Theor Appl Genet (1989) 78: 653–656

Diversity within and between populations of two sympatrically distributed *Hordeum* species in Jordan

A. A. Jaradat

Department of Agricultural Sciences, Jordan University of Science and Technology, P.O. Box 3030, Irbid, Jordan

Received March 15, 1989; Accepted July 31, 1989
Communicated by P. M. A Tigerstedt

Summary. The diversity of two sympatrically distributed barley species (*Hordeum vulgare* L. and *Hordeum spontaneum* C. Koch.) has been assessed for 7 morphometric and 13 qualitative traits. Phenotypically, *Hordeum vulgare* was more stable than *Hordeum spontaneum* for all morphometric traits; this is a reflection of domestication and selection. The overall diversity indexes were 0.546 ± 0.125 and 0.502 ± 0.113 for *Hordeum vulgare* and *Hordeum spontaneum*, respectively ($P = 0.095$). However, *Hordeum spontaneum* expressed a higher level of diversity for most qualitative traits. The observed similarity for a number of diversity indexes is probably due to gene flow between the two species.

Key words: *Hordeum vulgare* – *H. spontaneum* – Population diversity – Quantitative traits – Qualitative traits

Introduction

Landraces and primitive forms of barley (*Hordeum vulgare* L.), having evolved over thousands of years in a multitude of environments and local farming systems, developed abundant patterns of variation and would represent a largely untapped reservoir of useful genes for adaptation to arid and semiarid regions (Jaradat et al. 1987). On the other hand, wild barley (*Hordeum spontaneum* C. Koch), the immediate progenitor of cultivated barley, is shown to be a vast reservoir of genetic diversity (Nevo et al. 1986). It is one of the common annual grasses in Jordan; it occupies both primary habitats and segetal, man-made environments and enters the more xeric parts of the country (Jaradat 1988).

During the last decade there has been an increasing interest in using wild relatives of cultivated crop plants in breeding new cultivars (Harlan 1976; Nevo et al. 1986). These wild relatives have proven to be valuable sources of variation in breeding for wide adaptation, resistance to stress (Blume et al. 1983), short stature and high yield (Ceccarelli 1984).

The genetic diversity of the two sympatrically distributed species collected from Jordan and other countries in the Fertile Crescent has been assessed for eight isozyme systems (Jana et al. 1987). On an overall basis, wild barley was slightly more polymorphic than cultivated landraces of the species. However, these researchers found that cultivated barley in Jordan was more polymorphic than the wild species for the same isozyme systems. The research reported here was undertaken to assess the genetic diversity of 7 morphometric traits that are important in domestication and for 13 qualitative traits, in both wild and landrace populations of barley collected from the xeric region in Jordan.

Materials and methods

The materials used in this study were collected in 1986 from the xeric region of Jordan (Table 1). The paired samples of *Hordeum vulgare* L. and *Hordeum spontaneum* C. Koch came from nine sites in that region. Geographical and ecological information concerning the collection sites and number of collected plants of both species are given in the same table. The nine sites represent different soil types ranging from fine, mixed, thermic, typic Calciorthids to loamy-skeletal, hyperthermic, typic Torriorthents (Qudah 1983).

Method of sampling. Individual wild and cultivated barley plants growing in the same field were sampled from the nine sites described in Table 1. Spikes of individual plants were threshed and bagged separately. At sowing time, an observation nursery was established, where single spikes of the paired samples from each site were sown in single-row 1-m plots. Seven morphometric and 13 qualitative traits were recorded on 371 and 373 individual plants of *H. vulgare* and *H. spontaneum*, respectively.

Table 1. Geographical and ecological information concerning the collection sites and number of plants of *H. vulgare* and *H. spontaneum* from the xeric region in Jordan

No.	Site	Elevation (m)	Lat.	Long.	Mean rainfall	Mean temp. C.			No. of Plants	
						min.	mean	max.	*H. vulg.*	*H. spont*
1	Mafraq	740	32°20′N	36°06′E	150	−4	18	40	38	49
2	Mansurah	700	32°21′N	36°08′E	180	−4	18	40	32	35
3	Wadiabiad	860	30°40′N	36°10′E	200	−3	17	40	58	50
4	Abubana	1,000	30°50′N	35°30′E	200	−4	14	36	30	32
5	Rashadia	1,200	30°36′N	35°30′E	250	−8	14	34	40	36
6	Fjaij	900	30°36′N	36°00′E	180	−8	15	34	50	41
7	Qatrana I	780	31°20′N	36°07′E	150	−6	18	42	36	43
8	Qatrana II	800	31°17′N	36°05′E	150	−6	18	42	46	36
9	Qatrana III	820	31°15′N	36°02′E	150	−6	18	42	41	51

