Indian J. Genet., 70(3): 234-239 (2010)

Diversity among barley germplasm collection in India

Basudeb Sarkar, R. P. S. Verma, Rajender Parsad[1] and Jag Shoran

Directorate of Wheat Research (DWR), Karnal
[1]Indian Agricultural Statistics Research Institute (IASRI), Pusa, New Delhi 110 012

(Received: May 2009; Revised: May 2010; Accepted: July 2010)

Abstract

A total of 5337 barley accessions were evaluated for a number of traits. The accessions included indigenous germplasm collected from various parts of India; exotics selected from trials and nurseries received from ICARDA/CIMMYT, Mexico and ICARDA, Syria; as well as materials received from different countries over the last four decades. Out of the total accessions, 2801 were indigenous and 2536 exotic. Only 290 accessions were naked type, the rest were hulled. This paper summarizes results on classification and characterization of these accessions for various agro-morphological traits, associations among these traits, and frequency distribution and donors for days to heading, plant height and 1000-kernel weight.

Key words: Barley, germplasm, DUS traits, Cramer's coefficient

Introduction

Barley (*Hordeum vulgare* L.) is a grain crop, grown in India since ancient times. It is domesticated and cultivated together with wheat (*Triticum aestivum*), pea (*Pisum sativum)* and lentil (*Lens culinaris*), about 10,000 years ago in the Fertile Crescent of the Middle East [1]. In India, it has been traditionally considered a poor man's crop because of its low input requirements and adaptability to harsh environments like drought, salinity, alkalinity and marginal lands [2]. In India presently barley is grown on nearly 0.65 m hectare, with production of 1.33 million tons of grain yields, and average productivity of 2.05 tons/hectare (FAO, 2008). Globally barley ranks fifth among all crops in terms of production, with 142 million tons, (2003–2007 mean), behind maize (*Zea mays*, 714 million tons), rice (*Oryza sativa*, 623 million tons), wheat (*Triticum* spp., 604 million tons) and soybean (*Glycine max*, 211 million tons), (FAO, 2008). In India, barley is cultivated in both plains (Uttar Pradesh, Punjab, Rajasthan, Haryana, Madhya Pradesh and Bihar) and in the hills (Himachal Pradesh, Uttarakhand and Jammu & Kashmir). About 70-75% of the total production is used as cattle feed, and most of the remaining for malt. However, barley is an important human food especially at higher altitudes in the Himalayan region. In the tribal areas of the hills, it is used in the preparation of local beverages. Barley straw is used as animal feed and also as green fodder in dual purpose crop. Barley has good nutritional and even medicinal properties.

In recent years, use of barley as a source of raw material for the malting and brewing industries is increasing. To meet the requirement of different types of product, needed diverse germplasm to breed for product-specific varieties in feed and malt types. The rapid spread of improved crop varieties throughout the world has replaced many of the genetic resources essential for their continued improvement. The narrow genetic base of presently cultivated barley can become a serious threat to barley production in India unless proper care is taken to diversify the parental materials in breeding programs. The present study of germplasm evaluation was carried at the Directorate of Wheat Research (DWR), Karnal, to ensure availability of diverse parental materials and understand the association between different agro-morphological traits.

Materials and methods

Barley has the second largest number of germplasm accessions conserved globally, after wheat. In India, around 6400 accessions are available at NBPGR, while around 6000 accessions are maintained under active

*Corresponding author's e-mail: basudeb_dwr@hotmail.com
Published by Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012
Online management by indianjournals.com

