	Yield/plant
Plant height	0.29	0.00	0.08	-0.30	-0.59**	0.31	-0.46**
	0.25	0.08	-0.05	-0.40*	-0.70**	0.30	-0.36*
Productive tillers/plants		-0.21	-0.19	0.17	-0.28	-0.29	0.23
Spike length		-0.30	-0.25	0.20	-0.16	-0.27	0.20
			0.37*	-0.27	0.39*	0.26	-0.26
			0.49**	-0.56**	-0.19	0.24	-0.43**
Spikelets/spike				-0.15	-0.13	0.24	-0.24
Spike fertility				-0.60**	-0.08	0.26	-0.32
					0.34*	0.39*	0.55**
					0.68**	0.37*	0.73**
Grains/spike						0.51*	0.52**
						0.50**	0.44**
1000-grain weight (g)							0.66**
							0.76**

* P < 0.05; ** P < 0.01

Note: In each case figures in the upper row represent values for normal field-grown crop and those in the lower row represent values for stress conditions.

Table 3. Average and range values of different attributes of endemic wheats under saline and normal conditions, 1977-79, Pakistan.

Morphological character	Average		Range values	
	Control	Stress	Control	Stress
Spike length	11.5	12.1	9.4-14.1	10.2-15.0
Spikelets/spike	21.2	21.6	16.6-26.8	18.4-27.0
Spike fertility	94.3	84.3	55.6-99.9	44.8-98.0
Grains/spike	55.4	55.0	30.8-89.0	15.8-87.5
Yield/plant (g)	13.7	7.8	2.3-28.0	0.6-22.5
1000-grain weight (g)	25.5	10.2	12.0-50.0	6.0-30.0

only. Spike fertility showed a significant positive correlation with number of grains/spike, 1000-grain weight, and yield/plant under both the growing conditions. Number of grains/spike showed

significant positive correlation with 1000-grain weight and yield/plant. Thousand-grain weight showed the highest positive correlation with yield/plant under the two environments.

Table 4. Effect of salinity on different morphological characters of endemic wheat selections.

Accession No.	Spike length (cm)	Spikelets/spike	Spike fertility	Grains/spike	1000-grain weight (g)	Yield/plant (g)
4	10.2f (1)**	19.9ef 1.4(3)	91.1de 6.4(-6)	49.9f 6.5(9)	10.5gh 1.1(-40)	8.9fg 2.7(-46)
11	10.2f (-1)	19.8f 0.5(4)	98.0a 2.0(-2)	53.9f 8.1(-12)	10.2h 1.3(-38)	14.6b 4.1(-49)
109	12.5bc (4)	20.5def 1.3(1)	95.3abc 2.2(-1)	51.9f 5.4(-2)	12.2f 2.0(-27)	10.5e 3.5(-25)
7	11.9d (7)	21.9bc 1.1(4)	89.8def 5.4(-10)	82.6b 5.8(33)	12.4f 2.5(-36)	8.5gh 2.6(-35)
92	12.8b (15)	18.4g 1.6(11)	95.6ab 3.1(-4)	44.4g 7.3(-27)	12.5ef 1.6(-6)	22.5a 3.5(-8)
107	11.7de (-8)	21.2cd 1.5(-3)	87.4f 11.8(-9)	67.2b 15.7(-10)	14.0d 1.4(-19)	12.3c 6.2(-21)
119	12.4bc 0.8(2)	23.0b 1.1(6)	92.7bcd 7.1 (-7)	83.3a 12.4(17)	15.2c 2.2(-4)	12.2c 5.1(-8)
124	10.3f 0.4(8)	20.1def 0.8(4)	96.6a 3.2(-3)	52.2f 7.2(11)	11.0g 2.4 (-20)	10.4e 3.5 (-43)
140	13.6a 0.5 (21)	26.6a 0.9 (14.1)	49.9h 7.6 (-48)	29.7i 6.2 (-31)	12.9e 1.4 (-40)	2.4k 2.6 (-44)
396	12.8b 0.5 (13)	21.0cd 0.4 (-14)	83.8g 2.6 (-6)	38.0h 5.6 (-31)	13.0e 1.4 (-30)	5.0i 1.4 (-35)
398	12.1cd 0.7(12)	20.7de 1.8(3)	92.1cde 3.8 (-6)	64.3de 10.2(23)	16.0b 2.1(-26)	8.0gh 6.2 (-43)
578	11.9cd 0.8 (-2)	22.0bc 1.3 (11)	89.0ef 8.5 (3)	77.4c 11.8(27)	11.0g 1.4 (-10)	9.2f 2.6 (-29)
716	11.2e 0.6 (7)	21.3cd 3.6 (7)	96.3a 2.6 (-3)	60.4e 9.2 (-3)	10.8g 1.7 (-35)	11.4d 3.9 (-45)
788	11.6de 2.1(-13)	20.5def 3.0(-17)	83.2g 13 (-5)	52.3f 15.1 (25)	40.1a 2.2 (1.0)	3.7j 0.9 (6)
829	12.8b 0.9(7)	22.8b 1.2 (10)	95.6ab 2.2 (15)	87.5a 2.2 (23)	10.2h 2.4(-40)	2.8k 3.6(-49)

* Mean values in saline field means followed by the same letters and not significantly different at the 5% level.

** Values between parentheses indicate percent decrease/increase below/over control.

Plant attributes which have shown tight association with yield under both the environments were 1000-grain weight, spike fertility, and number of grains/spike. These attributes may be used as indices for selecting salt-tolerant genotypes in wheat. Giriraj *et al.* (1980) and Shakoor *et al.* (1978) also advocated the use of such selection criteria for screening wheat germplasm for salt tolerance.

Mean values of various plant characteristics under study in both the environments are presented in Table 3. Thousand-kernel weight and grain yield/plant were the traits most affected by salinity. A few relatively salt-tolerant genotypes have been selected and presented along with their characteristics in Table 4. Although substantial genotypic differences were observed for all traits, 1000-grain weight and grain yield/plant were consistently reduced by salinity.

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Genetic Diversity for Salt-Stress Resistance of Wheat in India

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Soil salinity and alkalinity problems affect nearly three million hectares in the Indo-gangetic plain and northwestern India where wheat is the preferred winter crop and faces more severe stress as compared to rainy season crops such as rice. Expanding use of underground waters of marginal quality for irrigation together with inadequate drainage measures and poor water management practices in canal command areas

also pose serious salt hazards. Successful wheat cultivation in these degraded land categories and stabilization/improvement of wheat yields in partially affected fields demand that wheat varieties for these situations should possess adequate level of salt-stress resistance in addition to having other desirable traits.

The challenging job of genetically modifying the plant for better adaptation to salt-affected soils is being actively carried out at the CSSRI through interdisciplinary efforts applying classical genetics in combination with modern techniques. An integrated plan to indicate the approach is outlined in Table 1. Pace of progress and ultimate success of such breeding projects, however, depends upon the magnitude of available genetic variability as well as heritability of plant characteristics that contribute

Table 1. Integrated approach to breeding wheat varieties for salt stress resistance.

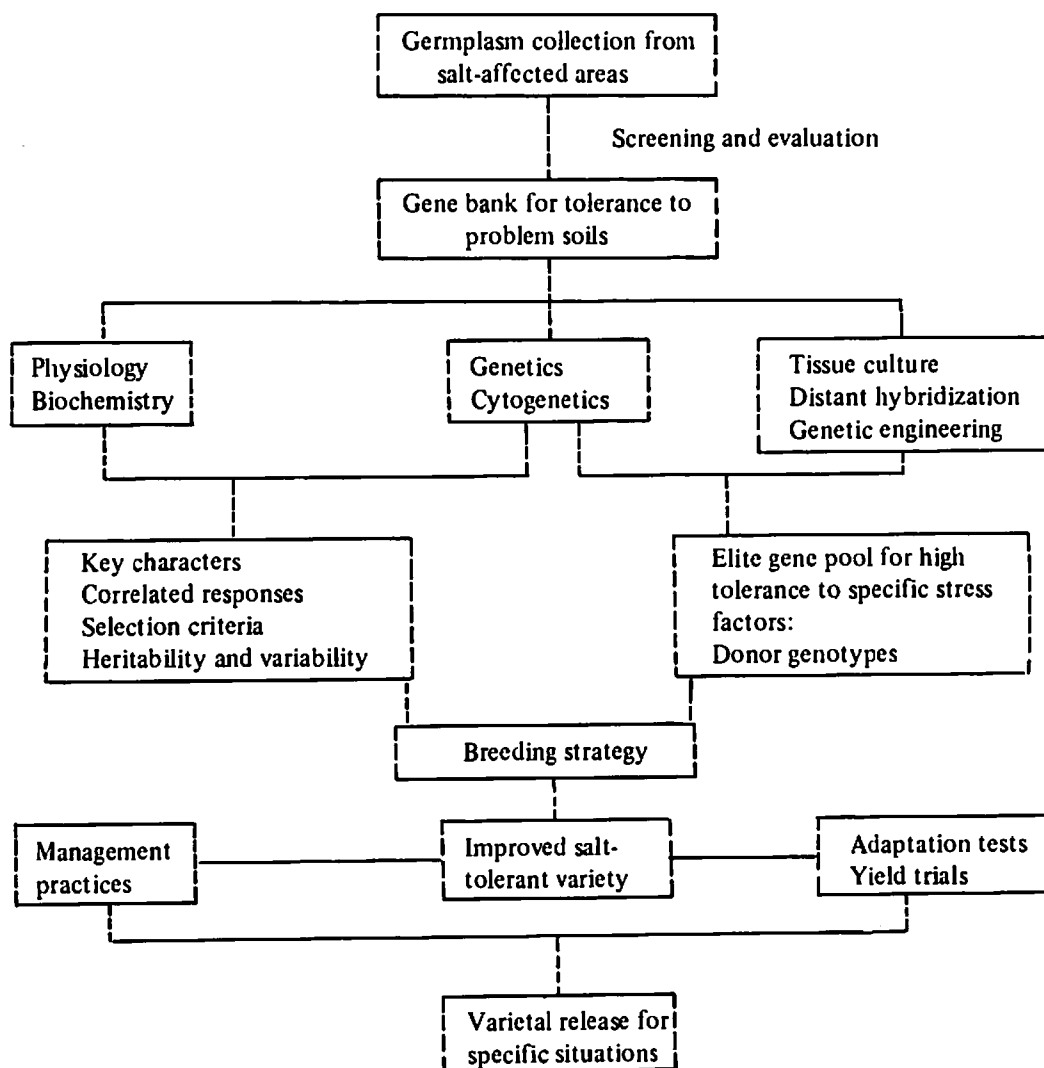




Fig. 1. Wheat material under study in the Division of Genetics and Plant Pathology.

to salt resistance, availability of reliable selection criteria, and efficiency of screening techniques employed for identification of desired genotypes in germplasm collection and segregating populations. It is also equally essential to begin with a clear working definition of the notion of salt-stress resistance in plants.

Concept and Measurement of Salt-Stress Resistance (SSR)

The SSR denotes a relative rating of the plant's response to a given level of stress under stated soil and climatic conditions. The expression of SSR depends upon numerous variables relating not only to the plant itself (such as the genotype, ploidy level, growth stage, and days to maturity) but also to the soil status (including texture, topography, fertility, depth of groundwater table, irrigation schedule, and water management) and to the atmospheric conditions (temperature, humidity, light, rainfall, wind, and pollution, etc.). More specifically, the SSR reflects the plant's ability to prevent, reduce, or overcome the possible injurious effects caused directly or indirectly by the presence of excessive soluble salts/toxic ions in its root zone. It follows that the SSR mechanisms present in

the plant result in a measurable increase in the level of soil stress required to produce a specified quantum of strain in the plant as measured by visible injury like foliar damage or 50% reduction in germination, growth, yield, and survival. Likewise, these mechanisms also lead to a decrease in the quantum of strain caused by a specified level of the stress factor. Both these considerations form the basis of our studies at the CSSRI.

Difference between less favorable and toxic edaphic environments also needs to be identified. Whereas unfavorability indicates simply a slowing down of the plant's metabolism because of deficiency (limiting effect) of water/nutrient ions, as occurs under conditions of drought or low fertility. Toxicity involves excess of specific ions that interfere actively with the plant's metabolism as happens largely in case of alkali and saline soils. Furthermore, toxicity affects not only the plant's ability to acquire resources by way of the acquisition of water, nutrients, CO₂, and light energy but also influences its ability to utilize these resources through inhibition of enzyme action, cell division, loss of respiratory substrates, etc. Several of these aspects are under investigation in the Division of Genetics and Plant Physiology at the CSSRI (Fig. 1).

