Plant Breeding 101, 95—106 (1988)

ISSN 0179-9541

International Center for Agricultural Research in the Dry Areas, Aleppo (Syria);
Iowa State University, Ames, Iowa (USA);
Lehrstuhl für Pflanzenbau und Pflanzenzüchtung, Technische Universität München, Freising-Weihenstephan (Germany, F.R.)

Evaluation of Barley (*Hordeum vulgare* L.) Landrace Populations Originating from Different Growing Regions in the Near East*

EVA WELTZIEN

With one figure and 10 tables

Received March 8, 1988 / Accepted March 20, 1988

Abstract

This study characterizes barley (*Hordeum vulgare* L.) germplasm that evolved under continuous cultivation in highly drought-prone areas of the Near East. Landrace populations originating from 70 locations in Syria and Jordan were evaluated under field conditions in Tel Hadia, Syria, on the basis of single head-row progeny performance. Significant genetic variation was found for all traits recorded: seed colour, kernel row number, growth habit, awn barbing, days to heading, culm length, leaf widths, awn length, early growth vigour, lodging score, and mildew resistance.

For most traits, large proportions of the total variation were found between head progenies within single populations. The qualitative traits, growth habit, seed colour, and awn barbing showed higher variation indices in populations originating from the drier regions of Syria. Populations from the drier regions headed slightly earlier, had narrower leaves, longer culms and tended to be more susceptible to lodging and mildew than populations originating in the higher rainfall areas in Syria.

For all traits, the variance components resulting from differences among populations within a particular growing region, as well as those among populations from different regions, were highly significant. This indicates that this germplasm stock contains materials with adaptability to these diverse growing conditions. The variability present within populations, as well as that among populations with similar adaptability, is sufficient to allow successful selection for productivity-related traits.

Key words: *Hordeum vulgare* — germplasm evaluation — days to heading — growth habit — leaf width — mildew resistance

Barley (*Hordeum vulgare* L.) cultivation in the Near East dates from the development of sedentary agriculture (HARLAN 1975). It is widely accepted that cultivated, two-rowed barleys originated from forms resembling its wild relative, *H. vulgare* ssp. *spontaneum* (BOTHMER and JACOBSEN 1985). Probably, barley has been an integral part of agriculture in the Near East for the past several millenia. Most remarkable among recent changes in barley distribution and acreage has been the enormous expansion of barley cultivation in the northeastern and eastern parts of Syria during the past 50—100 years (WIRTH 1971).

In the Near East, barley is grown mainly in dry regions and on poor soils. In Syria, where it dominates cropping areas with mean annual rainfall below 250 mm (KEATINGE et al. 1986), it is grown in rotation with fallow or in monoculture. Barley is planted before the first rains in the autumn. It is frequently grazed during late tillering (SOMEL 1984), and most commonly, the crop's total biomass is harvested for dry

* Joint contribution of the International Center for Agricultural Research in the Dry Areas, and Iowa State University. Journal Paper No. J-12816 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2447.

forage or grazed (NORDBLOOM 1983b). Both grain and straw are used as feed for sheep. In the zone of 250—350 mm annual rainfall, barley is grown in more diverse rotations where its culture involves more intense management. It is rarely grown under irrigation.

Barley varieties grown in the Near East are usually landraces. Only occasionally are modern cultivars successful. The term "landrace" is given to populations of genotypes of a crop species that have evolved in a cropping system of a particular region (BENNETT 1969, HARLAN 1975). Therefore, landraces are probably heterogeneous and well adapted to the prevailing growing conditions of an area. Historically, landraces have been the major sources of variation available for plant breeders (VRIES 1908).

The first systemic evaluations of the variability in small-grain crops for the Near East concentrated on traits of interest to plant taxonomists and plant geographers (JACUBZINER 1932, VAVILOV 1950). Large-scale evaluations of barley accessions held in world collections did not permit an assessment about the variability found in the Middle East because so few were from that region (TOLBERT et al. 1979, KAHLER and ALLARD 1981, TAKAHASHI et al. 1983). The evaluation of traits closely releated to growth, development, and productivity of barley landraces from the Himalayas (WITCOMBE and GILANI 1979, MURPHY and WITCOMBE 1981) and from Ethiopia (BEKELE 1983, 1984, NEGASSA 1985) have frequently revealed regional differentiation in trait expression when evaluated in Europe.

The following study was conducted to assess the patterns of variation for traits in barley landraces from the Near East and to evaluate the usefulness of this variation for local breeding programs. The investigation was carried out in Northern Syria where growing conditions resembled the habitats where this material was collected in Syria and Jordan. This allowed genecological interpretation of the data (LANGLET 1971) as an aid to identifying

Table 1. Characterization of 10 barley growing regions in Syria and Jordan, data collected from BRICHAUMBAUI and WALLEN (1963), WALTER and LIETH (1961), FAO and UNESCO (1974), and KEATINGE et al. (1986)