collection at DWR, Karnal. DWR also has the national responsibility for research coordination, evaluation, conservation and exchange on barley germplasm. In order to facilitate the availability of new genetic diversity in the national programme, during 2003-04 to 2006-07, a total of 5444 germplasm accessions were evaluated for different descriptors and evaluation traits (DUS). Each year a set of accessions was characterized for different agro-morphological traits. After removing the duplicates, finally 5337 accessions were considered for analysis and classification. The materials comprised of released varieties, advanced breeding lines, germplasm collections from different parts in India and exotic materials from different countries and international institutes. Among the materials evaluated, 2801 were indigenous and 2536 exotic (foreign) accessions. Most of the accessions were hulled (5047) types and only 290 were hull-less. Exotic accessions included introductions from different countries (Canada, Australia, Denmark, USA, Brazil, Argentina and Ethiopia) and selections made from international trials/observation nurseries received from ICARDA/CIMMYT Program, Mexico and ICARDA, Aleppo, Syria. All these materials were sown in the 2nd week of November at Directorate of Wheat Research (DWR) research farm, Karnal. Material was grown in a compact block in an augmented design with two rows of 2 meter length per plot for each genotype, repeating a released check (DWR28) after every 50 lines having 30 cm row-to-row spacing. Standard agronomic practices were followed. Observations were recorded on various plant descriptors based on Bioversity International (earlier International Plant Genetic Resources Institute) descriptors [3]. All these accessions were harvested during the 2nd week of April in each year and the grain samples were evaluated for various grain traits. Frequency distribution for different traits was analyzed using statistical software GENSTAT 10. Observation was recorded on different growth and qualitative traits, and individual score was given for each type of trait. Because of the large number of accessions, they were classified into different groups. A contingency table was prepared, and associations among different traits measured by Cramer's coefficient (C), using SAS software. Cramer's coefficient is uniquely useful when we have category wise discrete data about one or both sets of attributes or variable (e.g. in Table 2 we have classified different morphological traits into different classes). Cramer's coefficient is obtained as,

$$\sqrt{\frac{\chi^2}{N(L-1)}}$$

where N is total number of observations and L is the minimum of number of rows or columns in the contingency table. The Cramer coefficient lies between 0 and 1. Cramer coefficient 0 means that attributes are independent and 1 means perfect association between traits. Testing the significance of Cramer's coefficient is same as determining the significance of χ^2 statistic at (r-1)(c-1) degrees of freedom, where r is number of rows (number of categories in attribute 1) and c is number of columns (number of categories of attribute 2) in the contingency table. If the computed c^2 is more than tabulated c^2, then we say that Cramer's coefficient is significantly different from zero, which shows the strong association in the population between traits. It is interpreted as a measure of the relative strength of an association between two variables.

Results and discussion

The result showed that the germplasm accessions in DWR's active collection have the following characteristic features:

1. 80% of the total collection is of six-row types. Most of the two-row types have a lax ear head. Almost all accessions are awned except a very few with hooded plant type. A few accessions have very short awns or have awns in central rows.
2. 95% of the collection is hulled types with only 5% naked. Amongst the hulless types a few were hard threshing and the rest were free threshing types. In India naked barley is mainly cultivated on the high hills in the Himalayan regions and consumed as food barley.
3. 52% of the total collection is indigenous (local materials) and 48% are exotic types.
4. 87% have erect growth habit; the rest are semi-prostate or prostate types.
5. 92% have light yellow grain colour while 5% are purple or blackish grain colour with blue aleurone.

Agronomic traits of barley germplasm

Data were collected on days to 50% heading, plant height and 1000-kernel weight.

1. Days to 50% heading

Early types are essential in most barley producing areas in India. Barley cultivation is concentrated largely in the states of Uttar Pradesh, Punjab, Rajasthan, Haryana, Madhya Pradesh and Bihar in the plains, where wheat and mustard (in rainfed areas) are the main crops in the spring season. Rainfed barley production needs early varieties to escape from drought and late-season heat in late March and early April. However, in Punjab and Haryana barley is cultivated under limited irrigation under timely-sown conditions, but in some parts of these states long duration cotton is cultivated in the rainy season and harvested late by end of November or early December. Barley is preferred in these areas for sowing after the cotton harvest in December. Obviously early maturity is one of the main targets for India's barley improvement program. The heading days of both indigenous and exotic collections are presented in Fig. 1. Only 5% of exotic and 8% of indigenous germplasm are early heading (<75days), while 3% of exotic and 1% of indigenous accessions are very early heading (<70 days). About 56% of exotic and 61% of indigenous materials are intermediate in days to heading (80-90 days). Among the exotics, materials received in the form of international trials /nurseries from the ICARDA-CIMMYT Mexico program were early to intermediate in heading while materials received from ICARDA, Syria were intermediate to late. This may be due to the fact that winter in Syria is much longer and cooler than in Mexico and as a result selection pressure in ICARDA breeding program was for intermediate to late plant types.

2. Plant height

The distribution of plant height (Fig. 2) showed that only 3% of exotic and 2% of indigenous materials have dwarf (<70 cm) plant height. Among Indian materials, 17.3%, 23.5% and 23.6% have heights of 90-100, 100-110 and 110-120 cm respectively, compared to 17.5%, 14.9% and 15% respectively in the exotic materials. Finally, 21% of exotic and 31% of indigenous materials have plant height above 120 cm. These differences may be due to the fact that most exotic accessions are improved germplasm with relatively shorter plant types while indigenous materials are collection of local land races and varieties bred for traditional rainfed cultivation under low inputs. Similar results have been reported for the Chinese barley collection [4].

