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Status of introduction and conservation in barley (*Hordeum vulgare* L.)

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1. Introduction

Barley (*Hordeum vulgare*) is the fourth most important cereal crop after wheat, rice and maize in the world. It is one of the oldest and man's most dependable cereal crop to be domesticated and cultivated since the beginning of civilization. Barely is grown over a broad environmental range because of broad ecological adaptation, utility as feed and food grain and superiority of barley malt for use in brewing (Das *et al*, 2008).

There is a need to collect, conserve barley genetic resources to meet the known and unknown challenges of emerging diseases and climate change. For augmentation of diverse germplasm ICAR- National Bureau of Plant Genetic Resources (NBPGR) is the nodal institute with a well-established procedure and since its establishment in 1976 and a total of 80,124 accessions in barley were introduced/imported including trait specific/ value added accessions from different countries and International Institutes. Additionally, each year 2000-3000 accessions are imported as international nursery/ trials. International Centre for Agricultural Research in Dry Areas (ICARDA) has the global mandate for improvement of barley and is doing pre-breeding activities in barley. The new variability generated is made available to researchers, users in the form of International nurseries and trials and new form of variation in exotic material is made available through these nursery/trials. The national Genebank at ICAR-NBPGR conserves over eight thousand accessions of barley of which more than one thousand five hundred accessions are of exotic origin. Diverse introductions procured were utilized for incorporation of useful genes in the varieties like BG 105 derived from a cross between C141 (Punjab x Montless) resistant to yellow rust and smut released in Haryana for late sown and irrigated conditions and var. BG 108, a derivative of the cross between C 164 x Kindered (USA), resistant to yellow rust. Number of varieties *viz*., Ranjit (DL 70), DL 85, DL88, DL 171, P-I03 and RD 118were from one cross i.e., Mex-5-13 x BG-1, and possessed attributes like high yielding yellow rust resistance and adaptability to different agro- climatic conditions. EC 401464 for Mongolia possesses resistance to *Erysiphe gramini* spp *hordei* (Verma *et al*, 2006).

Many other varieties have been evolved from exotic introductions *viz*., Sona (HBL-87) hulled type, a selection from EB 233 from Canada, released in 1980 for lower and mid hills in Himachal Pradesh (up to 1500 msl) under timely and late sown, irrigated conditions. Thegrains are bold with light yellow color and resistant to yellow rust, powdery mildew, lodging and shattering. It has a high forage yield also. These varieties also possessmoderate resistance to *Helminthosporium* leaf stripe and loose smut. LSB (2) and Dolma (USA) both hull less cultivars selected from USA95 performed well in northern hill of Himachal Pradesh and released as primary introduction. Variety Clipper imported from Australia performed well in The Northern Plains. Variety Himani (BHS-12), a derivative of the cross cvs. Atlas-54 x NP 109, is highly resistant to yellow rust (Das *et al*, 2008).

Some other promising recent introductions included stripe rust and powdery mildew resistant accession EC123304-A from USA and tetraploid (EC137248) and diploid EC 137249, both from UK; dwarf and high yielding EC138742 from Japan, early maturing cold tolerant EC339893-944 and early heading with lodging resistant suitable for malting industry (E 362845-71) all the Syria; wild barley (*Hordeum spontaneum*) – bacterial leaf spot resistant line (EC328936-39) from USA; Oweolbosi Milyan- 16 (EC151529 from Korea).

Barley genetic resources conserved mainly comprise local landraces, primitive cultivars, exotic introduction, selected breeding materials, wild relatives and genetic stocks with specific characteristics. There is urgent need to collect, introduce and conserve all these resources to meet the known and unknown challenges *viz*. emerging diseases, insects, pests, soil and water constraints.ICAR-

NBPGR after its creation in 1976 has developed a very strong Indian Plant Germplasm Management System which operates in a collaborative and partnership mode with other organizations. The system has contributed immensely towards safeguarding the indigenous crop genetic resources and regulating access of PGR for enhancing the agricultural production and productivity in the country. India being one of the gene-rich countries of the world faces a unique challenge of protecting its natural heritage and evolving suitable mutually beneficial strategies for germplasm exchange with other countries. Since its inception NBPGR is working towards achieving collection, conservation, characterization of PGR addressing to and compliance of national and international regulations related to exchangeof plant genetic resources. Over the years, India has developed sound and scientific management regimes for *ex situ* conservation and access to its genetic resources (Dhillon and Saxena, 2003). Groups of institutions, scientific societies, non-governmental organizations are addressing the task with NBPGR, New Delhi, as the nodal agency for its coordination. It aims at efficient management of plant genetic resources by providing convenience of access to PGR for utilization in various crop improvement programmes.