Region	Mean annual rainfall (mm)	Mean temperature (°C)	Elevation above sea level (m)	Soil type, management practices
Jordan	160—400	19	800— 900	Calcic Xerosols/calcic Luvisols, frequently late planting
Suweida	300—400	15.5	800— 900	Vertic Cambisols, in rotation with wheat
Sidnaya	250—300	—	1300—1400	Chromic Luvisols, shallow, rocky soils; large variation in planting dates
Hama	250—350	16.5	400— 500	Chromic Vertisol, in diverse rotations, high yield expections
Idlib	450—550	17.2	500— 750	Chromic Luvisol, in complex rotations, intense management
Aleppo	270—330	17.4	400— 550	Calcic Luvisol/Vertisol; in rotation with wheat and food legumes
Ras el Ain	230—330	18.5	300— 420	Calcic Xerosol, gypsic Xerosols, barley monoculture, or in rotations with fallow
Raqqa	180—230	—	250— 320	Calcic Xerosol, monoculture, frequent green stage and mature crop grazing
Palmyra	<180	19.0	250— 550	Gypsic Yermosol, frequent late season mature crop grazing
Deir ez Zor	120+ Irrig.	18.0	200	Gypsic Fluvisols, saline, irrigated

adaptations to growing conditions with varying degrees of environmental stress. In those few instances when barley landraces have been evaluated (BROWN and MUNDAY 1982, BEKELE 1983, 1984, DAMANIA et al. 1983, 1985), variation within populations accounted for approximately 50 % of the total variation. Such variation has great value for improving productivi-

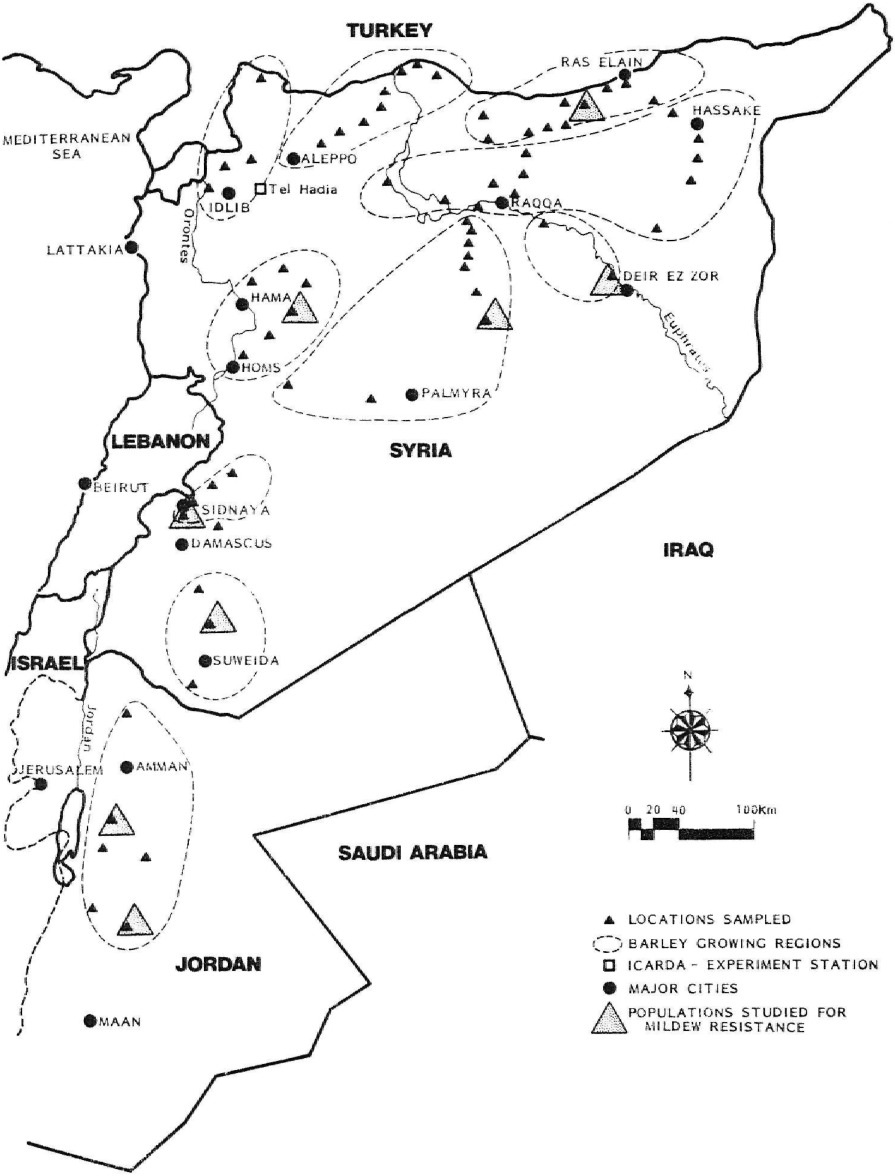

Fig. 1. Geographical origin of the barley landrace populations collected and their grouping in reference to the major barley growing areas

ty-related traits for the target environments. For traits such as developmental or resistance characters, this variation may provide population buffering (ALLARD and BRADSHAW 1964) of importance in different environments.

Materials and Methods

Landrace collection: Landraces were collected during the harvest season 1981 by using methods developed by MARSHALL and BROWN (1975). Seventy sampling sites were chosen to represent the various growing areas. The distance between sampling sites was at least 10 km, and at each site, 100 spikes were collected at random. Distance between individual spike sampling sites was approximately 1.5 m. The material collected at one site will be referred to as a population. The geographical locations of population sites and their groupings according to growing regions are shown in Figure 1. Growing regions covered a range of mean annual rainfall between 160—550 mm, mean annual temperatures between 15.5 and 19.0 °C, and a variety of soil types and management practices (Table 1). The exact geographical coordinates for each sampling site, and the seed samples, are kept at the Genetic Resources Unit of the International Center for Agricultural Research for Dry Areas (ICARDA),Aleppo, Syria and at the Bundesforschungsanstalt für Landwirtschaft (FAL), Braunschweig, Federal Republic of Germany (FRG).