3. Kernel weight

Thousand-kernel weight was measured on 5291 accessions (2789 indigenous and 2502 exotic). The overall average is 34.6 and 37.1 g for indigenous and exotic accessions, respectively. The distribution of kernel weight in Indian and exotic germplasm is shown in Fig. 3. Large kernel materials (over 50 g) are only about 2.1% and 6.7% in Indian and exotic barleys, respectively. Extra large kernels (>55 g) are only 0.9% and 1.67% in Indian and exotic materials, respectively.

Table 1. Sources identified for earliness, dwarf plant type and high 1000-kernel weight

Traits	Accession numbers
Earliness (<70 days)	EC-24882, IC-138001, IC-138011, IC-138035, IC-138110, IC-138118, 19^{th} IBON-139, EB-6529, EB-6514, 8^{th} EMBSN-24, ISBCB(2000-01)-110, ISBCB(2000-01)-113, 10^{th} EMBSN-1, 10^{th} EMBSN-6, 10^{th} EMBSN-39, 10^{th} EMBSN-51, 10^{th} EMBSN-52, 10^{th} EMBSN-58, 10^{th} EMBSN-60, IC-438109, IC-438120, IC-438122, IC-438125, IC-438126, IC-438127, IC-438130, IC-438129, IC-438188, IC-438261, EC-492293, 2^{nd} EMBSN-24, 2^{nd} EMBSN-25, CIHO-7654
Short plant height (<60 cm)	BON-LRA-M (90-91)-48, KARAN-756, CENTINELA, 2^{nd} IWFBON-123, BON-LRA-C(91-92)-69, BON-MRA(91-92)-47, BYT-LRA-C(91-92)-16, BON-LRA(87-88)-73, BCB(87-88)-135, B CB(87-88)-205, AZAD, EB-7014, BYDV(92-93)-721, BC-1403, BC-1478, BC-1492, BC-559, UBE-388, BCU-3223, BG-261, BM-76, RD-102, RD-782, IC.A-181, IC-36904E, IC-38801A, IC-82539, IC-82556, IC-82575, IC-118698, 20^{th} IBYT-4, 20^{th} IBYT-12, ISBCB(00-01)-17, ISBCB(00-01)-78, ISEBON(00-01)-7, IBLSGP(00-01)-8, IBLSGP(00-01)-9, IC-405272, IC-437890, IC-437998, IC-437867, IC-361921, IC-411586, IC-437868, IC-437877, IC-437879, IC-438249, IC-438253, EC-492200, EC-492182, EC-492299, EC-492333, IC-380989, IC-438143
High thousand grain weight (>50 g)	EC-329014, EC-329020, 19^{th} IBON-28, 19^{th} IBON-92, SHYRI, 19^{th} IBON-95, 19^{th} IBON-139, BCB(91-92)-41, BCB(91-92)-49, BON-LRA-C(91-92)-69, BONLRA-M(91-92)-12, BONLRA-M(91-92)-17, IBYT-LRA-C(91-92)-4, IBYT-LRA-C(91-92)-61, BON-LRA(87-88)-12, BON-LRA(87-88)-36, BON-LRA(87-88)-53, BYDV(91-92)-9, BYDV(91-92)-10, HBL-189, IC-25616, IC-36899A, IC-82750, IC-82771, IC-82818, IC-118655, 29^{th} IBON-2, 29^{th} IBON-10, 29^{th} IBON-20, 29^{th} IBON-25, 29^{th} IBON-29, 29^{th} IBON-55, 29^{th} IBON-74, 29^{th} IBON-80, 29^{th} IBON-111, 29^{th} IBON-116, 29^{th} IBON-122, 29^{th} IBON-124, 10^{th} EMBSN-8, 10^{th} EMBSN-11, 10^{th} EMBSN-39, IC-437913, IC-438162, IC-438275, EC-492199, EC-492210, EC-492328, EC-492364, EC-492394, 20^{th} IBON-3, 20^{th} IBON-38