There is a growing evidence that SSR and yielding ability of any variety are two independent characteristics. Comparison of SSR ratings should thus involve computation of indices (based on reductions caused by predetermined discriminatory level of stress in relation to corresponding controls grown in nonstress soil conditions) rather than the direct comparison of *per se* values of growth and yield parameters. Salinity response curves are also employed for comparing SSR ratings based on two considerations, namely, the maximum salinity level that does not cause any significant yield reduction and the yield decrement (%) per unit (dS/m) increase in salinity beyond that level.

Screening Technique

Our studies have shown that varietal responses observed under nutrient solution culture in trays or in salinized pots do not reflect the performance under field conditions. On the other hand data obtained from lysimeter-type testplots suitably filled with desired grades of alkali or saline soil have been found to be well correlated with those collected from satisfactorily conducted field experiments. Forty genotypes can be evaluated critically under comparable conditions in one of such testplots measuring 6 x 3 m (with a provision for drawing leached soil water samples at a depth of 1 m) with row length of 1.25 m and spacings of 30 cm between rows (Fig. 2). Under soil and climatic conditions prevailing at Karnal, soil PH_2 of 9.3 and exchangeable soil percentage of about 35 in case of alkali (sodic) soil stress and root zone EC_e around 10 dS/m in case of salinity stress have been found to be the most discriminatory for resolving meaningful varietal differences in wheat material regarding resistance to these soil environments.

Selection Methodology

Adaptation to saline and alkali soil conditions appears to be the consequence of favorable interaction among many coadapted gene complexes, implying that selection for the yield alone may be inefficient. Additional selection criteria may improve selection efficiency if sound and easily measurable indices can be developed.

Grain yield of cereal crops is proportional to the product of biomass (i.e., growth rate x growth duration) and harvest index. Selection for harvest index has been found to be much more efficient as

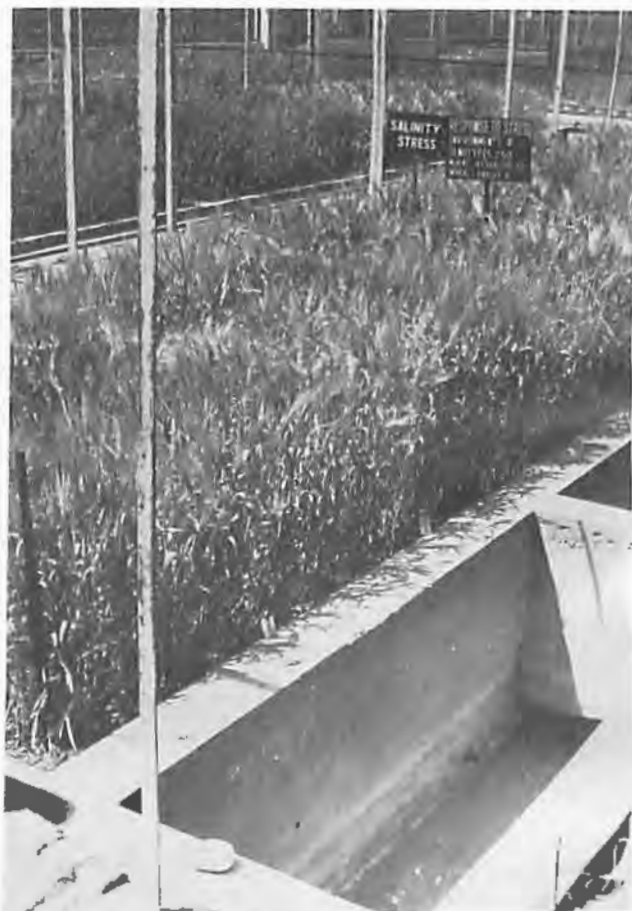


Fig. 2. Comparative study of varietal response to soil salinity and alkalinity (sodicity) under monitored conditions in lysimeter-type testplots.

compared to selection for grain yield itself where the selection objective was high grain yield under high yield environments but the situation in breeding for improved grain yield under salt-stress environments has been shown to be entirely different. A study of genotypic correlations of 14 characteristics with grain yield in wheat (Table 2) illustrates this point by showing that vegetative growth index, obtained by dividing the biomass minus grain yield by number of days to heading, had a stronger association with yielding ability under salt-stress as compared to harvest index. These data indicate that salt resistance index of wheat material may be improved by selecting on the basis of one parameter of vegetative phase (we use seedling growth rate in greenhouse and vegetative growth index under field conditions) and one parameter of the reproductive phase such as the spike weight and grain yield itself. Sequence as well as the most effective combination of selection intensities for these two

Table 2. Genotypic correlations of 14 characteristics with grain yield and salt-resistance index in wheat (N = 240; 20 varieties, 2 salinity levels, 3 replications, 2 years).

Characteristic	Correlation with	
	Grain yield	Salt resistance index*
Seed germination (%)	0.21	0.08
Seedling emergence rate	0.43	0.54
Seedling height (3 weeks)	0.48	0.24
Seedling growth rate	0.62	0.71
Mature plant height	0.52	0.39
Days to anthesis	0.12	0.09
Vegetative growth index	0.66	0.74
Ear bearing tillers/plot	0.23	0.35
No. of grains/plot	0.22	0.21
1000-grain weight	0.19	0.29
Spike weight	0.81	0.86
Straw weight/plant height	0.64	0.31
Biomass/plot	0.49	0.32
Harvest index	0.23	0.18

*Based on grain yield under salinity stress relative to that of control taken as 100.

selection criteria for obtaining maximum genetic advance for grain yield under salt stress, has been found to comprise 20% selection on the basis of reproductive phase criterion in the first instance followed by 40% reselection among the selected lines on the consideration of vegetative phase parameter. This results in an overall selection intensity of 8%. Our data have further shown that the tall indigenous cultivars having large total plant weight (biomass) have far superior adaptation to salt-affected soil conditions as compared to dwarf genotypes with high harvest index.

Genetic Resources Available

Average values of SY_{100} (threshold salinity level beyond which yield begins to decline significantly) and SY_{50} (salinity level causing 50% reduction in yield) for the wheat crop have been computed to be 7.5 and 12.4 dS/m, respectively. Corresponding values for soil alkalinity are pH_2 8.8 and pH_2 9.3. More significant, however, is the occurrence of nearly two fold varietal differences in this respect, supporting the feasibility of breeding wheat varieties best suited to specific situations of salt-affected areas.

Sizeable collections of wheat indigenous cultivars, still grown traditionally in different situations under little management care, have been made by the CSSRI. Critical evaluation of this material along with large stocks of germplasm built over the years revealed that the highest level of salinity-and alkalinity-stress resistance was identified in some of locally adapted cultivars of salt-affected areas. Outstandingly resistant material comprised red-grained tall selections from Kharchia wheats of Rajasthan and Rata wheats of Bhal tract of Gujarat. Three of these selections (KR 375, KR 385, and KR 387) are being used as donors for salt resistance in our recombination breeding program designed to combine superior salt resistance with reasonably good grain yield potential (Fig. 3). Performance of promising lines, emanating from this project, is being studied under well monitored soil conditions. Two selections developed earlier from a cross involving 'HD 2009' and 'Kharchia 65,' namely, CSW 538 and CSW 540 are now being tested for their performance under field conditions. Varieties 'WH 157,' 'HD 1982,' and 'HP 916' were found to have better resistance to alkali soil conditions than other high-yielding varieties though level of their tolerance is much lower than that noted in some of the KR selections.

Data on mineral analysis of plants growing in alkali soil have shown that superior resistance of KR lines to alkali soils is related to their strikingly better ability for potassium extraction under competition with sodium. It is not yet established, however, whether the higher potassium content in leaves indicates luxury consumption or confers nutritive advantage reflected in better grain yield. Our evaluation of a large number of both bread (hexaploids) and durum (tetraploids) wheat for tolerance to alkali soil conditions has also shown that the former group was notably far superior in this respect as seen from foliar injury as well as grain yield reductions.

Outlook

Traditional cultivars of salt-affected areas should be looked upon as elite sources of salt-stress resistance for modern wheat varieties designed for high-productivity environments. Genetic variability for such resistance currently available in wheat materials notwithstanding, there is a need to collect and evaluate more indigenous cultivars from areas where salt stress has been exerting selection pressure over long periods. Comparative study of



Fig. 3. Salt-tolerant Kharchia wheat selection no. KR 387.

closely related genotypes and near isogenic lines showing distinct heritable differences regarding salt-stress resistance is essential for elucidation of genetic control of varietal adaptation since this information will accelerate the on-going selection and breeding program.

Major genes controlling uptake/utilization of nutrients or exclusions of toxic ions have been reported in several crops, particularly in soybeans, tomato, and maize. Whereas resistance to specific ion effects in most cases shows a qualitative type of inheritance governed by a single or a few genes with major effects; tolerance to osmotic effects usually follows a quantitative type of inheritance with polygenic control. This situation obviously complicates the job of plant breeders engaged in combining superior salt-stress resistance with good yielding ability. Unfortunately, very limited basic research has been conducted so far on cereals under salt-stress environments.

Many wild relatives of wheats, growing naturally in salt-affected lands, show outstanding adaptation to saline environment. For example, diploid tall wheatgrass [*Elytrigia* (= *Agropyron*) *elongatum* ($2n = 2x = 14$)] and the decaploid species *E. pontica* ($2n = 10x = 70$) have been reported to survive salt concentrations as high as 1.5 times of seawater (Dewey 1960; Shannon 1978; McGuire and Dvorak 1981) and hold promise for genetic improvement of

salt resistance via distant hybridization and selective transfer of adaptive gene-complexes from these valuable resources (Dvorak *et al.* 1985; Storey *et al.* 1985). Also, materials derived from wheat x barley crosses open up new vistas in this context (Islam *et al.* 1981; Rana 1984). Furthermore, use of cell culture technique in generating more genetic variability, developing better salt-tolerant lines, and understanding salt tolerance at the cellular level, has aroused considerable excitement and expectations in recent years (See: Staples and Toenniessen 1984 for contributions by Stavarek, Rains, and Hanson).

To sum up, it seems quite feasible now to develop superior wheat varieties that will withstand moderate increases in soil salinity and alkalinity without undergoing significant yield reductions. It also appears within reach to evolve wheat varieties capable of growing and yielding satisfactorily at salinity and alkalinity levels beyond their survival range at present (See also: Kingsbury and Epstein 1984).

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- components of yield, and (c) inheritance of physiological and biochemical attributes which contribute to yield. The latter approach affords the possibility of improving yield through genetic manipulation of yield-affecting characters which are likely to be under much simpler genetic control and more highly heritable than total yield or yield components (Rahman *et al.* 1977). Physiological studies have indicated that green parts above the flag leaf node make a sizeable contribution to grain yield, and selection for large green parts above the flag leaf node is recommended (Simpson 1968). Flag leaf plays a major role in cereal grain yield particularly under semiarid conditions (Kirkham 1983). It contributed 41-43% to grain weight and kernel number/spike (Ibrahim and Abo Elenein 1977). About 70-90% of the C-14, assimilated by the flag leaf and ear, was translocated to the grains without any effect of awns in this respect (Olugbemi *et al.* 1976b). Lines with large flag leaf area had higher kernel weight and were higher yielding (Berdhal *et al.* 1972).

Net photosynthetic rates of ears having larger awn size were considerably higher than those of small awns. Ears of awnless bread wheat lines contributed about 10% to the photosynthesis of organs above the flag leaf node and awns increased this to about 18% (Olugbemi *et al.* 1976a). As compared to awnless wheat cultivars, awned cultivars have been found to produce higher yield, heavier kernels, and higher test weight with more pronounced effects in droughty years (Atkins and Norris 1955).

Flag leaf removal resulted in greater reduction of grain, yield, test weight, and kernel weight as compared to awn removal (Patterson and Ohm 1975). Flag leaf and/or awn removal significantly reduced grain yield of wheat, kernel number/plant, and kernel weight (Duwayri 1984).

Previous physiological studies focused on morphophysiological traits controlling yield, but hybrid populations were not used; therefore, these studies provided no information on the inheritance of these traits. However, such information is useful to the plant breeder who would use these traits as selection criteria for the improvement of grain yield. The present study reports results on flag leaf area, and awn weight and length in addition to grain yield/plant of hybrid and segregating populations derived from 10 durum wheat (*T. turgidum* L. var. *durum*) crosses.