Landrace evaluation: The barley accessions were grown in 1981/82 at ICARDA center at Tel Hadia, Syria, where the predominant soil type is a calcic luvisol. During the growing season, 338 mm of rainfall were received, which approximates the long-term average of 342 mm (ICARDA 1984). Temperatures were below average during January—March. Planting took place during the week of 7—14 December in a field that was fallowed in the two previous seasons. Weeds were controlled manually during the booting stage.

From each of the 70 populations, 100 spike progenies were sown. For 37 populations, each spike provided enough seed to plant a 1-m row, and rows were spaced 50 cm apart. For the remaining 33 populations, only 3—5 seeds per spike were available, so they were sown in hills spaced 50 cm apart in perpendicular directions. Every eleventh plot was sown with one of two check cutivars, either "Badia", an improved six-row cultivar used in ICARDA breeding nurseries or "Arabic abied", a landrace population used as a Syrian national check. During the growing season, 12 traits were recorded on a plot basis (Table 2).

Table 2. Traits measured on spike rows from 70 barley landrace populations

Trait	Unit of measurement	Explanation
Growth habit	score	1 = erect, 2 = semi-erect, 3 = prostrate
Early growth vigour	score	1 = much more vigorous than adjacent check cultivars 9 = much less vigorous than adjacent check cultivars
Days to heading	d	days after sowing
Mildew infestation	score	1 = no symptoms observed 9 = heavy sporulation observed on the head and flag leaf (only on 33 populations)
Culm length	cm	rounded to the nearest 5 cm, average height from soil to head peduncle
Flag leaf width	mm	measured on the widest part of the leaf of one random plant in 50 randomly chosen head rows per population
Width of penultimate leaf	mm	measured on the widest part of the leaf on the same 50 plants that were measured for flag leaf width
Awn length	cm	measured on one randomly chosen plant in the same head rows as the previous traits
Awn barbing	score	1 = smooth, 2 = semi-smooth, 3 = rough
Seed colour	score	1 = white, 2 = non-white
Lodging susceptibility	score	1 = plot completely upright (90°) 9 = plot laying on ground (0°)
Kernel row number	score	2 = 2-rowed, 6 = 6-rowed

Table 3. Frequencies of character states for kernel row number, seed colour, growth habit, and awn barbing within barley landrace populations from 10 growing regions

Region	Kernel row no.		Seed colour		Growth habit			Awn barbing		
	2 row	6 row	white	non-white	erect	semi-erect	pros-trate	smooth	semi-smooth	rough
Jordan	100.0	0.0	96.2	3.8	86.4	12.7	0.9	27.3	55.5	17.2
Suweida	100.0	0.0	94.9	5.1	44.9	48.6	6.4	29.1	44.6	26.4
Sidnaya	99.5	0.5	97.5	2.5	68.3	30.5	1.3	40.6	6.1	53.3
Hama	99.8	0.2	88.5	11.2	59.6	38.9	1.5	72.3	23.8	4.0
Idlib	100.0	0.0	99.7	0.3	54.4	44.4	1.3	81.0	18.0	1.0
Aleppo	100.0	0.0	26.5	73.5	44.6	49.6	5.8	70.1	14.8	15.2
Ras el Ain	100.0	0.0	20.3	79.7	33.1	50.5	16.4	60.4	14.4	25.3
Raqqa	100.0	0.0	28.1	71.9	35.5	47.3	17.2	61.6	11.1	27.3
Palmyra	99.7	0.3	38.5	61.5	48.4	39.2	12.3	60.8	9.6	29.6
Deir ez Zor	0.0	100.0	76.9	23.1	16.0	56.2	27.8	0.0	0.6	99.4
Overall	96.9	3.1	54.5	45.5	49.6	40.8	9.6	54.9	17.8	27.3

On 61 lines from eight populations (Fig. 1), mildew infection types were evaluated by using an isolate of *Erysiphe graminis* D.C. F. sp. *hordei* Marchal from the Near East. The inoculation was carried out as described by ASLAM and SCHWARZBACH (1981). The infection types were scored according to TORP et al. (1978), and scores from 0 to II—III were considered resistant.

Statistical analysis: The data were analyzed by using the Statistical Analysis System (1985) by applying the procedure Proc Means, Proc Frequencies, and Proc Nested.

Table 4. Percentages of spike progenies with wide, awned outer glumes in 13 barley populations from 5 regions

Region	Population	%
Hama	31	64.5
	59	2.0
	60	71.0
	61	2.0
Aleppo	24	3.2
	25	19.8
	27	3.2
	54	13.0
	55	8.0
Ras el Ain	45	2.0
Palmyra	34	9.0
	40	1.0
Sidnaya	62	1.0

The total variance of a quantitative trait was analyzed according to the following hierarchical linear model:

$x_{ijk} = \mu + r_i + p_{ij} + e_{ijk}$, where

x_{ijk} = single plot observation
μ = overall mean
r_i = effect of the ith region
p_{ij} = effect of the jth population within the ith region
e_{ijk} = deviation of single progeny value from population mean (genetic and environmental effects confounded).