Table 2. Mean values and coefficients of variation for seven quantitative traits measured on paired samples of *H. vulgare* and *H. spontaneum* collected from the xeric region in Jordan. The lower the c.v., the higher the stability of the trait across locations

Trait	*H. vulgar*		*H. spontaneum*	
	Mean	c.v.	Mean	c.v.
Flag-leaf length	11.60*	8.95	7.90	28.48
Flag-leaf width	0.72*	9.35	0.55	31.69
Awn length	14.90*	7.80	11.19	14.80
Peduncle length	25.62	9.30	34.90*	18.96
Flag-leaf sheath	8.19	10.56	17.20*	19.69
Plant height	55.10	6.27	65.10*	15.05
No. of tillers	10.23*	23.25	7.96	21.31

* indicates a significant difference (Tukey = 0.05) between species

Statistical analysis. A simple *t*-test was employed to compare morphometric traits among species within each site. Stability of these traits for each species over sites was calculated and expressed as a coefficient of variation (c.v.). The lower the c.v. for a particular trait, the higher its stability over sites and species.

Frequency data for qualitative traits were used to estimate the following indexes: (1) diversity indexes per site for each species and for individual qualitative traits, (2) average diversity indexes for each species and for each site, and (3) a stability index for each trait over sites.

A diversity index (H') for a trait, site or species was estimated as:

$$H' = [n \log(n) - \Sigma fi \log(fi)]/n$$

where n is the sample size and fi is the number of observations in category (i.e. phenotype) i. However, the magnitude of H' is affected not only by the distribution of the data but by the number of categories (phenotypes in this case), for the maximum possible diversity, theoretically, for a set of data consisting of k categories is

$$H'_{max} = \log k.$$

Therefore, a modified diversity index was used as follows:

$$J' = H'/H'_{max}$$

thus expressing the observed diversity as a proportion of the maximum possible diversity (Zar 1984).

Results and discussion

Both species differed significantly from each other for all morphometric traits (Table 2). The wild species, *H. spontaneum*, is characterized by having taller plants, longer peduncles, shorter and narrower flag leaves, shorter awns and fewer tillers than the domesticated species. The differences between species within each site followed the same pattern. However, the phenotypic diversity which was detected in this analysis does not necessarily reflect the full genotypic variability present in both species. Some of the genotypic variability may occur at loci which control physiological attributes not necessarily related to phenotypic differences (Vega and Frey 1980).

Stability of traits, expressed as c.v. values, varied within and among species (Table 2). Although plant height and awn length were the most stable traits in both species, *H. spontaneum* was more variable for these two, and other traits, than the cultivated species.

Diversity indexes per site for individual traits in both species are presented in Table 3. The data suggest that some traits (e.g. plant waxiness) are totally monomorphic in both species and over all sites. On the other hand, some traits (e.g. seed color, glume hairiness and straw strength) are highly polymorphic in most sites, and still other traits are highly polymorphic in one species in one site but not in the other species in the same site.

The level of diversity in both species, as presented in Table 3, can be summarized as follows: out of 117 pairs of diversity index estimates, both species were monomorphic for 54 pairs, and equally polymorphic for 6 pairs. However, polymorphism was higher in *H. spontaneum* for 37 J' estimates, while it was higher in *H. vulgare* for 20 J' estimates. The observed similarity for 50 J' estimates is probably due to gene flow between these two sympatrically distributed species (Nevo et al. 1986).