Inheritance of Morphophysiological Characters and Grain Yield in Durum Wheat Crosses

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Grain yield in wheat (*Triticum turgidum* L. var. *durum*) is the end product of the interaction of a large number of physiological and biochemical processes in the plant and therefore is genetically complex. Genetic studies of grain yield can be conducted at three levels; (a) inheritance of total yield, (b) inheritance of the individual physical

Materials and Methods

The parents used in crosses were: Hourani, Mexicali 75, Fg/s/Palest/Mexi/s/31/Ruff/s/Fg/s/, Yamuna, JNK, and Njoro 227. The genotypes were chosen on the basis of two criteria: (1) genetic diversity and (2) variability in the characters studied. The permanent features of the six genotypes are presented in Table 1. All possible crosses among the six genotypes were made by hand emasculation and pollination. Ten crosses were studied because adequate amounts of F₁ seeds were available for these crosses only. The seeds were planted on 26 December 1982 in Jubeiha near Amman. The soil is clay loam and was fertilized with 60 and 30 kg/ha of ammonium sulphate and trisuperphosphate, respectively. The total rainfall of the growing season 1982/1983 was 678 mm falling in the early part of the season. The F₁ and F₂ populations for each cross together with their parents were sown in 2.5 m rows placed 30 cm apart in a randomized complete block field experiment with two replications, and at a rate of 25 seeds per row. The experimental rows assigned to each of the P₁, P₂, F₁, and F₂ populations for each cross were 1, 1, 1, and 2, respectively.

Data on four plant characters were collected for each plant as follows:

Grain yield: weight (g) of grain harvested from each plant.

Awn length: 10 awns were taken at random from the main spike and the length (cm) was measured, then the average was recorded.

Awn dry weight: average weight (g) of the chosen 10 awns.

Flag leaf blade area: obtained by multiplying leaf length X maximum flag leaf width X 0.68 (cm). Coefficient for converting width-length measurements to leaf area were obtained from the regression of actual leaf area on the product of width X length.

Genetic analysis: Data from the two replications were pooled to compute means and variances of each population. The theoretical means corresponding to additive and nonadditive gene action were computed from the following formulae used by Burton (1951).

$$\text{Theoretical arithmetic } \bar{F}_1 = (\bar{P}_1 + \bar{P}_2)/2$$

$$\text{Theoretical arithmetic } \bar{F}_2 = (\bar{P}_1 + 2\bar{F}_1 + \bar{P}_2)/4$$

$$\text{Theoretical geometric } \bar{F}_2 = \text{antilogarithm of } (\log \bar{P}_1 + 2\log \bar{F}_1 + \log \bar{P}_2)/4$$

The minimum number of genes controlling the expression of the four characters was estimated from the following formula attributed to Sewall Wright by Burton (1951):

$$n = 0.25 (0.75 - h + \bar{h}) D^2 / (G^2 F_2 - G^2 F_1)$$

where $h = (\bar{F} - \bar{P}_2) / (\bar{P}_2 - \bar{P}_1)$, $D = \bar{P}_2 - \bar{P}_1$, \bar{P}_1 = the mean of the smallest parent, \bar{P}_2 = the mean of the largest parent, \bar{F}_1 = the mean of the F₁ population, \bar{F}_2 = the mean of the F₂ population.

Degrees of dominance, h_1 and h_2 for the characters studied in the F₁ and F₂ populations, respectively, were calculated using the potence ratio method (Romero and Frey 1973). In this method:

Table 1. Parental values for four traits involved in 10 durum wheat crosses grown in the 1982/1983 season, Jubeiha, Amman, Jordan.

Parents	Origin	Grain yield/plant (g)	Flag leaf area (cm ²)	Awn weight (g)	Awn length (cm)
Hourani	Jordan	7.90a*	23.8a	0.13b	12.0cd
Mexicali 75	CIMMYT	8.84a	22.7ab	0.10cd	13.5bc
Yamuna	Syria	7.86a	26.1a	0.16a	16.4a
Fg/s/	CIMMYT	5.78a	19.8bc	0.09d	12.8c
JNK	India	7.50a	19.4bc	0.12bc	14.2b
Njoro 227	Kenya	6.25a	16.7c	0.08d	11.1d

* Means followed by the same letter within a column are not significantly different at the 5% probability level, using Duncan's Multiple Range Test.

$$h_1 = (\bar{F}_1 - Mp)/Hp - Mp$$

$$h_2 = (\bar{F}_2 - Mp)/Hp - Mp$$

where Mp = the mid parent and Hp = the high parent. To determine whether h_1 and h_2 values were significantly different from zero, the F_1 and F_2 means were compared with corresponding mid parent value via "t" test.

Heritability in the broad sense (H) was expressed as the ratio of the genotypic variance to the phenotypic variance.

$$H = (\frac{2}{6} F_2 - \frac{2}{6} E) / \frac{2}{6} F_2.$$

Environmental variance was estimated from the formula:

$$\frac{2}{6} E = (\frac{2}{6} P_1 + \frac{2}{6} P_2 + \frac{2}{6} F_1) / 3 \text{ (Allard 1960).}$$

Genotypic coefficient of variation (GCV) was estimated using the method of Burton (1952):

$$GCV = \frac{(\text{genotypic variance})^{1/2}}{\bar{X}} \times 100$$

where \bar{X} = phenotypic mean of the F_2 population.

Simple phenotypic correlation coefficients were estimated to describe the associations among the various traits.

Results and Discussion

Gene action: The gene action involved in the expression of the different characters was determined by computing the theoretical means corresponding to additive and nonadditive gene action.

Overdominance and heterosis of higher grain yield/plant was detected in all crosses in F_1 generation with the exception of the cross Mexicali 75 x Hourani which showed additive gene action since both observed and arithmetic means were not significantly different (Table 2). Inbreeding depression was observed in the F_2 generation of the crosses Njoro 227 x Hourani, Mexicali 75 x Hourani, Yamuna x Mexicali 75, JNK x Njoro 227, and Fg/s/ x Njoro 227, and heterosis for the cross Hourani x Mexicali 75 was also determined.

The observed F_2 means of each of the crosses JNK x Hourani, JNK x Mexicali 75, Yamuna x JNK, and Njoro 227 x Fg/s/ were in close agreement with both the calculated arithmetic and geometric F_2 means

which made it difficult to determine the type of gene action in the F_1 generation. The reciprocal crosses of Mexicali 75 x Hourani and Hourani x Mexicali 75 revealed different types of gene action, suggesting maternal inheritance, whereas the cross Fg/s/ x Njoro 227 and its reciprocal showed similar types of gene action, indicating the absence of maternal effect. The h_1 and h_2 values for degree of dominance could be different due to confounding effects of epistatic gene action in which case h_2 values would be lower than corresponding h_1 values. This was observed in the case of grain yield/plant for the crosses JNK x Hourani, Hourani x Mexicali 75, JNK x Mexicali 75, Yamuna x JNK, and Njoro 227 x Fg/s/.

Overdominance and heterosis of larger flag leaf area was observed in the crosses JNK x Hourani and Yamuna x JNK in the F_1 and F_2 generations. The crosses Hourani x Mexicali 75, JNK x Mexicali 75, JNK x Njoro 227, Fg/s/ x Njoro 227, and Njoro 227 x Fg/s/ showed overdominance and heterosis of larger flag leaf area in the F_1 generation. However, Njoro 227 x Hourani cross exhibited full dominance since its observed mean was approximately equal to the large flag leaf area parent and significantly different from respective arithmetic mean. Additive gene action was detected in the crosses Mexicali 75 x Hourani and Yamuna x Mexicali 75 in the F_1 generation.

The reciprocal combinations revealed different types of gene action, suggesting maternal inheritance for this character. The type of gene action in the F_2 generation of most crosses was not clear because observed, arithmetic, and geometric means were nonsignificantly different; therefore both additive and multiplicative gene actions may be involved. H_2 values were lower than corresponding h_1 values in three crosses (Hourani x Mexicali 75 and Fg/s/ x Njoro 227 and its reciprocal cross), providing evidence for epistatic gene action.

The crosses Hourani x Mexicali 75 and Yamuna x JNK exhibited overdominance and heterosis of heavier awns in the F_1 and F_2 generations and in the F_1 generation of the crosses JNK x Mexicali 75 and Fg/s/ x Njoro 227 and its reciprocal cross. Partial dominance of heavy awns was exhibited in the crosses Njoro 227 x Hourani and JNK x Njoro 227 in the F_1 generation. Overdominance of small awn weight was shown in the cross Mexicali 75 x Hourani in the F_1 generation. Additive gene expression was detected in the F_2 generation of the cross Fg/s/ x Njoro 227 and in the F_1 generation of the cross Yamuna x Mexicali 75. Inbreeding depression in the

Table 2. Parental, F₁, and F₂ means and degrees of dominance for grain yield/plant of F₁ and F₂ populations of 10 durum wheat crosses, 1982/83. Jubeiha, Amman, Jordan.

P ₁	P ₂	Parents ¹		F ₁ population			F ₂ population			h ₂
		P̄ ₁	P̄ ₂	X̄	AF ₁	h ₁	X̄	AF ₂	GF ₂	
JNK	x Hourani	7.50a	7.90a	11.87	7.70**	20.85**	10.19	9.78	9.58	0.44**
Njoro 227	x Hourani	6.25a	7.90a	8.81	7.07**	2.10**	7.19	7.94*	7.88*	37.50**
Mexicali 75	x Hourani	8.84a	7.90a	8.41	8.37	0.08	6.86	8.39**	8.38**	6.80**
Hourani	x Mexicali 75	7.90a	8.84a	12.62	8.37**	9.04**	11.73	10.49*	10.27*	1.50*
JNK	x Mexicali 75	7.50a	8.84a	12.53	8.17**	6.51**	11.32	10.35	10.10	1.28
Yamuna	x Mexicali 75	7.86a	8.84a	11.04	8.35**	5.49**	7.93	9.69**	9.59**	4.14**
Yamuna	x JNK	7.86a	7.50a	11.73	7.68**	22.50**	9.10	9.70	9.47	0.65
JNK	x Njoro 227	7.50a	6.25a	8.98	6.87**	3.35**	6.05	7.93**	7.84**	8.74**
Fg/s/	x Njoro 227	5.78a	6.25a	7.78	6.01**	7.37**	4.79	6.90**	6.84**	17.58**
Njoro 227	x Fg/s/	6.25a	5.78a	11.42	6.01**	22.54**	8.10	8.72	8.28	0.50

*, ** Significant at the 5 and 1% levels, respectively.

1. Parental means followed by the same letter are not significantly different at the 5% probability level, using Duncan's Multiple Range Test.

X̄ = Observed mean; AF₁ and AF₂ = calculated arithmetic means for F₁ and F₂ populations, respectively; GF₂ = calculated geometric mean for F₂ population; and h₁ and h₂ degrees of dominance for the F₁ and F₂ populations, respectively.

Table 3. Estimates of heritability (H), genotypic coefficient of variation (GCV), and number of gene (N) for grain yield/plant, flag leaf area, awn weight, and awn length in 10 durum wheat crosses, 1982/83, Jubeiha, Amman, Jordan.

Cross	Grain yield/plant			Flag leaf area			Awn weight			Awn length		
	H	GCV	N	H	GCV	N	H	GCV	N	H	GCV	N
JNK	0.47	32.50	1.48	0.41	14.09	0.29	0.70	28.78	0.02	0.84	26.78	0.07
Njoro 227	0.00	00.00	0.00	0.00	00.00	0.00	0.02	3.52	1.68	0.04	1.75	1.63
Mexicali 75	0.00	00.00	0.08	0.09	6.35	0.09	0.00	00.00	0.00	0.00	00.00	0.00
Hourani	0.29	21.87	0.00	0.08	5.44	1.74	0.65	37.62	0.32	0.00	00.00	0.00
JNK	0.55	41.99	0.72	0.06	4.32	2.82	0.09	6.79	1.25	0.00	00.00	2.43
Yamuna	0.00	00.00	0.00	0.00	00.00	3.25	0.11	6.63	1.10	0.31	7.21	0.47
Yamuna	0.00	00.00	0.00	0.47	15.01	0.55	0.37	10.73	0.85	0.18	2.54	5.50
JNK	0.30	23.62	0.23	0.00	00.00	0.96	0.00	00.00	1.12	0.00	00.00	4.00
Fg/s/	0.00	00.00	1.24	0.13	7.24	0.45	0.00	00.00	0.94	0.00	00.00	0.00
Njoro 227	0.27	21.81	0.00	0.44	14.31	0.70	0.00	00.00	3.49	0.19	4.49	2.58
Mean	0.19	14.18	0.17	6.68	9.41	0.19	0.16	4.28				

Table 4. Coefficients of phenotypic correlation among grain yield/plant, flag leaf area, awn weight, and awn length of 10 durum wheat crosses in the F₂ generation, 1982/83, Jubeiha, Amman, Jordan.