An estimate of the environmental error was obtained from the variation among check plots. The within-populations variance for qualitative traits was analyzed by using „Shannon-Weaver-Information" (SWI) Indices, calculated using the following formula:

$$SWI = -\sum_{i=1}^{n} p_i \log_2 p_i,$$

where p_i is the relative frequency of state i of the character concerned for a population. The maximum possible index value increases with the number n of character states. Therefore, to compare indices obtained for different traits, they were standardized to a maximum value of 1. To test whether populations from the various regions showed different levels of within-population variation, the nonstandardized indices for each trait were subjected to a two-level hierarchical analysis of variance. This allowed estimates of the proportions of variance due to regional effects and due to differences among populations within regions.

For two constrasting barley growing regions, separate estimates of variation within populations ($\hat{s}_e^2$) were obtained for traits that exhibited some genetic differentiation among spike progenies. The variance component estimates were compared by F-tests to determine any possible impact of the environment under which the populations evolved on this variation component.

Results and Discussion

Qualitative Traits

Barley collected in Syria and Jordan predominantly had two-rowed spikes (Table 3). Exceptions were two populations that originated from the irrigated banks along the Euphrates River near Deir ez Zor, which had only six-rowed spikes. In three other populations, six plants with six-rowed spikes were discovered. These findings agree well with previous reports that describe all barley grown under rainfed cultivation in the Near East as being two-rowed (BOTHMER and JACOBSEN 1985, TOLBERT et al. 1979). The origin of the six-rowed accessions is uncertain. Perhaps they were introduced during a Canadian development project in the Euphrates River basin because farmers in Syria frequently refer to six-rowed barley as "Canadian barley". Six-rowed barley lines have been found along the Euphrates River previously (ARNON 1972, CAESAR and SNOY 1964) and also have been reported in Turkish barley landraces: However, their exact origin was not given (TAKAHASHI et al. 1983).

A morphological mutant with wide, awned outer glumes was found frequently in populations from northwestern Syria (Table 4). In most populations this mutant was present in low frequencies but it dominated the two populations collected east of Hama. This mutant resembles known mutants (TSUCHIYA 1974), and its genetic similarity to them is being investigated.

Lemma colour showed an array ranging from white and grey to brown and black. However, because environment influences the expression of the colour intensity, lemma colour of a progeny was classified only as white and non white. Barley from Jordan had uniformly white seeds (Table 3), and accessions from the western part of Syria had primarily white seeds. In the eastern dry area of Syria, dark-seeded samples were common, but some spike progenies were white-seeded in each population from this region. Farmers in Syria assume that dark-seeded barley lines have higher drought tolerance than do white-seeded accessions. The distribution of the two that I found corroborates this assumption.

Awn barbing varied considerably within the barley populations. Smooth, semi-smooth, and rough-awned types were found (Table 3). Within the two-rowed barley accessions, smooth-awned types predominated, but in populations from Syria and Jordan, semi-smooth and rough awns occurred at higher frequencies than in northern Syria. The distribution of smooth-awned barley coincided well with areas where mature barley is grazed in poor years (NORDBLOOM 1983a); sheep prefer smooth-awned spikes. However, no information exists about methods that farmers in those areas may use in selection and seed preparation. Awn barbing is a trait frequently used by farmers to differentiate *H. spontaneum* from cultivated barley, which resemble each other closely. All six-rowed barley accessions had rough awns (Table 3), which supports the suggestion that the six-rowed samples that I collected were introduced.

Growth habit varied enormously among spike progenies within populations as well as among 10 growing regions (Table 3). Prostrate growth habit, which is commonly referred to as winter growth habit, was found regularly. Populations from northeastern Syria had frequencies of progenies with prostrate growth habit between 12 and 27 %. Those from western and southern Syria primarily had erect plants. This distribution coincides well with the increasingly continental weather patterns from west and south to east, and the greater grazing by sheep in northeastern Syria (NORDBLOOM 1983b).

When within-population variation for qualitative traits was summarized, it was shown that kernel row number did not contribute to variation within populations, whereas seed colour, awn barbing, and growth habit were of increasingly greater importance (Table 5). In a study of Iranian barley landraces, row number and seed colour contributed little to strain variation (BROWN and MUNDAY 1982), but BEKELE (1984) and NEGASSA (1985), who studied Ethiopian collections, found that row number was the most variable of all qualitative traits. All qualitative traits are easily influenced by selection, but selection pressures practised by the farmers have not been analyzed in any investigation.

Table 5. Mean Shannon-Weaver-Information (SWI) indices for barley landrace populations from 10 growing regions in Syria and Jordan

Region	Kernel row no.	Seed colour	Growth habit	Awn barbing	Mean index over traits
Jordan	0.00	0.21	0.37	0.77	0.34
Suweida	0.00	0.26	0.80	0.75	0.46
Sidnaya	0.04	0.14	0.60	0.68	0.36
Hama	0.02	0.39	0.66	0.54	0.40
Idlib	0.00	0.02	0.66	0.45	0.28
Aleppo	0.00	0.80	0.76	0.70	0.58
Ras el Ain	0.00	0.69	0.87	0.82	0.59
Raqqa	0.00	0.83	0.88	0.80	0.63
Palmyra	0.02	0.81	0.82	0.72	0.59
Deir ez Zor	0.00	0.57	0.85	0.03	0.36
Mean SWI index over regions	0.01	0.58	0.75	0.70	0.51

The northern regions, except Deir ez Zor, all have higher SWI indices than the populations sampled in the south (Table 5). This was due mainly to greater variation for seed colour and growth habit.