Average diversity for *H. vulgare* over traits and sites was estimated as 0.546 ± 0.125 and for *H. spontaneum* as 0.502 ± 0.113. A *t*-test indicated that there is no signifi-

Table 3. Diversity index estimates per site for individual qualitative traits in *H. vulgare* and *H. spontaneum* collected from nine sites in the xeric region in Jordan

Trait	Site								
	Species	Mafraq	Mansura	Wadi-abiad	Abu-bana	Ras-hadia	Fjaij	Qatrana		
								I	II	III
Plant waxiness	*vulgare*	0	0	0	0	0	0	0	0	0
	spontaneum	0	0	0	0	0	0	0	0	0
Leaf hairiness	*vulgare*	0.687	0	0	0	0	0	0	0	0
	spontaneum	0.387	0	0	0	0	0.665	0.359	0	0
Awn roughness	*vulgare*	0	0.691	0.589	0	0.462	0	0	0	0.598
	spontaneum	0.626	0	0.690	0	0.591	0.665	0.660	0	0
Visibility inside	*vulgare*	0	0	0	0	0.295	0	0	0	0
glumes	*spontaneum*	0	0	0	0	0.591	0	0	0.690	0
Lemma color	*vulgare*	0	0.594	0.401	0	0.504	0.227	0	0	0
	spontaneum	0.693	0.686	0.693	0	0.451	0.410	0	0.690	0.637
Nature of collar	*vulgare*	0	0	0.333	0	0.387	0	0	0	0
	spontaneum	0	0.367	0	0	0	0	0	0	0.362
Awn color	*vulgare*	0	0	0	0.646	0	0	0	0	0
	spontaneum	0.675	0.5	0.367	0	0.451	0.410	0.647	0	0.521
Glume color	*vulgare*	0	0	0	0	0.669	0	0	0	0
	spontaneum	0.504	0.44	0.69	0	0.45	0.41	0.57	0	0.52
Visibility of lemma	*vulgare*	0	0	0	0	0	0	0	0	0
steril spikelets	*spontaneum*	0	0	0.47	0	0	0	0	0	0.362
Seed color	*vulgare*	0	0.594	0.672	0	0.693	0.551	0	0.595	0.598
	spontaneum	0	0.673	0	0	0.451	0	0	0.69	0
Glume hairiness	*vulgare*	0.693	0.691	0.644	0	0.691	0.5	0	0.67	0.598
	spontaneum	0	0.673	0.405	0	0.451	0	0	0.69	0.69
Straw strength	*vulgare*	0	0.685	0.678	0	0.574	0.692	0	0.689	0.598
	spontaneum	0	0	0.593	0	0.451	0.487	0.66	0.69	0.649
Shape of lemma	*vulgare*	0	0	0	0	0	0	0	0	0
apex	*spontaneum*	0	0.673	0	0	0.687	0	0.359	0	0

Table 4. Diversity index estimates for traits in *H. vulgare* and *H. spontaneum* paired samples, averaged over nine sites in the xeric region in Jordan.

Trait	Diversity index	
	H. vulgare	*H. spontaneum*
Plant waxiness	0.000	0.000
Leaf hairiness	0.069	0.143*
Awn roughness	0.237	0.339*
Visibility inside glumes	0.030	0.130*
Lemma color	0.182	0.431*
Nature of collar	0.073	0.074
Awn color	0.065	0.361*
Glume color	0.068	0.363*
Visibility of lemma of steril spikelets	0.000	0.084
Seed color	0.394*	0.183
Glume hairiness	0.460*	0.294
Straw strength	0.485*	0.357
Shape of lemma apex	0.000	0.174*

* Indicates a significant difference (Tukey = 0.05) between species

cant difference between the two estimates ($P = 0.095$). However, *H. spontaneum* has significantly higher J' estimates for 7 traits, while *H. vulgare* has significantly higher J' estimates for 3 traits. The two species did not differ significantly from each other for the J' estimates of the remaining 3 traits (Table 4). It appears that in these two *Hordeum* species, qualitative variation is less limited by natural selection than is quantitative variation, which affects survival and production (Zohary 1983). Also, it appears that under cultivation, certain plant traits are released from selection pressure and some qualitative traits (e.g. glume hairiness, lemma and seed color) are highly variable in the wild but not in the domesticated species. This finding is in agreement with the suggestion made by Witcombe and Giliani (1979).

Qualitative traits differed in their overall diversity estimates (over species and sites). The most stable ones were plant waxiness, visibility of lemma of sterile spikelets, visibility inside glumes and shape of lemma apex. The highly diverse traits were: straw strength, glume hairiness, lemma color and seed color (Table 5).