Cross		Grain yield/plant		Flag leaf		Awn weight	
P ₁	P ₂	Flag leaf area	Awn weight	Awn length	Awn weight	Awn length	Awn length
JNK	x Hourani	0.37*	0.54**	0.45**	0.27	0.22	0.87**
Njoro 227	x Hourani	0.42**	0.24	0.18	0.41**	0.11	0.62**
Mexicali 75	x Hourani	0.36**	0.30*	0.46**	0.29*	0.40**	0.77**
Hourani	x Mexicali 75	0.35**	0.11	-0.01	0.09	0.00	0.64**
JNK	x Mexicali 75	0.40**	0.29*	0.22	0.36**	0.46**	0.59**
Yamuna	x Mexicali 75	0.38**	0.42**	0.42**	0.47**	0.42**	0.79**
Yamuna	x JNK	0.28	0.31*	0.45**	0.31*	0.44**	0.76**
JNK	x Njoro 227	0.31*	0.11	0.24	0.33*	0.51**	0.62**
Fg/s/	x Njoro 227	0.34**	0.15	0.18	0.29*	0.54**	0.63**
Njoro 227	x Fg/s/	0.33**	0.08	0.10	0.45**	0.55**	0.59**

*, ** Significant at the 5 and 1% levels, respectively.

F₂ generation was obtained in the crosses Njoro 227 x Hourani, JNK x Mexicali 75, and Njoro 227 x Fg/s/, whereas in the crosses Hourani x Mexicali 75 and Yamuna x JNK unexpected heterosis was detected. H₂ values were lower than respective h₁ values in the crosses JNK x Hourani, JNK x Njoro 227, and Fg/s/ x Njoro 227 and its reciprocal cross, revealing evidence for epistasis.

Overdominance and heterosis of long awns were clear in the F₁ generation of the crosses Njoro 227 x Hourani, JNK x Mexicali 75, and Fg/s/ x Njoro 227 and its reciprocal cross and in the F₁ and F₂ of the cross Yamuna x JNK. Full dominance of long awns was observed in the F₁ generation of the cross JNK x Njoro 227, whereas, partial dominance of long awns was detected in the F₁ generation of the cross Yamuna x Mexicali 75 and in the F₂ generation of the cross Hourani x Mexicali 75 because their observed means were significantly different than arithmetic means and closer to the long awns parent. Overdominance of short awns was detected in the cross Mexicali 75 x Hourani and its reciprocal in the F₁ generation. Additive gene action was obtained in the cross JNK x Hourani in the F₁ generation.

Estimates of heritability, genetic coefficient of variation, and number of genes for the different traits are shown in Table 3. Average heritability estimates were 0.19, 0.17, 0.19, and 0.16 for grain yield/plant, flag leaf area, awn weight, and awn length, respectively. However large estimate variation existed among the crosses for each trait. The cross JNK x Hourani was characterized by large genotypic variability for all traits.

The ranges of variation in minimum gene number

controlling the expressions of grain yield/plant, flag leaf area, awn weight, and awn length were 0.08-1.48, 0.09-3.25, 0.02-3.49, and 0.07-5.50, respectively, in various crosses, suggesting polygenic control for the different characters. Crosses showing zero gene number have biased estimates, indicating that assumptions listed by Sewall Wright (Burton 1951) do not apply to the situation. Also it is clear that crosses showing high heritability values had a small gene number and vice versa. Therefore, larger gene number will reveal a more pronounced environmental effect and thus lower heritability values.

Correlation among characters: Table 4 presents the phenotypic correlation coefficients among the various traits. It is clear that flag leaf area ranked first for positive association with plant grain yield since all crosses exhibited significant positive correlation coefficients except Yamuna x JNK. Awn weight ranked second and awn length ranked third for positive interrelationship with grain yield.

Flag leaf area also showed a high significant positive association with awn weight and length.

Therefore, selection based on large flag leaf area, and heavy and long awns could result in higher yielding genotypes.

The present study indicates a polygenic control for all characters. However, estimates of heritability showed that substantial progress could be achieved by applying selection pressure for all characters. This study provides evidence for the importance of flag leaf area, awn weight, and awn length for predicting grain yield in durum wheat.

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Heterosis and Combining Ability Studies in Durum Wheat

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Manifestation of hybrid vigor and combining ability in wheat has been accomplished since long. The estimation of heterosis and combining ability effects can help to isolate some superior parents and cross combinations for further exploitation in a breeding program for selecting desirable segregants. Although many reports are available on the combining ability studies in bread wheat, only a few pertain to durum wheat (Kaltsikes and Lee 1971; Widner and Lebsack 1973).

Several workers have reported presence of heterosis for grain yield (Bitzer and Fu 1972; Briggles *et al.* 1964; Brown *et al.* 1966; Chowdhry *et al.* 1972; Fonseca and Patterson 1968; Hussain and Aslam 1975; Kaltsikes and Lee 1971), 1000-kernel weight (Brown *et al.* 1966), number of spike/plant (Brown *et al.* 1966), and plant height (Briggles *et al.* 1964; Chowdhry *et al.* 1972; Hussain and Aslam 1975) in wheat. Gyawali *et al.* (1968) proved specific combining ability effects to be significant for grain yield, kernel weight, spike numbers, and plant height during 1 year. Walton (1971) studied two complete diallel crosses with five and eight parents and demonstrated general combining ability to be important for yield and yield components. Specific combining ability effects were measurable only in the five-parent diallel cross. Gill *et al.* (1979) reported that both the general and specific combining ability variances were significant for grain yield, grain weight, spike length, plant height, and peduncle length. The parents such as JNK 4W-183 and Crane's' were best combiners for yield and some other components of yield. Cross combinations MPO x Crane's' and Crane's' x HD4537 showed high specific effects for grain yield and various other characters and were expected to generate promising segregants for use in durum breeding programs.

The present study was therefore planned in a set of diallel crosses involving five durum wheat varieties to gather information about heterotic and combining ability effects of the parents and hybrids. The information so derived will prove useful in further accelerating the durum improvement program.

Table 1. Heterotic effects (%) over mid- and better parent in durum wheat.

Cross	Plant height	Number of tillers/plant	Number of grains/spike	100-grain weight	Grain yield/plant
Candéal Durum Buck x Faisca	+1.39 (-1.24)	+4.98** (+2.88**)	+3.78 (-0.04)	+1.29 (+0.21)	+35.41** (+29.02**)
Candéal Durum Buck x Haurani 27	+20.25** (4.21**)	+8.33* (+3.41**)	+5.70 (-4.98)	+23.31** (21.54**)	+59.43** (+55.26**)
Candéal Durum Buck x Maioral	+1.37 (-2.68*)	+1.20 (-7.81**)	-2.57 (-8.69*)	+7.08** (-3.20**)	+19.71** (+16.35**)
Candéal Durum Buck x Valsaco	+6.63** (+5.93**)	+5.45** (+1.54*)	+4.92 (+0.48)	+6.81 (+6.58**)	+27.25** (+20.09**)
Faisca x Haurani 27	+17.34** (+4.02**)	+6.85** (+4.02**)	+11.16* (-3.35)	+10.07** (+9.83**)	+69.62** (+58.99**)
Faisca x Maioral	+1.77 (-4.71**)	+6.27** (-1.37)	+7.85 (-2.39)	-3.82 (-12.10**)	+3.40 (-4.11)
Faisca x Valsaco	+3.37** (+0.06)	-5.42** (-7.10**)	+1.11 (+0.52)	+1.08 (-0.21)	+12.26** (+11.14**)
Haurani 27 x Maioral	+20.65** (1.01)	+10.29** (+5.00**)	+26.94** (+21.37**)	+3.59 (-5.04**)	+42.38** (+41.16**)
Haurani 27 x Valsaco	+19.53** (+3.01*)	+8.56** (+7.58**)	+7.07 (-7.36)	+13.15** (+11.46**)	+43.38** (+32.79**)
Maioral x Valsaco	+1.94 (-1.52)	-2.32** (-7.81**)	+4.97 (-5.51)	-1.88 (-11.46**)	-2.72 (-10.61**)

Values within parentheses show heterosis over better parent.

*, ** Significant at 0.05 and 0.01, respectively.

Materials and Methods

Five wheat varieties (Candéal Durum Buck, Faisca, Haurani 27, Maioral, and Valsaco) were grown at the Wheat Research Institute, Faisalabad, during rabi 1980. All possible cross combinations (excluding reciprocals) were attempted amongst parental lines in early March 1981. The parents and their F_1 's, replicated three times, were dibbled in the field during rabi 1981 following randomized complete block design in a plot size of 3 m x 0.30 m. Row to row and plant to plant spacings were 30 and 15 cm, respectively. At maturity, 10 plants were selected at random from each treatment in a replication and the data on plant height, number of tillers/plant, number of grains/spike, 100-grain weight, and grain

yield/plant were recorded. Heterotic effects over mid- and better parent were determined as the deviation of hybrid from mean of its parents. Combining ability analysis was carried out following method II and model I and II of Griffing (1956).

Results and Discussion

Six crosses exhibited positive and highly significant, and four showed positive but nonsignificant heterotic effects for plant height over their respective mid-parents (Table 1). Both positive and negative heterosis were observed over better parents to varying degrees in all the crosses.

For number of tillers/plant, cross combination Haurani 27 x Maioral showed highest heterotic effects

over mid-parent, while Haurani 27 x Valsaco exhibited maximum heterosis over better parent. Candéal Durum Buck x Haurani 27, Candéal Durum Buck x Valsaco, and Faisca x Haurani 27 were other reliable crosses, reflecting attractive heterotic effects over mid- and better parent. It may be observed that crosses involving Haurani 27 as one of the parents have performed well. Consequently, this parent can be used in crosses for improving tiller numbers.

Cross Haurani 27 x Maioral showed highest and highly significant heterosis over mid- (26.9**) and better parent (21.31**) values for number of grains/spike. Faisca x Haurani 27 was the other good combination, reflecting positive and significant heterotic effects over mid-parent. Crosses with Haurani 27 as one of the parents showed better heterotic effects than other cross combinations, indicating better performance of Haurani 27 for increasing grain numbers/spike. These combinations can be expected to throw better segregants.

For 100-grain weight, highest positive and highly significant heterosis over mid- and better parent values was observed in the cross Candéal Durum Buck x Haurani 27 followed by the hybrid combinations Haurani 27 x Valsaco, Faisca x Haurani 27, and Candéal Durum Buck x Valsaco, respectively. Crosses involving Haurani 27 as a parent, exhibited sound heterotic effects, and thus superiority of this parent for increasing grain weight can be of great interest. Plants possessing higher grain weight can be selected from these combinations in the subsequent generations. Cross combination Haurani 27 x Maioral showing positive but comparatively lower and nonsignificant heterotic effects over mid-parent, and negative and highly significant over better parent may be due to the contribution of the parent Maioral.

Exciting, positive, and highly significant heterotic effects over mid- and better parent for

grain yield/plant were observed in the cross Faisca x Haurani 27, followed by Candéal Durum Buck x Haurani 27, Haurani 27 x Valsaco, Haurani 27 x Maioral, and Candéal Durum Buck x Faisca (Table 1). Negative heterotic effects over mid- and better parent were shown by the cross Maioral x Valsaco for this character and thus proved to be a useless combination. The performance of this cross for other characters was also hopeless. With the exception of cross Haurani 27 x Maioral other crosses involving Haurani 27 as one of the parent promised highest, positive, and highly significant heterosis, confirming the superiority of this parent for increasing grain yield.