The analysis of variance of SWI indices (Table 6) confirmed that most variation among populations was due to effects among regions for all traits. This indicated that regional differences in management practices or environmental conditions had a larger effect on intrapopulation variation than local differences in management and seed exchange.

Quantitative traits

Overall, the average period from planting to 50 % heading for the 700 barley accessions was 133 days (Table 7). This value would rank as intermediate to late when compared with barley in the breeding programme at ICARDA. Population means ranged from 123 days (Pop 70 from Jordan) to 137 days (Pop 58 from the Idlib region), but means for the regions varied only slightly (Table 7). There was a tendency for populations from Jordan and southern Syria to be early, and those from western Syria, which receives high annual rainfall, headed 1—2 days later than populations from the dry region in eastern Syria.

In contrast, variation for heading dates among spike progenies within populations was very large. The mean range was 17.9 days (Table 7). Heading data is considered to be a trait of great adaptive importance, especially in environments subject to drought (FISCHER 1981). My results indicate that no strong directional selective pressure for this trait existed within the production systems of Jordan and Syria. Probably, the enormous variation for

Table 6. Means of the Shannon-Weaver-Indices, their total variances, and components due to regional effects and differences between populations within regions, expressed in percent of total variance

Trait	Overall SWI mean	Total SWI variance	Variance component between regions (%)	Variance component within regions (%)
Seed colour	0.546	0.134	68.03	31.97
Growth habit	1.149	0.115	79.15	20.85
Awn barbing	1.059	0.141	59.88	40.12
Mean index	0.918	0.087	75.30	24.69

Table 7. Means of eight quantitative traits for barley landraces from 10 different barley growing regions and mean ranges of selected trait expressions within the populations of a region

Region	Days to heading mean (d)	Days to heading range	Culm length mean (cm)	Culm length range	Flag leaf width (mm)	Width of penultimate leaf (mm)	Awn length (cm)	Early growth vigour (score)	Lodging susceptibility (score)	Mildew infection (score)
Jordan	129.7	15.1	52.4	30.0	10.1	13.0	15.3	4.8	5.4	2.2
Suweida	131.7	18.0	47.8	33.3	10.5	13.6	14.9	3.8	5.8	2.4
Sidnaya	133.8	21.0	46.7	35.0	9.1	11.8	14.4	4.9	5.4	2.5
Hama	133.7	17.7	45.2	32.5	8.7	11.6	14.9	4.6	4.7	2.9
Idlib	134.2	21.8	45.5	25.0	8.6	11.3	15.4	4.5	4.3	—
Aleppo	132.5	17.9	48.4	30.6	8.6	11.5	14.4	4.6	5.7	3.8
Ras el Ain	132.4	15.6	51.5	31.8	8.3	11.2	13.8	4.6	5.8	3.8
Raqqa	133.5	18.7	49.2	33.1	8.4	11.3	14.4	4.9	5.8	4.3
Palmyra	132.7	20.1	51.0	34.0	8.9	12.3	13.9	5.0	5.6	3.2
Deir ez Zor	134.3	13.0	67.4	35.0	11.7	14.3	13.5	3.8	7.3	—
Overall mean	132.6	17.9	49.8	32.0	9.0	11.9	14.4	4.7	5.5	3.5
LSD 5 %	0.05	—	1.0	—	0.1	0.1	0.3	0.2	0.2	0.2

heading date within populations contributes to the stability of performance of the landraces by providing population buffering (ALLARD and BRADSHAW 1964).

Culm length of the 7000 spike progenies of barley averaged 49.8 cm, which is short, when compared with introduced six-rowed cultivars in the ICARDA breeding program. There was considerable variation for this trait among regions (Table 7). The two six-rowed populations from Deir ez Zor were approximately 20 cm taller than most two-rowed populations. Among the two-rowed populations, there was a tendency towards greater culm length for populations from the drier growing regions in Syria (Palmyra, Raqqa, Ras el Ain) and from Jordan. Because plant height would be suppressed by the drought conditions in these regions, taller culms would be advantageous, especially for mechanical harvesting. As observed for days to heading, variation for culm length among lines within populations was large (Table 7).

Generally, the barley accessions were susceptible to lodging (i.e., they had high scores) even though no mineral nitrogen was applied in my experiment. Some differentiation for lodging was observed for populations from diverse growing regions. Populations from Hama and Idlib regions, where high yields occur, had significantly lower lodging scores than populations from the dry parts of Syria and Jordan (Table 7). On average, there was very large variation of lodging scores within populations.

Barley landrace leaves were narrow, except for the six-rowed populations from Deir ez Zor (Table 7). Populations from Jordan and southern Syria had significantly wider leaves than those from northern Syria. Accessions with the narrowest leaves were found in populations originating from southeastern Syria, which is very dry.

Mean awn length was 14.4 cm, which is intermediate to long when compared with breeding lines at ICARDA (Table 7). The ranges and distributions of awn lengths found within the barley populations were similar to those found for a large collection of Turkish barley lines evaluated in Japan (TAKAHASHI et al. 1983). Means for barley lines from different regions differed significantly, but no association was evident between awn length and major environmental factors.