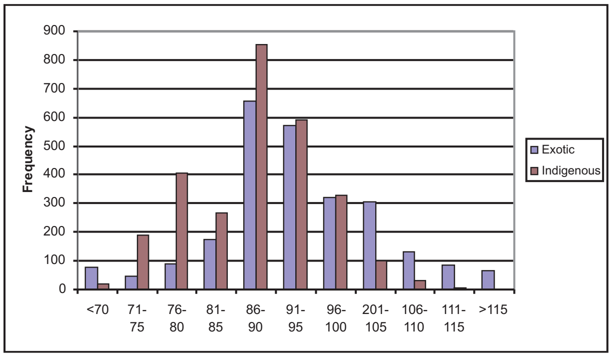

Fig. 1. Comparison of heading days in Indian and exotic barley

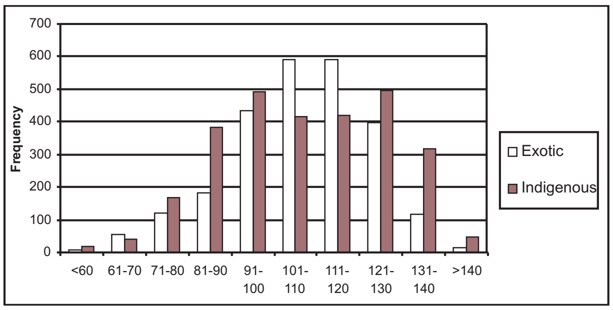

Fig. 2. Distribution of plant height in Indian and exotic barley

The range of 31-40 g 1000 grain weight is the most frequent (54.4%) and 41-50 g is the next (16.4%) for Indian accessions. Similarly among exotic most materials, 47% fall in 31-40g category followed by 41-50g (25.9%). The two-rowed accessions showed higher

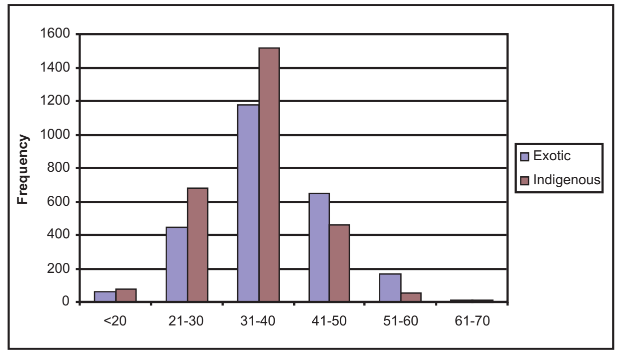

Fig. 3. Comparison of 1000 kernel weight in Indian and exotic barley

thousand-kernel weight due to better grain filling than six row types. Based on the observations recorded, a few germplasm accessions have been identified as sources for earliness, short plant height and high kernel weight (Table 1).

Observations were also recorded on various agro-morphological traits *viz*., basal pigmentation, auricle pigmentation, upper node pigmentation, awn pigmentation, plant height, days to 50% heading, spike density, ear waxiness, stem waxiness, ear attitude, ear length, awn roughness, grain colour, grain shape and grain size (Table 2). Cramer's coefficient of association was applied among selective traits to measure the degree of association between these traits. Germplasm accessions were classified into different groups as per the Bioversity International classification.

Table 2. Descriptors recorded for morphological characterization of barley

1	Basal pigmentation	Absent (1); Light pigmented (2); Dark pigmented (3)
2	Auricle pigmentation	Absent (1); Light pigmented (2); Dark pigmented (3)
3	Upper node pigmentation	Absent (1); Light pigmented (2); Dark pigmented (3)
4	Plant height (cm)	Height of the plant at maturity
5	Stem waxiness	Waxy (1); non-waxy (2)
6	Ear waxiness	Waxy (1); non-waxy (2)
7	Ear attitude(angle)	Erect (1); semi-drooping (2) and drooping (3)
8	Days to flower	Number of days from sowing to 50% of the plants in flower
9	Ear length	Measured from base to the tip of the spike except awn
10	Awn pigmentation	Yellow (1); reddish purple (2)
11	Spike density	A visual measure of spike density; 1=lax 2=intermediate 3=dense
12	Awn roughness	Smooth=1; rough =2
13	Grain shape	Oval (1); intermediate (2) and elongated (3)
14	Grain size	Small (1); medium (2) and bold (3)
15	Grain colour	Amber (1); yellow (2); purple (3) and black (4)
16	1000-seed weight	Weight of 1000 seeds in grams

Table 3. Association among different qualitative and quantitative characters in barley