Combining Ability

a) **General combining ability:** The analysis of variance for combining ability showed that both the general and specific combining ability variances were highly significant for all the characters (Table 2). For reducing plant height Maioral and Faisca were good combiners. Parent Maioral also proved to be the best combiner for the number of tillers/plant, followed by Haurani 27, while Candéal Durum Buck was the poorest (Table 3). For number of grains/spike Faisca and Valsaco were found to be the best combiners, while Haurani 27 was the poorest. For 100-grain weight and grain yield/plant, Haurani 27 was a better general combiner. Faisca also proved to be a good combiner for grain yield/plant. It may be concluded that Haurani 27 and Faisca are the best general combiners.

b) **Specific combining ability:** Five crosses namely Candéal Durum Buck x Faisca, Candéal Durum Buck x Maioral, Faisca x Maioral, Faisca x Valsaco, and Maioral x Valsaco showed significantly high specific effects for reducing plant height, while Candéal

Table 2. Analysis of variance for progeny means and combining ability.

Source of variation	DF	Plant height	Number of tillers/plant	Number of grains/spike	Mean square	
					100-grain weight	Grain yield/plant
Blocks	2	18.04	0.17	41.27	7.88	43.98
Progenies	14	961.57**	2.61**	102.53**	69.49**	127.98**
Error	28	1.85	0.82	24.03	7.31	8.90
gca	4	915.73**	1.06*	72.83**	0.56**	36.31**
sca	10	82.45**	1.32**	18.72**	0.97**	49.19**
Error	28	0.62	0.27	0.98	0.02	2.97

*, ** Significant at 0.05 and 0.01, respectively.

Table 3. Estimates of general combining ability (gca) effects for different characters.

Parental lines	Plant height	Number of tillers/plant	Number of grains/spike	100-grain weight	Grain yield/plant
Candéal Durum Buck	-4.29**	-0.50**	-0.32**	+0.20	+0.30
Faisca	-2.53**	-0.37**	+3.32**	-0.05	+1.03**
Haurani 27	+20.10**	+0.38**	-3.80**	+0.22	+2.53**
Maioral	-5.73**	+0.80**	-2.45**	-0.47	-3.63**
Valsaco	-1.82**	-0.26*	+3.24**	+0.09	-0.24
SE ±	0.26	0.17	0.33	0.00	0.58

*, ** Significant at 0.05 and 0.01, respectively.

Table 4. Estimates of specific combining ability (sca) for different characters.

Cross	Plant height	Number of tillers/plant	Number of grains/spike	100-grain weight	Grain yield/plant
Candéal Durum Buck x Faisca	-1.95**	+0.29*	+1.32**	-0.11*	+3.66**
Candéal Durum Buck x Haurani 27	+10.36**	+0.33*	+0.10	+0.62**	+5.84**
Candéal Durum Buck x Maioral	-2.18**	-0.22	-3.65**	+0.15*	+1.35*
Candéal Durum Buck x Valsaco	+1.85**	+0.49*	+2.60**	+0.08*	+3.02**
Faisca x Haurani 27	+8.37**	+0.28*	+2.49**	+0.21**	+10.15**
Faisca x Maioral	-1.04**	+0.59*	-0.24	-0.11*	-2.17**
Faisca x Valsaco	-0.31	-0.76**	-1.02*	+0.00	-0.40
Haurani 27 x Maioral	+10.67**	+0.76**	+9.41**	-0.08*	+4.26**
Haurani 27 x Valsaco	+9.26**	0.64**	+0.54*	+0.28**	+4.62**
Maioral x Valsaco	-1.88**	-0.46*	+0.49*	-0.11*	-2.28**
SE ±	0.55	0.36	0.69	0.10	1.19

*, ** Significant at 0.05 and 0.01, respectively.

Table 5. General and specific combining ability components for different characters (model II).

Source	Plant height	Number of tillers/plant	Number of grains/spike	100-grain weight	Grain yield/plant
G_g^2	+238.08	-0.07	+15.46	-0.12	-3.68
G_s^2	+81.83	+1.06	+17.74	+0.95	+46.22
G_g^2/G_s^2	+2.91	-0.07	+0.87	-0.13	-0.08

Durum Buck x Faisca, Candéal Durum Buck x Haurani 27, Candéal Durum Buck x Valsaco, Faisca x Haurani 27, Faisca x Maioral, Haurani 27 x Maioral, and Haurani 27 x Valsaco showed significant effects for increasing number of tillers (Table 4). Significantly high specific effects for number of grains/spike were reflected by the crosses Candéal Durum Buck x Faisca, Candéal Durum Buck x Valsaco, Faisca x Haurani 27, Haurani 27 x Maioral, Haurani 27 x Valsaco, and Maioral x Valsaco. Cross combinations Candéal Durum Buck x Haurani 27, Candéal Durum Buck x Maioral, Candéal Durum Buck x Valsaco, Faisca x Haurani 27, Haurani 27 x Valsaco exhibited significant specific effects for 100-grain weight, and crosses Candéal Durum Buck x Faisca, Candéal Durum Buck x Haurani 27, Candéal Durum Buck x Valsaco, Faisca x Haurani 27, Haurani 27 x Maioral, and Haurani 27 x Valsaco for grain yield.

Cross combinations Faisca x Haurani 27, Candéal Durum Buck x Haurani 27, Haurani 27 x Valsaco, Haurani 27 x Maioral, Candéal Durum Buck x Faisca, and Candéal Durum Buck x Valsaco showed highly significant specific combining effects for grain yield/plant as well as for various other attributes, thus offering better possibilities of exploitation for the development of superior lines in the durum breeding program. Cross Faisca x Haurani 27 may be expected to throw excellent hybrids in the segregating generations as both the parents are best general combiners for grain yield (Table 4). On the basis of these results, it is suggested that the parents Haurani 27 and Faisca can be exploited for the improvement of durum wheat.

General combining ability components of variance were higher for plant height than those of specific combining ability, indicating additive genetic effects for this trait (Table 5). However for other characters such as tillers/plant, number of grains, 100-kernel weight, and yield, the specific combining ability components of variance were higher, showing preponderance of nonadditive genetic effects for these characters. According to Gill *et al.* (1979) several workers have found nonadditive genetic

effects for grain weight and yield and additive effects for plant height and spike length in wheat.

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Role of Interspecific Hybridization in Breeding for Early Maturity in Triticum durum

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Triticum aestivum (bread wheat) and *T. durum* (macaroni wheat) are the two most dominant species of wheat in commercial cultivation. In general, the present semidwarf varieties of durum wheat are late in maturity which makes them unfit for multiple cropping in tropical and subtropical countries, such as India. Moreover, sometimes a sudden rise in temperature during the grain-filling period causes shrivelling of grains in these late-maturing types, leading to reduction in their yield. To overcome this deficiency, research was carried out at the IARI, New Delhi, to generate new variability for earliness in durum wheat by interspecific hybridization method, and then selecting segregants showing very early maturity.

Materials and Methods

HD 4519, a semidwarf variety of durum, was used as an agronomic base and was crossed to three donor varieties, viz., Foligirosum, NP 200, and Australian line belonging to three different species, namely, *T. carthlicum*, *T. dicoccum*, and *T. aestivum*,

respectively. NP 200 and Australian line are somewhat early in maturity while Foligirosum is a semiwinter type. F₁ hybrids from the three cross combinations were backcrossed to the agronomic base followed by selfing and selections in subsequent generations. In *carthlicum* and *dicoccum* backgrounds only one backcross was made while in *aestivum* background two backcrosses were made to overcome sterility problem. Segregants phenotypically similar to durum and with early maturity were selected in each generation till uniformity was achieved.

The early-maturing derivatives so obtained were evaluated for grain yield, 1000-kernel weight, and days to heading and maturity in replicated trials using Sonalika, the most popular and earliest maturing *aestivum* cultivar, as a check. Raj 1555, the highest yielding, but, late-maturing durum cultivar was also used as a check. Multilocation tests were conducted for yield while for 1000-kernel weight and maturity, data were collected at Delhi center only. Crop was grown under good fertility and irrigated conditions using N, P, and K fertilizers at the rates 100, 50, and 30 kg/ha, respectively.

Derivatives were classified as D₁ and D₂ to indicate their height class. D₁ height ranged between 95 and 100 cm (Sonalika); while D₂ ranged between 85 and 95 cm (Raj 1555).

Results and Discussion

Data presented in Table 1 indicate that it is possible to improve durums for a number of characters simultaneously through the use of interspecific

Table 1. Yield, maturity, kernel weight, and height class of early durum lines and cultivars tested at Delhi and Akola during 1982-84.

Entry	Donor species	Height class	Yield (q/ha)			Average	Days to heading	Days to maturity	1000-kernel weight (g)
			1982/83 Delhi	1983/84 Delhi	1983/84 Akola				
Derivative									
IWP 5034	<i>T. carthlicum</i>	D ₂	78.0	54.5	30.3	54.3	93	121	42.0
IWP 5049	<i>T. dicoccum</i>	D ₂	80.0	59.5	31.5	57.0	96	126	39.0
IWP 5050	<i>T. aestivum</i>	D ₁	70.3	58.5	25.5	51.4	91	123	42.6
IWP 5070	<i>T. aestivum</i>	D ₁	72.9	61.6	23.0	52.5	91	121	42.0
IWP 5061	<i>T. aestivum</i>	D ₂	81.1	53.9	23.5	52.8	94	121	38.6
IWP 5065	<i>T. aestivum</i>	D ₁	73.5	57.2	26.2	52.3	89	121	42.6
IWP 5027	<i>T. aestivum</i>	D ₁	75.8	59.7	23.3	52.9	89	121	48.0
Cultivar (check)									
Sonalika (<i>aestivum</i>)		D ₁	71.7	54.3	30.2	52.1	96	128	38.0
Raj 1555 (<i>durum</i>)		D ₂	83.7	62.2	27.7	57.9	99	133	42.0
CD (critical difference)			7.0	6.0	7.2		1.5	2.0	2.9

Table 2. Yield (q/ha) of IWP 5019 (a *dicoccum* derivative) and Sonalika in multilocation tests carried out during 1982-84 in India.

Entry	Height class	1982/83			1983/84			Akola	Average
		Niphad	Pantnagar	Pune	Niphad	Pantnagar	Pune		
IWP 5019 (<i>T. durum</i> x <i>T. dicoccum</i>)	D ₂	33.0	37.5	39.7	30.4	29.6	31.8	28.2	32.9
Sonalika	D ₁	28.5	51.3	32.6	33.9	31.6	25.7	30.4	33.4
CD		5.2	7.5	5.7	4.3	4.8	7.3	5.1	

hybridization. Most of the lines have shown early heading and early maturity as well when compared with Sonalika. With regard to yield, interspecific lines have yielded either better or equal to Sonalika. Certain lines like IWP 5049 and IWP 5061 during 1982/83 and IWP 5070 during 1983/84 significantly outyielded Sonalika at Delhi. During 1983/84 all the derivatives (except IWP 5034 and IWP 5061 at Delhi) showed parity in yield with Raj 1555 at both the locations, namely, Delhi and Akola. However, during 1982/83, only three lines (IWP 5034, IWP 5049, and IWP 5061) showed parity in yield with Raj 1555. This differential behavior of derivatives with Raj 1555 is due to exceptionally prolonged winter during 1982/83 favoring the yield of late-maturing variety Raj 1555, which is nearly 12 days later in maturity as compared to most of the derivatives. IWP 5049 being equal to Sonalika but earlier than Raj 1555 by 7 days in maturity has shown consistent parity in yield with Raj 1555 but better yield potential compared to Sonalika.

These early-maturing derivatives have also shown better kernel weight. All the derivatives have either equal or better kernel weight compared to Sonalika. Except IWP 5049 and IWP 5061, other lines gave equal or better kernel weight than Raj 1555. This indicates that earliness has not affected kernel weight in these derivatives. The height class of these lines ranged from D₂ to D₁ and was comparable to the two checks.

IWP 5019, a free threshing *dicoccum* derivative, was tried with Sonalika during 1982-84 in multilocation tests in Peninsular, India. This region is characterized by hot, dry climate and relatively short crop duration compared to northern India. Yield data (Table 2) indicate that IWP 5019 gave as good yield as Sonalika in both the years. Under Delhi conditions this derivative is nearly 10 days earlier in maturity compared to Sonalika. Its height (D₂) is also suited to high fertility level of the soil.

The above findings suggest that interspecific hybridization can be used as one of the effective tools for evolving early and improved plant types in durum wheats.

Inheritance of Straw Length in Hexaploid Triticale

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Triticale (*X triticosecale* Wittmack) was derived, at the primary level, from a cross of tetraploid wheat and diploid rye. The early triticales were 6-8 feet tall and susceptible to lodging leading to decreased grain yield (Zillinsky and Borlaug 1971). In winter triticales, lodging is the consequence of their excessive height (Wolski and Tymieniecka 1980; Gregory 1983). Thus, development of short statured triticales became the major concern of the triticale improvement programs during the seventies (Zillinsky 1974). The continuous introduction of Rht genes from Norin 10 based bread wheat into triticale resulted in progressively reduced plant height genotypes (Skovmand *et al.* 1984).