On average, this barley collection was slightly more vigorous in late-tillering stages than the check "Badia" (Table 7). The six-rowed populations from Deir ez Zor and the three populations from Suweida were significantly more vigorous than all other populations. However, the observable differentiation among populations for this trait showed no

Table 8. Frequency of mildew infection types in a sample of 61 landrace lines from 7 regions when inoculated with isolate Ni-is-l

Region	No. of lines tested	Infection type					
		0	I-II	II-III	III	III-IV	IV
Jordan	14	1	—	3	1	1	8
Suweida	8	1	—	—	—	5	3
Sidnaya	10	—	—	—	—	1	9
Hama	9	—	—	—	—	—	9
Ras el Ain	8	—	—	—	—	—	8
Palmyra	3	—	—	—	—	—	3
Deir ez Zor	9	—	—	—	—	—	9

discernible association with weather patterns or differences in management practices.

A natural epidemic of powdery mildew (*Erysiphe graminis* D.C. f. sp. *hordei* Marchal) permitted an evaluation of the barley accessions for field resistance to this disease. Susceptibility to mildew was common in all populations. However, the leaf area diseased and the spread to the flag leaf and spike were limited, which led to an average score of 5.5, a rating of moderately susceptible (Table 7). Populations from Jordan and southern and western Syria had significantly lower mildew scores than those from northern Syria, where this disease is rarely found. The higher level of resistance of the populations from southern regions could be confirmed by an analysis of the infection types of 61 progenies from the 8 selected populations (Fig. 1). Resistance to the isolate Ni-is-l occurred only in the two populations from Jordan (Wadi el Hassa and Madaba) and the population from Um Zeitoun.

The total variation found for each quantitative trait was subdivided into three components. For all traits, the largest proportion of the total variation was attributable to differences among lines within populations (Table 9). Because the spike progenies were grown without replication, this variance component undoubtedly is overestimated. For the majority of traits, the magnitude of variation among spike progenies surpassed the variance component attributable to differences between populations.

Differences between population means were highly significant for all traits. Such differences have been analyzed in wild grass species (e.g.,

Table 9. Estimates of variance components due to regional effects, differences between populations within regions, and between lines within populations, expressed in percent of total variance; the estimate of the error variance is expressed in percent of the variation within populations

Trait	Total variance	Variance component (%)			Error variance
		Between regions	Within regions	Within populations	
Days to heading	18.34	8.01	28.26	63.73	8.1
Culm length	73.04	18.60	25.44	55.96	66.1
Flag leaf width	3.29	17.91	25.69	56.39	100.0
Width of penultimate leaf	3.91	15.71	24.68	58.61	100.0
Awn length	2.86	10.57	10.53	78.90	96.3
Lodging score	2.81	7.37	23.90	68.73	38.0
Mildew score	1.50	34.78	10.90	54.32	19.0
Early growth vigour	1.97	3.78	15.81	80.41	—
Mean	—	14.60	20.7	64.7	—

Table 10. Estimates of the variation among lines within populations for two groups of populations, and their F-ratios

	Hama, Idlib (high rainfall)		Palmyra (very low rainfall)		
	$\hat{s}_e^2$	d.f.	$\hat{s}_e^2$	d.f.	F
Culm length	37.21	970	48.19	938	1.30**
Days to heading	14.22	970	12.83	938	1.11
Lodging score	1.66	970	2.43	938	1.46**
Early growth vigour	1.35	970	1.81	938	1.34**
Awn length	2.66	466	2.69	507	1.01

** Significant at P = 0.005

ALLARD et al. 1968), and they are generally considered to have some adaptive significance (LANGLET 1971, OSMOND et al. 1980). In cultivated species, different practices in seed multiplication and preparation can be a cause for such differences also. I attempted to separate these two effects by partitioning the differences between population means into a component due to regional differences (mainly climatic) and a component due to differences between populations within regions. The present results show that most of the variation between populations was within regions and therefore of a local nature. Regional differences due to adaptation to different climatic conditions contributed little to the overall variation (Table 9). The groupings of the populations were based entirely upon rough climatic data and agronomic practices, and they may not reflect actual relationships among these populations. Investigations of their phenotypic similarity will be reported elsewhere.

The present experiment revealed large variation among spike progenies within populations for both qualitative and quantitative traits (Tables 5, 9). For the quantitative traits, the comparison of the variance component "within populations" with an estimate of the environmental variance indicates genetic variation among progenies within populations for five traits (Table 9). This could be confirmed in replicated yield trials conducted with a sample of lines from this collection (WELTZIEN and FISCHBECK 1987). The quantity of genetic variation within populations in my study was large when compared with expectations expressed in a review of research of wild, self-pollinated species (LOVELESS and HAMRICK 1984).

However, in other studies, cultivated barley populations with high variation within populations have been found. In Ethiopian landraces, an average of 77 % of the total variation occurred among single plants within populations (BEKELE 1983). From a similar study of 16 barley populations from Yemen and 16 from Nepal conducted by DAMANIA et al. (1985), I computed that 57 % and 34 %, respectively, of the total variation was due to differences between plants within populations. These results are further indications that variation within populations is a sizeable component of the total variation in germplasm collections of cultivated plants. However, in these two instances, it was not possible to estimate the genetic variation.