Traits	DF	Cramer's coefficient	χ^2 values	No. of observation	Probability
Basal by auricle pigmentation	4	0.19	383.19	5337	<0.001
Basal by upper node pigmentation	4	0.21	457.16	5337	<0.001
Basal pigmentation by awn pigmentation	2	0.07	26.84	5322	<0.001
Auricle by upper node pigmentation	4	0.21	469.04	5337	<0.001
Auricle pigmentation by awn pigmentation	3	0.09	49.89	5322	<0.001
Plant height by days to 50% heading	8	0.27	790.05	5252	<0.001
Plant height by spike density	2	0.10	57.15	5256	<0.001
Days to 50% heading by spike density	4	0.07	32.41	5328	<0.001
Ear waxiness by stem waxiness	1	0.29	446.25	5336	<0.001
Ear attitude by ear length	8	0.12	158.19	5301	<0.001
Awn roughness by awn pigmentation	1	–0.006	0.19	5319	0.65
Grain colour by shape	6	0.15	238.03	5310	<0.001
Grain colour by size	6	0.14	218.93	5310	<0.001
Grain shape by size	4	0.19	423.14	5310	<0.001
Grain size by 1000 grain weight	10	0.33	1163.36	5286	<0.0001

The results presented in Table 3 indicate that all characters studied had a strong positive association between each other except between awn roughness and awn pigmentation.

The barley improvement program at Directorate of Wheat Research (DWR) and Barley Network centers under the All India Coordinated Wheat and Barley Improvement Program (AICW&BIP) of ICAR and states department of agriculture has made tremendous progress over last four decades in developing improved barley varieties for various agro-climatic conditions both under irrigated and rainfed conditions with resistance to prevalent diseases and insect pests. Over the years the barley network refined its research priorities in view of the changing scenario during last one and half decades and updated its objectives to address the needs of malt, feed and fodder type barley in the country. The major priorities of barley improvement program in the country are:

- Development of high yielding varieties with superior malting qualities.
- Development of cultivars for restrictive environments i.e. rainfed, saline/sodic soils, brackish water and diara lands (lands with annual recurrence of floods).
- Development of dual purpose varieties for green fodder and grain as cattle feed.
- Incorporation of resistance to various biotic stresses like rusts, leaf blights, aphids and cereal cyst nematode.

Research efforts over years resulted in gradual improvement in productivity of the varieties under different production conditions. As a result a number of varieties suitable to different cultural and agro-climatic conditions have been developed over the years. The genetic gain in yield potential under different production conditions is quite evident through new varieties developed by the barley research centers in the country. In addition to grain yield, the barley breeders have successfully incorporated resistance to major biotic and abiotic stresses in the barley genotypes. However, there is further scope for improving the yield level when compare with the yield level of other countries in the world and world average.

The incorporation of genetic diversity in Indian barley breeding program from international institutes (ICARDA/CIMMYT) and various research institutes of developed countries received major emphasis over last four decades. This has helped in developing and releasing over 100 varieties for different agro-climatic conditions as feed, food and malt barley varieties both under irrigated and rainfed condition with diversity in morphological, agronomic and biotic and a-biotic stresses. The addition of genetic diversity on sustained basis would continue to be hallmark of a successful breeding program. Collection and maintenance of genetic diversity has been an important priority for breeding program across the world. Knowledge of germplasm is a key requirement for future breeding progress [5]. However, proper exploitation of the germplasm by identifying donors for different traits needs to be given high priority. Knowledge of basic morphological traits is equally important to define the plant architecture/ideotype needed for a specific production condition and to understand the association among these characters. The various agro-morphological traits studied, are strongly associated with each other. This will help in analyzing germplasm collections of different categories to develop a core subset of germplasm, keeping maximum diversity with minimum number of accessions, and using this diversity in germplasm improvement programs.

Acknowledgements

The work was supported financially by the ICAR AP Cess Fund project on evaluation of barley germplasm for biotic and abiotic stresses and malting quality. We are grateful to ICAR for funding the project.

References

1. **Smith B. D.** 1998. The Emergence of Agriculture. Scientific American Library, HPHLP, New York, 231 pp.
2. **Chanddola R. P.** 1999. New Vistas in Barley Production (Jaipur, India: Printwell).
3. **IPGRI.** 1994. Descriptor of barley (*Hordeum vulgare* L.). International Plant Genetic Resources Institute. Rome, Italy. 45p
4. **Sun L., Lu W., Zhang J. and Zhang W.** 1999. Investigation of barley germplasm in China. Genet. Resour. Crop Evol., **6**: 361-369.
5. **Rasmussen D. C.** 1992. Barley breeding at present and in the future. *In*: L. Munk (ed.), Barley Genetics VI, Vol **II**. pp. 865-867.