The main objective of NIAB triticale program is the evolution of short statured genotypes with high-yield potential. To achieve this goal, it is essential to know the inheritance pattern of reduced plant height. This investigation was, therefore, undertaken to study the inheritance of plant height in crosses between tall and dwarf parents derived from the international triticale gene pool.

Materials and Methods

Triticale germplasm derived from international gene

Table 1. Straw length segregation in the F₂, BC₁, and BC₂ generations.

Generation	Number of plants				X ²	P
	Semidwarf	Tall	Short	Dwarf		
F ₂	68	42	18	8	0.094	0.990 - 0.995
BC ₁	60			18	0.1549	0.70 - 0.75
BC ₂	33	101			0.010	0.90 - 0.95

pool was characterized for straw length. Beagle "S" was the tallest parent having a plant height of 147 cm, and Cml-Kal-Kal was the dwarfest parent with a mean plant height of 60 cm. These were intercrossed for raising F₁, F₂, BC₁, and BC₂ progenies. The parents, F₁, F₂, BC₁, and BC₂ were planted in a randomized complete block design with three replications, at NIAB farm during the 1983/84 season.

Data on plant height (cm) were recorded from the base to the tip of spike both for segregating generations and parents.

Results and Discussion

The frequency distribution of parents and crosses is presented in Fig. 1.

It is clear from the distribution pattern that genes for dwarfing are acting in a partially dominant manner. F₁ plants were shorter than the mid-parent value. F₂ plants could be classified into four height groups: tall (120-160 cm), short (70-85 cm), semidwarf (75-120 cm), and dwarf (60-70 cm). BC₁ plants were separated into two distinct classes; semidwarf and dwarf, while in BC₂ there were semidwarf and tall plants.

The straw length segregation in the F₂, BC₁, and BC₂ generation from Beagle "S" x Cml-Kal-Kal is presented in Table 1.

Table 1 shows that F₂ produced 68 semidwarf, 42 tall, 18 short, and 8 dwarf plants, indicating two independent gene pairs segregation. In the BC₁, a 3:1 genetic ratio was observed, namely 3 semidwarf and 1 dwarf plants, while in the BC₂ generation, a ratio of 3:1 tall and semidwarf was apparent.

These results suggest that two major genes are involved for plant height expression in these triticale lines but they do not fully account for the observation. For instance, segregating populations are bimodal but do not clearly fit into discrete rating. On the other hand, the present data indicate the involvement of a number of modifiers along with

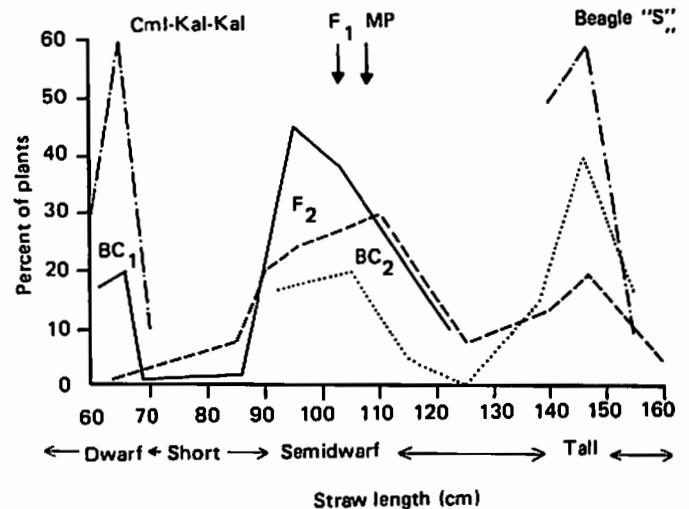


Fig. 1. Straw length distribution curves of parents/crosses of triticale.

the major genes. Nolepa (1984) has also reported the presence of major genes in his short statured triticale mutants derived after chemical treatment with mutagens.

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Seed Germination of Six Durum Wheat Cultivars in Relation to Soil Moisture

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In subhumid and semiarid areas of eastern Algeria, large and unpredictable climatic variations are frequent (Cote 1974). The occurrence of early rains, in particular, varies greatly from year to year which may considerably affect seed germination and hence cereal production in those areas.

The present experiment is designed to study the seed germination of six different durum wheat (*Triticum turgidum* L. var *durum*) cultivars grown in Algeria and the effect of soil moisture on germination.

Materials and Methods

The study was conducted in Nov and Dec 1982 using six cultivars: three from Algeria; Bidi 17, Hedba 3, and Oued Zenati 368, all selected from local landraces, two introduced cultivars; Cocorit from CIMMYT, Mexico, and INRAT 69 from Tunisia, and one (here after referred to as Polonicum) derived from a cross made at CNRA between a *Triticum polonicum* line and a dwarf selection of Zenati Bouteille.

All seeds are derived from the season's harvest except the seed of Cocorit which is obtained from the previous crop season.

Germination Potential: Germination potential has been measured by percent germination of 100 seeds placed on a blotting-paper in covered Petri dishes placed in the laboratory at ambient temperature (10-18°C). Four replications were used for each cultivar and germinated seeds were counted daily until a constant number of seedlings was reached which occurred in about 15 days. Due to seed infection by fungal diseases in certain samples, readings were repeated after appropriate fungicidal treatment.

Mean Germination Time: Mean germination time (MGT) for treated seed was calculated as:

$$MGT = \frac{1}{N} \sum n_i d_i$$

Where n_i is the number of germinated seed on day "i", d_i is the rank order of day "i", and N is the total number of germinated seed.

Soil Moisture Content: Soil was sampled from the upper soil layer (20 cm) at El Khroub Research Experiment Station. It was irrigated to saturation and let dry slowly. Subsamples were taken at different dates and placed in Petri dishes, then 50 seeds were put to germinate in each Petri dish. Germination was thus studied for a gradient of soil moisture from saturation to below wilting point. "Catch up" germination was examined following irrigation of dried soil.

Results and Discussion

Germination Potential: Germination potential was similar for all cultivars except Polonicum which showed significantly lower germination potential when seeds were left untreated. However, after fungicide was applied, all varieties showed no significant differences with a mean germination percent of 83 for Cocorit, 93 for Polonicum, 94 for INRAT 69, 97 for Bidi 17, 98 for Oued Zenati 368, and 99 for Hedba 3.

These results indicate that heavy disease infection of seed for cultivars such as Polonicum may seriously inhibit germination, and this confirms the results obtained by Owen (1952).

Mean Germination Time: Germination started on the fourth day of sowing and ended on the eleventh, with a maximum occurring on the sixth or seventh day, depending on the cultivar. The mean germination time was 6.2 days for Bidi 17, 5.4 for Hedba 3, 5.7 for Oued Zenati 368, 6.9 for Cocorit, 6.1 for INRAT 69, and 6.7 for Polonicum. The long germination time for Cocorit may be attributed to the poor-quality seeds used.

Effect of Soil Moisture: Results in Table 1 show that germination in water-saturated soil was not the same for all cultivars. In particular, Hedba 3 and Oued Zenati 368 seem to be better adapted to such soil conditions which, however, are rare in Algeria. These two cultivars also showed a good germination of around 80% in relatively dry soils (18.5% of soil moisture).

Except for Polonicum, all cultivars exhibited a drastic decrease in germination potential in both saturated and dry soils. The local cultivars Hedba 3

Table 1. Effect of different soil-moisture treatments on seed germination (%) of six durum wheat cultivars.

Identification No.	Treatment		Cultivar					
	Soil moisture (%)	Description	Bidi 17	Hedba 3	Oued Zenati 368	Cocorit	INRAT 69	Polonicum
I	57.5	Water saturation	23	47	47	29	28	15
II	36.6	Field capacity	96	96	98	86	98	95
III	18.5	50% field capacity	55	79	84	67	72	84
IV	11.5	Wilting point	Slight increase in seed volume due to some water absorption no visible change					
V	4.3	Extremely dry						

Table 2. "Catch up" germination following repeated irrigations of soils subjected to treatments IV and V.

Treatment	Soil moisture content (%)		Germination (%)					
	Initial	Final	Bidi 17	Hedba 3	Oued Zenati 368	Cocorit	INRAT 69	Polonicum
IV	11.5	18.8	17	25	22	16	26	20
	18.8	22.4	24	30	33	21	36	32
	22.4	27.0	29	39	34	23	38	37
V	4.3	11.8	7	14	13	3	2	13
	11.8	15.5	22	28	25	20	24	34
	15.5	19.3	42	48	35	23	43	51

and Oued Zenati 368 thus appear to be more adapted to large soil moisture fluctuations than exotic cultivars.

In dry soil conditions, Polonicum showed a good germination potential, similar to Oued Zenati 368. It is perhaps important to note that this cultivar is derived from a cross involving the local cultivar Zenati Bouteille.

For the soil treatments IV (soil at wilting point) and V (driest soil conditions), soil water absorbed by the seeds was determined by comparing the weight of the planted seeds with the mean weight of dry seeds. It was found that all cultivars have pumped water from the soil in treatment IV but not in treatment V where only Cocorit, INRAT 69, and to a lesser extent Hedba 3 were able to extract some moisture from the soil.

"Catch up" germination was assessed through repeated irrigations of soil previously subjected to treatments IV and V (Table 2). It was found that sown seeds that were initially dry (as in treatment

V) germinated better following irrigation in comparison to seeds that have previously absorbed some moisture as in treatment IV. Thus sowing in dry soils may be hazardous to normal seed germination if soil and seed conditions are conducive to partial imbibition of seeds.

Acknowledgement

Thanks are due to Dr H. Ketata for translating this article from French.

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Economics of Fertilizer Use for Better Wheat Production

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It is necessary to apply adequate fertilizer to improved and high-yielding varieties of crops to obtain maximum returns and yields. Use of fertilizer, particularly P_2O_5 and K, is limited among farming community in Azad Kashmir. Fertilizer application in the area has already been known to increase wheat grain by 2.75 times and dry matter by 3-4 times (Aslam 1985). Combination of N and P_2O_5 has been reported to give the best net increase in yield for wheat production (Vyas *et al.* 1980).

Keeping in view the economic conditions and social setup of the farming community, an experiment was conducted to determine the economical fertilizer application rate to wheat for maximum benefit.

Materials and Methods

The trial was conducted in rainfed conditions at Kotli (609 m above sea level) during the 1982/83 growing season in a completely randomized block design with four replications. Average rainfall of the area is about 200 mm during winter and a good wheat crop is usually grown under nonirrigated conditions.

Six rows were planted in each plot of 5 x 1.5 m and four harvested. The wheat variety Pak 81 was sown as an indicator at a seed rate of 100 kg/ha. The following fertilizer combinations were used:

Treatment No.	Nutrients (kg/ha)*
1	0:0:0
2	90:90:0
3	120:120:0
4	200:200:0
5	120:120:80
6	160:160:0

*Using Nitrophos and Sulphate of Potash.

Table 1. Grain yield of Pak 81 wheat with different fertilizer application rates at Kotli, 1982/83.

Treatment No.	Yield (kg/ha)
1	1180 c
2	3010 b
3	3580 a
4	3760 a
5	3860 a
6	3980 a

LSD = 449.2

CV = 9.23

All fertilizer was applied at the time of planting. Grain yield was recorded and data were subjected to analysis of variance. Net benefit was calculated and marginal analysis was done to compare the economics of the treatments (Perrin *et al.* 1976).

Results and Discussion

The grain yield from different treatments is presented in Table 1.

Yield in check (T1) was significantly lower than in all other treatments, indicating that even a small amount of fertilizer applied can result in a considerable increase in grain yield. Fertilizer application at the lowest rate resulted in an increase in grain yield by at least 2.5 times as compared to no fertilizer application. The difference between treatments 3, 4, 5, and 6 was non-significant ($P < 0.05$) but all of them were better than treatments 1 and 2. The yield was almost three times lower in check than that from high-yielding fertilizer combinations.

Partial budget of the experiment is given in Table 2 to find out the net benefit.