In the present study, sizeable genetic variation within populations was found for traits conferring adaptation, such as days to heading, culm length, lodging susceptibility or growth habit. This leads to the suggestion that this variation, as a result of natural selection, provides population buffering against highly variable environmental factors. The comparison of "within-population" variance component estimates for the two most contrasting growing regions in Syria supports the concept that greater variation within populations is associated with more stressful environments (Table 10).

These results suggest that, in future cultivar development in these areas, the possibility of mixing selected pure lines to obtain populations with diversity for adaptive traits should be investigated. Furthermore, this variation within populations is a source of well-adapted and diverse breeding material, which might allow fast progress from selection for productivity-related traits at the onset of a new breeding program.

Zusammenfassung

Charakterisierung von Landgersten aus unterschiedlichen Anbaugebieten des Nahen Ostens

In dieser Untersuchung werden Kulturgersten (*Hordeum vulgare* L.) beschrieben, die aus Anbaugebieten mit häufig auftretender Dürre stammen. Siebzig Landsortenpopulationen aus Syrien und Jordanien wurden unter Feldbedingungen in Tel Hadia, Syrien, geprüft. Signifikante, genetisch bedingte Variation wurde für alle erfaßten Merkmale festgestellt: Samenfarbe, Zeilenzahl, Wuchsform, Grannenbezahnung, Tage bis Ährenschieben, Halmlänge, Blattbreiten, Jugendentwicklung, Lageranfälligkeit und Mehltauresistenz.

Für die Mehrzahl der Merkmale wurde ein erheblicher Anteil der Gesamtvariation zwischen den Linien innerhalb der Populationen festgestellt. Diese Varianz war besonders hoch für Merkmale, die mit Wachstum und Ertragsentwicklung in Beziehung stehen und läßt daher signifikante Selektionserfolge erwarten. Für die qualitativen Merkmale Wuchsform, Samenfarbe und Grannenbezahnung war diese Variation größer in Populationen, die aus den Trockengebieten Syriens stammten. Populationen aus den Trockengebieten blühten zudem etwas früher, hatten schmalere Blätter, längere Halme und waren anfälliger gegenüber Lager und Mehltau.

Für alle quantitativen Merkmale waren die Varianzkomponenten, bedingt durch regionale Effekte sowie durch Unterschiede zwischen Populationen innerhalb Regionen, hoch signifikant. Dies deutet darauf hin, daß diese Kollektion Material mit Anpassungsfähigkeit an diese extremen Wachstumsbedingungen enthält.

The financial support received during this study from the Evangelisches Studienwerk Villigst, Gesellschaft für technische Zusammenarbeit (GTZ) and the World Food Institute of Iowa State University is gratefully acknowledged. Thanks are due to C. FROMM for carrying out the mildew inoculation study, to Prof. Dr. Dr. h. c. G. FISCHBECK and Dr. K. J. FREY for valuable support and revision of the manuscript, and to my sister Friederike for helping with the harvest and threshing of the material.

References

ALLARD, R. W., and A. D. BRADSHAW, 1964: Implications of genotype-environmental interactions in applied plant breeding. Crop Sci. **4**, 503—508.

— —, S. K. JAIN, and P. L. WORKMAN, 1968: The genetics of inbreeding populations. Adv. Genet. **14**, 55—131.

ARNON, I., 1972: Crop production in dry regions. Vol. II. Systematic Treatment of the Principal Crops. London: Leonard Hill.

ASLAM, M., and E. SCHWARZBACH, 1981: An inoculation technique for quantitative studies of brown rust of barley. Phytopathol. Z. **99**, 87—91.

BEKELE, E., 1983: Some measures of gene diversity analysis in landrace populations of Ethiopian barley. Hereditas **98**, 127—143.

— —, 1984: Relationship between morphological variance, gene diversity and flavonoid patterns in the landrace populations of Ethiopian barley. Hereditas **100**, 271—294.

BENNETT, E., 1969: Genecology, genetic resources and plant breeding. Genet. Agrar. **24**, 210—220.

BOTHMER, R. V., and N. JACOBSEN, 1985: Origin, taxonomy and related species. In: RASMUSSEN, D. C. (ed.), Barley. Am. Soc. Agron., Madison, WI, 19—56.

BRICHAUMBAUT, G. P. DE, and C. C. WALLEN, 1963: A study of agroclimatology in semi-arid and arid zones of the Near-East. W.M.O. Tech. Note **56**.

BROWN, A. H. D., and J. MUNDAY, 1982: Population genetic structure and optimal sampling of land races of barley from Iran. Genetica **58**, 85—96.

CAESAR, K., und M. L. SNOY, 1964: Beobachtungen an Getreideformen beim Anbau in verschiedenen Klimagebieten. Z. Acker-Pflanzenbau **121**, 235—255.

DAMANIA, A. B., E. PORCEDDU, and M. T. JACKSON, 1983: A rapid method for the evaluation of variation in germplasm collections of cereals using polyacryl gel electrophoresis. Euphytica **32**, 877—883.

— —, M. T. JACKSON, and E. PORCEDDU, 1985: Variation in wheat and barley landraces from Nepal and the Yemen Arab Republic. Z. Pflanzenzüchtg. **94**, 13—24.

FAO and UNESCO, 1974: Soil-map of the World, Vol. 1. Paris, France.