Table 5. Diversity indexes for individual qualitative traits over both *Hordeum* species and nine sites in the xeric region of Jordan

Trait	Diversity index
Plant waxiness	0.000a
Leaf hairiness	0.106ab
Awn roughness	0.273d
Visibility inside glumes	0.079a
Lemma color	0.306e
Nature of collar	0.073a
Awn color	0.216c
Glume color	0.215c
Visibility of lemma of steril spikelet	0.042a
Seed color	0.289d
Glume hairiness	0.377e
Straw strength	0.421f
Shape of lemma apex	0.087a

Diversity index estimate values followed by the same letter do not differ significantly (Turkey = 0.05)

Table 6. Average diversity index estimates for nine sites in the xeric region of Jordan, over 13 qualitative traits and both *Hordeum* species

Site	Diversity index
Mafraq	0.171c
Mansurah	0.260e
Wadiabiad	0.249e
Abubana	0.000a
Rashadia	0.337f
Fjaij	0.178c
Qatrana I	0.116b
Qatrana II	0.193cd
Qatrana III	0.215d

Values followed by the same letter do not differ significantly from each other (Tukey = 0.05)

The nine sites differed significantly from each other in their J' estimates (Table 6). Site 4 was the least diverse, while site 5 was the most diverse. The striking similarity between the low J' estimates for sites 1, 6, 7 and 8 reflect the extreme xeric environment in these sites. Average rainfall in these sites is 150 mm. The more diverse sites are 3 and 5, with higher rainfall (250–280 mm) and relatively fertile soils. Although sites 3, 8 and 9 are within the xeric region, the relativily high J' estimates for these sites are probably due to the additional stored soil moisture collected during the rainy season through water harvesting in these particular sites.

As expected (Jana et al. 1987), great differences between the two barley species for morphometric and qualitative traits have been found. The observed similarity between the two barley species based on isozyme characters could be the reflection of a relatively unimportant role of these isozymes in differentiation between the wild and the cultivated forms of barley during domestication. In a recent study involving wild and primitive cultivated barley in parts of the Near East Fertile Crescent, including Jordan, Jana and Pietrzak (1988) found that cultivated barley populations were able to maintain a level of diversity similar to that in its wild progenitor species for 16 isozyme loci.

It can be concluded that landraces and primitive forms of barley are less variable than, but are equally valuable genetic resources as their immediate evolutionary progenitor, *H. spontaneum*. However, these landraces and primitive forms are much more vulnerable to genetic erosion than wild barley.

References

Blume A, Ebercon A, Sinmena B, Goldenberg H, Gerchter-Amitai Z, Grama A (1983) Drought resistance reactions of wild emmer and wild emmer × wheat derivatives. In: Proc 6th Int Wheat Genet Symp Kyoto, pp 433–438

Ceccarelli S (1984) Utilization of landraces and *Hordeum spontaneum* in barley breeding for dry areas at ICARDA. Rachis 3:8–11

Harlan J (1976) Genetic resources of wild relatives of crops. Crop Sci 16:329–333

Jana S, Pietrzak LN (1988) Comparative assessment of genetic diversity in wild and primitive cultivated barley in a center of diversity. Genetics 119:981–990

Jana S, Pietrzak LN, Jaradat AA (1987) Assessment of diversity in wild and cultivated barleys of the Fertile Crescent: A new outlook. Barley Genet 5:103–107

Jaradat TT (1988) Genetic variability and environmental assosiation of wild barley (*Hordeum spontaneum* C. Koch.) in Jordan. Master's thesis submitted to Yarmouk University, Irbid

Jaradat AA, Jaradat TT, Jana S, Srivastava JP (1987) Diversity for quantitative characters in Jordanian landraces of barley. Barley Genet 5:109–117

Nevo E, Beiles A, Zohary D (1986) Genetic resources of wild barley in the Near East: structure, evolution and application in breeding. Biol J Linn Soc 27:355–380

Qudah B (1983) Land use in Jordan. Special publication, Ministry of Agriculture, Amman

Vega V, Frey Y (1980) Transgressive segregation in inter- and intraspecific crosses of barley. Euphytica 29:585–594

Witcombe J, Giliani M (1979) Variation in cereals from the Himalayas and the optimum strategy for sampling plant germplasm. J Appl Ecol 13:915–924

Zar JH (1984) Biostatistical analysis. Prentice-Hall, New York

Zohary D (1983) Wild genetic resources of crops in Israel. Isr J Bot 32:97–127