It is evident from Table 2 that treatment 5 gave the highest net benefit. Although treatment 6 resulted in the highest yield, it was second in net benefit and difference in yield of these two treatments was nonsignificant. Among the significantly high-yielding treatments, the combination of 200 kg N and 200 kg P_2O_5 /ha was the lowest in net benefit. Higher amount of nutrients does not necessarily result in higher yields. Sharpe *et al.* (1976) reported that 128 kg P_2O_5 /ha produced better wheat yield as compared to 256 and 384 kg P_2O_5 /ha.

Table 2. Partial budget of wheat fertilizer trial.

	Treatment					
	1	2	3	4	5	6
Gross yield (kg/ha)	1180	3010	3580	3760	3860	3980
Net yield ^a	1062	2709	3222	3384	3474	3582
Gross benefit (Pakistani Rs. 2.0/kg)	2124	5418	6444	6768	6948	7164
Variable costs						
Fertilizer ^b	0	792	1056	1760	1184	1408
Fertilizer application (2 days @ Rs. 30/day)	0	60	60	60	60	60
Total variable costs	0	852	1116	1820	1244	1468
Net benefit	2124	4566	5328	4948	5704	5696

a = 10% field losses.

b = Based on the prices of Nitrophos and Sulphate of Potash in July 1983.

Table 3. Marginal rate of return of fertilizer trial.

Treatment No.	Net benefit	Variable cost	Change from next highest benefit		
			MINB	MIVC	MRR (%)
5	5704	1244	376	128	293.8
3	5328	1116	762	264	288.6
2	4566	852	2442	852	286.6
1	2124	0			

MINB = Marginal increase in net benefit.

MIVC = Marginal increase in variable cost.

MRR = Marginal rate of return.

After taking the dominating treatments, marginal analysis was performed to find out the treatment with best marginal rate of return. The results are shown in Table 3.

It is again confirmed from Table 3 that treatment 5 was the best as it gave the maximum marginal rate of return. Another interesting point to note is that the use of K with N and P₂O₅ was better than a combination of even higher rates of N and P₂O₅ only.

It is therefore recommended that for wheat, fertilizer should be applied at 120:120:80 kg/ha for maximum economic returns. Although the marginal rate of return is higher in treatment 3 than in treatment 2 but the second best choice of treatment 2 would be wise due to the very little difference between these two treatments.

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Short Communications

Development of Multiline Cultivars in Wheat

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As a result of the "wheat revolution" of the 1960s, large wheat areas in India were grown to a limited number of cultivars, thus narrowing the genetic base of the wheat crop grown in the country, and increasing the danger of exposure to widespread diseases such as leaf rust. As the two most widely grown bread wheat cultivars Kalyansona and Sonalika have become susceptible to leaf rust, attempts are now being made to produce intravarietal diversification for leaf rust resistance through development of multilines.

The present study was undertaken to assess the possible advantage of multilines using three commercial bread wheat varieties, viz, Kalyansona, Sonalika, and Janak as recurrent parents for the development of near isogenic lines through limited backcrossing. Fourteen cultivars were used as donors of genes for leaf rust resistance.

The individual components representing homogeneous populations and their mechanical mixtures representing the multilines were studied in four environments during two seasons. For each background, four types of multilines were formed: one "clean" and three "dirty" multilines (DML) with 16.33 or 50% susceptible constituents.

Data were recorded for the following traits:

- (a) Leaf rust reaction and intensity of attack in the homogeneous and heterogeneous populations.
- (b) Spread of leaf rust in pure lines and multilines.
- (c) Effect of leaf rust on yield and yield-contributing components.
- (d) Adaptability of the homogeneous and heterogeneous populations.

The rate of rust spread was computed in two ways:

- (1) In terms of area under disease progress curve (AUDPC) using the formula:

$$\text{AUDPC} = I \left[\frac{1}{2} (\text{sum of first and last observation}) + \text{sum of all in-between observations} \right]$$

where, I is the constant interval between two consecutive recordings.

- (2) By transforming the data into Log_e and $\text{Log}_e Y/100-Y$ separately. For both transformations, a regression coefficient was calculated to measure the rate of disease spread.

Out of the three methods, 'AUDPC' was found the best measure of rate of spread followed by the transformation into $\text{Log}_e Y/100-Y$ method.

Susceptible component lines in pure stand showed high rates of rust spread and buildup throughout the season. In the same components, when grown as part of composite population, the rust buildup started late and the progress was also very slow.

Dirty multilines exhibited different types of rust reaction both resistant and susceptible. The susceptibility of composite populations is independent of that of the component. Dirty multilines were found to show significant reduction in rate of spread in comparison to the component means under two conditions, viz, high disease pressure or composite population carrying considerably higher proportion of susceptibility.

Among the 12 multilines tested in all three backgrounds, clean multilines in 10 trials showed significantly superior grain yield over their respective component means. The same was true with 16% DML in three trials, 33% DML in two trials and 50% DML in six trials. The average gains of grain yield in all these composite populations, were higher over their respective recurrent parents than component means.

All these multilines showed reduction in biological yield in comparison to their component means. However, this reduction in biological yield did not cause losses in grain yield.

Thousand-kernel weight and harvest index consistently improved in multiline cultivars. Kernels/head and tillers/m² produced by these composite populations were similar to those of their component means as well as recurrent parents.

Stability analyses of yield and yield components in pure line and multiline cultivars were carried

out. Individual lines in pure stand can show either significant or nonsignificant, nonlinear response and similarly high or low value of linear response for grain yield, harvest index, and 1000-kernel weight. When these lines were grown as part of multiline cultivars there was a drastic reduction in both types of response. Multiline cultivars showed linear response very near to one and their nonlinear response was very small. The analysis suggested that clean multilines were relatively less stable than dirty ones.

Based on the above findings, it may be possible to develop multilines of these three commercial wheat varieties. Multilines in general, and particularly those with susceptible components could contribute to stabilizing yield and, to a certain extent, reducing rust development.

Effect of Soil Moisture on Stomatal Closure in Wheat

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Two durum wheat (*Triticum turgidum* L. var. *durum*) and one bread wheat (*Triticum aestivum* L.) cultivars were grown in pots under different soil moisture levels. Stomatal behavior in relation to soil moisture was studied using Molish infiltration technique (Wormer and Ochs 1959). A 1-12 scale was used to describe stomatal behavior where 1 indicates maximum opening and 12 indicates maximum closure. Data were collected using the upper area of the flag leaf when the plants were at the end of culm elongation stage.

The results (Fig. 1) show that stomatal opening varies with soil moisture. Opening of stomata is maximum at field capacity at around 24% soil moisture and starts decreasing when soil moisture content decreases to a value specific for each variety, i.e. 20% for INRAT 69, 16% for Ben Bechir (both durum wheat varieties), and 24% for Florence-Aurore (a bread wheat variety). Stomatal closure is maximum at wilting point, corresponding to a soil moisture content of 10-12%. Similar results were reported for other crops by Gaskell and Pearce (1983); Dennis *et al.* (1984); and El Sharkawy *et al.* (1984).

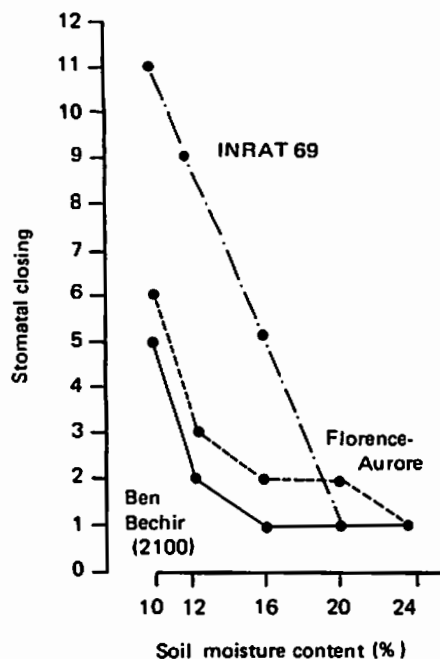


Fig. 1. Stomatal behavior of three wheat varieties under varying soil moisture.

It thus appears that stomatal response to drought stress in wheat is a varietal characteristic. In particular, certain cultivars tend to close their stomata to a greater extent than others in dry soils and open them only when sufficient moisture is available.

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Recent Publications

Feistritzer, W.P. (ed.). 1977. Cereal seed technology, FAO, Rome, Italy. ISBN 92-5-100460-9. 238 pp

This volume attempts to provide a worldwide review of the principles and objectives, organization, and methods of cereal seed production, quality control, and distribution. It discusses the latest findings on cereal seed and pays particular attention to the situation in developing countries.

The book provides bibliographical references and contains appendixes with more technical details. It is recommended primarily for those involved in cereal seed production and utilization, including plant breeders, seed growers, processors, quality control officers, dealers, and extension agents; and also for students of agriculture.

Austin, J.E. (ed.). 1979. Global malnutrition and cereal fortification. Ballinger Publishing Company, Cambridge, Massachusetts, UK, ISBN 0-88410-366-8. 307 pp

This book examines cereal fortification in the light of the existing case histories and what has been learned from them. It provides a systematic way of considering fortification, in terms of the nutritional need, the particular commodity system structure, the technological requirements and constraints, consumer acceptability, and the entire question of the economics of the intervention.

This volume is a significant contribution to the nutrition intervention literature. It is a valuable tool for those responsible for making food and nutrition policy or for planning and implementing nutrition programs.

Pomeranz, Y. (ed.). 1981. Advances in cereal science and technology, Vol. 4. American Association of Cereal Chemists, St. Paul, Minnesota, USA. ISBN 0-913250-21-X. 342 pp

Southam, E. and Schofield, P. (compilers). 1981. Insect pests of pre-harvest wheat and their control in the developing world: 1075-1980. Crop information service annotated bibliographies series No. 1. Centre for Overseas Pest Research, College House,

Wrights Lane, London, W8 5SJ, UK. ISBN 0-85135-124-7. 62 pp

This is the first in a new series of annotated bibliographies aimed at filling gaps in the literature coverage of pest management in the developing world. It contains information on the insect pests that can affect the pre-harvest wheat in developing countries. This information was collected from different sources, and is based on documents retrieval and search from different international information systems and data base, and also from primary scientific journals.

The bibliography contains 206 citations from early 1975 to mid 1980. It is a useful source of information for all scientists working on wheat in the developing world and elsewhere.

FAO (Food and Agriculture Organization of the United Nations). 1983. Cereals: selected aspects of production, trade and price policies. FAO, Rome, Italy. ISBN 92-5-101463-9. 133 pp

This publication brings together a selection of analytical papers prepared in FAO's Commodities and Trade Division. These papers, three of which refer to grains and seven to rice, were prepared to assist the examination of a variety of commodity policy questions at recent sessions of the Intergovernmental Groups on Grains and Rice.

In this publication, reviews of national rice policies in six countries are given (Brazil, Burma, Korea, Nigeria, Thailand, and USA).

Kruger, J.E. and LaBerge, D.E. (eds). 1983. Third international symposium on pre-harvest sprouting in cereals. Westview Press, Boulder, Colorado, USA. ISBN 0-86531-535-3. 312 pp

This volume represents the Proceedings of the Third International Symposium on Pre-harvest Sprouting Damage in Cereals, held at Hecla Island, Manitoba, Canada, in June 1982. It presents scientific research conducted internationally since 1978 and geared toward solving the problem of pre-harvest sprouting. Its multidisciplinary approach incorporates the perspectives of plant breeders.

physiologists, and biochemists to provide a rounded discussion of the possible alternatives.

Porceddu, E. (ed.). 1983. Breeding methodologies in durum wheat and triticale. Proceedings of a workshop held at University of Tuscia, Italy, 17-19 Nov 1983. University of Tuscia, Italy. 207 pp

Bushnell, W.R. and Roelfs, A.P. (eds). 1984. The cereal rusts. Harcourt Brace Jovanovich, Orlando, Florida. ISBN 0-12-148401-7. 546 pp

This two-volume publication brings together in a single reference source the accumulated knowledge of the cereal rusts. Its contents reflect the great diversity and extent of the knowledge of cereal rust, including results of research at the level of molecules, cells, plants, fields, and even epidemics sweeping across continents. Volume I presents the historical, evolutionary, taxonomic, structural, genetic, and physiological characteristics of cereal rust fungi and the diseases they cause in cereals. Volume II is devoted to individual cereal rust diseases, their distribution, epidemiology, and control.