FISCHER, R. A., 1981: Optimizing the use of water and nitrogen through breeding of crops. In: MONTEITH, J., and C. WEBB (eds.), Soil Water and Nitrogen, in Mediterranean Type Environments, 249—278. The Hague: Nijhoff/Jungk.

HARLAN, J. R., 1975: Crops and Man. Am. Soc. Agron., Madison, WI.

ICARDA, 1984: Annual Report 1983, Aleppo, Syria.

JACUBZINER, M. M., 1932: The wheats of Syria, Palestine and Transjordania. Tr. Prikl. Bot. Genet. Sel. Suppl. **53**, Leningrad.

JAIN, S. K., C. O. QUALSET, G. M. BHATT, and K. K. WU, 1975: Geographical patterns of phenotypic diversity in a world collection of durum wheats. Crop Sci. **15**, 700—704.

KAHLER, A. L., and R. W. ALLARD, 1981: World-wide patterns of genetic variation among four esterase loci in barley (*Hordeum vulgare*). Theor. Appl. Genet. **59**, 101—111.

KEATINGE, J. D. H., M. D. DENNETT, and J. ROGERS, 1986: The influence of precipitation regime on the management of dry areas in northern Syria. Field Crops Res. **13**, 239—249.

LANGLET, O., 1971: Two hundred years genecology. Taxon **20**, 653—722.

LOVELESS, M. D., and J. L. HAMRICK, 1984: Ecological determinants of genetic structure in plants populations. An. Rev. Ecol. Syst. **15**, 65—95.

MARSHALL, D. R., and A. H. D. BROWN, 1975: Optimum sampling strategies in genetic conservation. In: FRANKEL, O. H., and J. G. HAWKES (eds.), Crop Genetic Improvement for Today and Tomorrow, 53—81. Cambridge Univ. Press.

MURPHY, P. J., and J. R. WITCOMBE, 1981: Variation in Himalayan barley and the concept of centers of diversity. Proc. 4th Int. Barley Genet. Symp., Edinburgh. Barley Genetics VI, 26—36.

NEGASSA, M., 1985: Patterns of phenotypic diversity in an Ethiopian barley collection, and the Arussi-Bale highland as a center of origin of barley. Hereditas **102**, 139—150.

NORDBLOOM, T. L., 1983a: Livestock — Crop Interactions. The case of green stage grazing. ICARDA, Disc. Paper No. **9**, Aleppo, Syria.

— —, 1983b: Livestock — Crop Interactions. The decision to harvest or to graze a mature grain crop. ICARDA, Disc. Paper No. **10**, Aleppo, Syria.

OSMOND, C. B., O. BJORKMAN, and D. J. ANDERSON, 1980: Physiological Processes in Plant Ecology. Berlin: J. Springer Verlag.

SOMEL, K., 1984: Barley survey 1981—82, Vol. 3. ICARDA Res. Rep. **12**.

Statistical Analysis System, 1985: SAS User's Guide: Statistics, Version 5 Edition. Cary, NC.

TAKAHASHI, R., S. YASUDA, J. HAYASHI, T. FUKUYAMA, I. MORIYA, and T. KONISHI, 1983: Catalogue of barley germplasm preserved in Okayama University. Inst. for Agric. and Biol. Sci., Okayama Univ., Kurashiki, Japan.

TOLBERT, D. M., C. O. QUALSET, S. K. JAIN, and J. C. CRADDOCK, 1979: A diversity analysis of a world collection of barley. Crop Sci. **19**, 789—794.

TORP, J. H., P. JENSEN, and J. H. JORGENSEN, 1978: Powdery mildew resistance genes in 106 northwest European spring barley varieties. R. Vet. Agric. Univ. Steril. Res. Inst., Copenhagen, Denmark. Yearb. 1978, 75—102.

TSUCHIYA, T., 1974: Preliminary results on genetic studies of outer glume characters in barley. Barley Genet. Newsl. **4**, 76—78.

VAVILOV, N. I., 1950: Selected writings of N. I. Vavilov. The origin, variation, immunity, and breeding of cultivated plants (transl. by K. STARR CHESTER). Chron. Bot. B. Waltham Mass. USA.

VRIES, H. DE, 1908: Pflanzenzüchtung. Berlin: Verlag P. Parey.

WALTER, H., und H. LIETH, 1961: Klimadiagramm Weltatlas. Jena: VEB G. Fischer.

WELTZIEN, E., and G. FISCHBECK, 1988: Genotypic variability and productivity of local barley landraces under marginal growing conditions in Syria. Arid Lands: Today and Tomorrow; Tuscon, Arizona, USA; 20—25 October 1985. Proc. Int. Res. and Dev. In: WHITEHEAD, E. E., C. F. HUTCHINSON, B. N. TIMMERMANN, R. G. VAREDY (eds.), 511—522, Boulder, Colo.: Westview/Cress.

WIRTH, E., 1971: Syrien. Eine wissenschaftliche Länderkunde. Darmstadt: Wiss. Buchges.

WITCOMBE, J. R., and M. M. GILANI, 1979: Variation in cereals from the Himalayas and the optimum strategy for sampling germplasm. J. Appl. Ecol. **16**, 633—640.

Author's address: Dr. Eva WELTZIEN, Cereals Program, ICRISAT, Patancheru, P.O., Andhra Pradesh 502 324 (India).