Gallagher, E.J. (ed.). 1984. Cereal production. Proceedings of the Second International Summer School in Agriculture held by the Royal Dublin Society in cooperation with UK Kellogg Foundation. Butterworths in association with the Royal Dublin Society, UK. ISBN 0-407-00303-7. 354 pp

These proceedings present a series of major papers and abstracts on cereal production written by internationally known scientists from many countries. The aspects of cereals covered by these contributions range from morphology, growth, and development to the quality of crops and include a review of the high-input, high-yield cereal production systems in use in western Europe. Soil problems, nitrogen fertilization, and the use of growth regulators are examined. Other topics of international interest on computer-based EPIPRES system of crop protection in Europe, and elsewhere are covered in this volume.

This volume is an invaluable source of information to all cereal scientists.

IAEA (International Atomic Energy Agency). 1984. Cereal grain protein improvement. IAEA, Vienna, Austria. ISBN 92-0-11184-3. 388 pp

The two volumes will serve the needs not only of cereal rust investigators, but also of plant

pathologists generally, as a reference source for teaching, extension, and research.

Zadoks, J.C. and Regsdijk, F.H. 1984. Agro-ecological atlas of cereal growing in Europe. Vol. 3. Atlas of cereal diseases and pests in Europe. Pudoc, Wageningen, The Netherlands. ISBN 90-220-0863-0. 119 pp

Boumans, G. 1985. Grain handling and storage. Elsevier Science Publishers B.V., Amsterdam, The Netherlands. ISBN 0-444-42439-3. 436pp

This volume provides a survey of various techniques and practical engineering options for the study, design, construction, safety, operation, and maintenance of grain handling and storage facilities. It covers the following topics:

- general layout and structural design of grain handling facilities,
- loading and unloading equipment,
- mechanical handling, conveying, and weighing systems,
- dust collection and separation,
- electrical control and automation systems, and
- safety measures to be taken and maintenance.

This publication is recommended for manufacturers and promoters, and particularly for plant engineers and technicians who are active in the field of grain handling.

Bright, S.W. and Jones, M.G.K. (eds). 1985. Cereal tissue and cell culture. Advances in agricultural biotechnology, No. 15. Martinus Nijhoff, the Hague, The Netherlands. ISBN 90-247-3190-9. 304 pp

This volume contains contributions from a group of scientists with wide experience in cereal tissue and cell culture from Britain, USA, and Australia. It covers a wide range of aspects important in developing new ways of improving cereals, and describes successful technologies and areas where further research is urgently needed.

IFIS (International Food Information Service). 1985. Bibliography of dictionaries and vocabularies on food nutrition and cookery, IFIS, FSTA reference series No. 4. ISBN 3-922961-04-6. 139 pp, DM 60

This bibliography consists of 436 entries. Each reference consists of a bibliographical and an explanatory section, the first giving all details necessary to identify that particular publication, the latter giving some information on the contents. An author and a subject index are also provided.

Forthcoming Events

Advanced Course on Plant Breeding and Seed Production, 15 Oct 1985 - 31 May 1986, Mediterranean Agronomic Institute of Saragossa, Saragossa, Spain

Organized by the International Center for Advanced Mediterranean Agronomic Studies, the course is aimed at training specialists in the field of plant breeding so that they can furnish the farmer with the best adapted seeds to his particular agro-ecological conditions. It is designed to train graduates and plant breeders in the areas of the development and execution of plant breeding programs and in the management of propagation and storage of the seed.

Canadian Wheat Production Symposium, 3-5 Mar 1986, Saskatoon Inn, Saskatoon, Saskatchewan, Canada

Sponsored by the College of Agriculture, Department of Crop Science and Plant Ecology, Crop Development Centre, and Division of Extension of the University of Saskatchewan, the symposium will discuss current wheat production in Canada with emphasis on the western grain belt. Topics will include an overview of wheat production in Canada, current production technology, management of pests and diseases, new variety development, utilization of the various kinds of wheat, wheat markets, and marketing strategies.

Contact: Bruce Hobin, Division of Extension and Community Relations, University of Saskatchewan, Saskatoon, SK, Canada S7N 0W0.
Phone (306) 966-5551.

Second Arab Congress of Plant Protection, 24-27 Mar 1986, Damascus, Syria

Contact: S. Sheikho, STIP, ICARDA, P.O. Box 5466, Aleppo, Syria.

Agricultural Research Policy Seminar, 14-24 Apr 1986, University of Minnesota, St. Paul, Minnesota, USA

Contact: Fred Hoefler, 405 Coffey Hall, University of Minnesota, 1420 Eckles Avenue, St. Paul, MN 55108, USA.

Twelfth ICC Congress on Bread for the Future and Small Baked Goods throughout the World, 23-24 Apr 1986

Contact: Fremdenverkehrszentrale Hamburg, e.v. Tourist Information, Bieberhaus, Hachmannplatz 1, D-200, Hamburg 1.

38th International Symposium on Crop Protection, 6 May 1986

Contact: The Secretary, Faculty of Agricultural Sciences, St University, Coupure Links 653, D-9000 Gent, Belgium.

Ninth International Congress of Cytology, 26-29 May 1986

Contact: International Department, Royal Agricultural Society of England, National Agricultural Ctr, Stoneleigh, Kellingworth, Warwickshire, UK CU8 2L2.

Farm Management in Practice Seminar, 16 June - 11 July 1986, University of Minnesota, Agricultural Extension Service, St Paul, Minnesota, USA

This 4-week seminar will focus on the application of modern business management techniques to the farm business, and examine the current status of the profession. Topics such as the farm manager in the USA and other countries; tools and techniques of the profession, financial management; enterprise economics; appraisal technique; professional practices, fees, and liability; response to changing national and international policies; and others will be covered in the seminar.

Contact: Fred Hoefler, Ph.D. Extension Specialist. International Program Development, 405 Coffey Hall, University of Minnesota, 1420 Eckles Ave. St Paul, MN 55108, USA.

Telex TWX: 298421 UM COL AG
Phone: 612-373-0725.

International Organization of Plant Biosystematists (IOPB) Symposium: Differentiation Patterns in Higher Plants, 13-18 July 1986, Zurich, Switzerland.

Contact: Dr Krystyna Urbanska, Geobotanisches Institut, E.T.H., 38 Zurichbergstrasse, CH-8044, Zurich, Switzerland.

Second International Conference on Insect Neurochemistry and Neurophysiology, 4-6 Aug 1986, University of Maryland, USA

Contact: ICINN 1986 Registration, Insect Reproduction Lab., USDA Bldg, 306, RM 119, Barc-East, Beltsville, MD 20705, USA.

10th International Plant Nutrition Colloquium, 4-9 Aug 1986, University of Maryland Centre, Adult Education, College Park, Maryland, USA

Contact: Miklos Faust, Agricultural Research Service, Faust Laboratory, Room 120, Bldg 004, Beltsville. Agricultural Research Centre - West Beltsville, Maryland 20705, USA.

Sixth International Congress on Pesticide Chemistry, 10-17 Aug 1986, Ottawa, Ontario, Canada

Contact: Chemical Institute of Canada, 151 Slater Street, Suite 966, Ottawa, Ontario, K1P 5H3, Canada.

International Conference on Tropical Entomology, 31 Aug - 5 Sept 1986, Kenyatta International Conference Centre, Nairobi, Kenya

Contact: Dr M.F.B. Chaudhury, Secretary General, International Conference on Tropical Entomology, P.O.Box 30772, Nairobi, Kenya, Tel: 43049, 43081, 43235, 43719. Telex: 22058.

10th Long Ashton Symposium on Hormone Action in Plant Development - Critical Appraisal, 22-25 Sept 1986

Contact: The Science Liaison Officer, Long Ashton Research Station, University of Bristol, Long Ashton, Bristol, UK BS18 9AF.

International Symposium on Automatic Control and Optimization of Food Processes, 12-13 Nov 1986, Paris, France

Following the symposium, the International Exhibition of Food Machinery - GIA organized by the Food Work-

ing Party of the European Federation of Chemical Engineering, will be held, 13-19 Nov 1986, Paris, France.

International Seminar on Food Consumption Patterns and Policies in Maghreb Countries, Dec 1986

Contact: Conference Programming Section, FAO, via delle Terme di Caracalla, 00100 Rome, Italy.

Second International Conference on Food Science and Technology, 19-21 May 1987, IFIS Berlin, FRG.

To be organized by Satz-Rechen-Zentrum, Hartmann und Heenemann KG, and International Food Information Service (IFIS). The conference will address the following topics:

- information services in food science and nutrition
- the impact of new technologies on food information services
- the reaction of the user to new services and to new information products in food science.

Contact: Dr Hans W. Fock, Satz-Rechen-Zentrum, Hartmann und Heenemann, Lutzowstr 105, 1000 Berlin 30, FRG.

Second International Conference on Quantitative Genetics, 31 May - 5 June 1987, Raleigh, N.C., USA

The conference is designed to survey advances made in quantitative genetics since the first international conference held in Ames, Iowa, in 1976. It will include sessions on animal breeding, plant breeding, ecology, evolution, forestry, human genetics, molecular genetics and theory.

Contact: Dr B.S.Weir, Conference Secretary, Department of Statistics, North Carolina State University, Box 8203, Raleigh, NC 27695-8203, USA.

International Botanical Congress, 24 July - 1 Aug 1987, International Congress Centre, Berlin, FRG

The Congress will be held under the auspices of the International Union of Biological Sciences (IUBS), and will cover all branches of plant science, one of the Congress programs will be devoted to "Genetics and Plant Breeding."

Contact: Secretariat 14, International Botanical Congress, c/o Botanischer Garten und Botanisches Museum, Königin-Luise-Strasse 6-8, D-1000 Berlin 33, FRG

CONTRIBUTORS' STYLE GUIDE

Policy

The aim of the newsletter is to publish quickly the results of recent research. Articles should normally be confined to a single subject, be of good quality and of primary interest to research, extension and production workers, administrators and policy makers. Articles for publishing in the newsletter should not be submitted to or published in any other journal.

Editing

Articles will be edited to preserve uniform style but substantial editing will be referred to the author for his approval; occasionally, papers may be returned for revision.

Disclaimers

The views expressed and the results presented in the newsletter are those of the author(s) and not the responsibility of ICARDA. Similarly, the use of trade names does not constitute endorsement of or discrimination against any product by ICARDA.

Manuscript

Articles should be typed double spaced on one side of the page only. The original and two other legible copies should be submitted. The contributor should include his name and initials, title, program or department, institute and postal address and telex number if available. Photographs, figures, tables etc. should be either 8.5 cm wide (single column) or 17.5 cm wide (double column including space). Figures and diagrams should be drawn in India ink; send original artwork, not photocopies. Define in footnotes or legends any unusual abbreviations or symbols used in a figure or table.

Units of measurement are to be in the metric system, e.g., t/ha, kg, g, m, km, ml (= milliliter), m².

The numbers one to nine should be written as words except in combination with units of measure; all other numbers should be written as numerals, e.g., Nine plants, 10 leaves, 9 g, ninth, 10th, 0700 hr.

Examples of common expressions and abbreviations

3g, 18 mm, 300 m², 4 Mar 1983; 27% ; 50 five-day old plants; 1.6 million; 23 μg; 5°C; 1980/81 season; 1981-83; Fig., No.; FAO, USA. *Fertilizers*: 1 kg N or P₂O₅ or K₂O/ha.

Mon, Tues, Wed, Thurs, Fri, Sat, Sun; Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec. versus = vs, least significant difference = LSD, standard error = SE ±, coefficient(s) of variation = CV(s).

Probability: Use asterisks to denote probability * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Botanical. Include the authority name at the first mention of scientific names. Cultivar(s) = cv(s), variety = var(s), species = sp./spp., subspecies = subsp., subgenus = subg., forma = f., forma specialis = f.sp.

References

Journal articles: Baker, R.J. and Briggs, K.G. 1983. Relationship between plant density and yield in barley. *Crop Science* 23(3): 590-592.

Books: Evans, L.T. and Peacock, W.J. (eds.). 1981. *Wheat science - today and tomorrow*. Cambridge University Press, Cambridge 290 pp.

Articles from books: Zadocks, J.C. and van Leur, J.A.C. 1983. Durable resistance and host pathogen environment reactions. Pages 125-140 in *Durable Resistance in Crops*. Plenum Publications Corporation, New York.

Papers in proceedings: Srivastava, J.P. 1983. Status of seed production in the ICARDA region. Pages 1-16 in *Seed Production Technology*. Proceedings of the Seed Production Technology Training Course-1, ICARDA/the Government of Netherlands, 20 Apr - 6 May 1982, Aleppo, Syria. Available from ICARDA.



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