2. Historical perspective of exchange of barley genetic resources

Introduction of plant material on a worldwide basis had been mostly carried out without regard to well defined procedures, but several countries have established plant introduction services/ organization for channelizing, import and export (exchange) of plant germplasm .

In India, there is a single window system for the exchange of small samples of plant germplasm (including transgenics) meant for research, and ICAR- NBPGR is the authorized nodal institution . It regulates the import of seeds/planting material for research under the provisions of Plant Quarantine (Regulation of Import into India) Order, 2003 of the Destructive Insects and Pests (DIP) Act of 1914 (Tyagi *et al*, 2007) The plant introductions include germplasm, elite strains, improved varieties, genetic stocks and related species from various parts of the world. In order to prevent the introduction and spread of pests associated with PGR and to ensure that only pest-free material is supplied to the indentors, strict plant quarantine protocol is followed including post-entry quarantine (Ram Nath, 1996; Parakh and Gautam, 1999). The imported consignments treated with pesticides are grown and observed in post-entry quarantine facilities (screen houses, glasshouses) for detection of exotic pests. Seed harvested only from pest-free healthy plants is supplied to the indenters (Mathur and Lal, 1996; Khetarpal *et al*, 2001). ICAR- NBPGR is empowered by the Ministry of Agriculture and Farmers Welfare to undertake quarantine processing of all germplasm and research material including transgenics under exchange for both public and private sectors (Bhalla *et al*, 2009; Dhillon *et al*, 2001). For associated quarantine pests of Barley as per Plant Quarantine (Regulation of Import Into India) Order 2003 , the seeds should be free from (a) Glume rot (*Pseudomonas syringe* pv. *atrofaciens*); (b) Barley Stripe mosaic (Hordeivirus); (c) Ergot (*Claviceps purpurea*) and (d) Granary weevil (*Sitophilus granaries)*(PQ Order 2003). Besides the additional declarations required in the phytosanitary certificate as per PQ Order, there are several potential quarantine pests which could be a threat during import of barley from various countries in the world viz; insects like *Ahasverus advena* (Foreign grain weevil)*; Mayetiola destructor* (Hessain fly); *Oscinella frit (*frit fly); fungi like *Claviceps purpurea* (ergot); *Monographella nivalis* (Foot rot of cereals);*Phaeosphaeria nodorum* (Glume blotch); *Rhizoctonia oryzae-sativae (*Aggregate sheath spot); *Tilletia laevis*(common bunt); *T. tritici (*common bunt); *Tilletia controversa* (Dwarf bunt of wheat); bacteria like*Acidovoraxavenae* subsp. *avenae* (Bacterial leaf blight); *Pseudomonas fuscovaginae* (Sheath brown rot);*Pseudomonas syringae* pv. *atrofaciens* (Basal glume rot); *Pseudomonas syringae* pv. *coronafaciens* (Halo blight); *Pseudomonas syringae* pv. *striafaciens* (Bacterial barley black node); viruses like *Arabis mosaic virus* (ArMV); *Barley stripe mosaic virus* (BSMV); High plains virus (HPV); *Wheat streak mosaic virus* (WSMV); nematodes like *Anguina tritici* (wheat gall nematode) and *Pratylenchus brachyurus*. In addition a number of weeds are also associated with barley germplasm which could be a quarantine threat

Exotic germplasm is utilized in various crop improvement programs, enhancing yield parameters, incorporating resistance/ tolerance to various biotic and abiotic stresses and value addition. Since the establishment of the Bureau diverse genetic resources in barley were imported / introduced from different countries. A total of 80,124 accessionswas imported from Argentina, Australia, Canada, China, Eritrea, Finland, France, Hungary, Lebanon, Mexico, Morocco, Netherlands, Russia Syria, Thailand, UK, USA (Tyagi *et al* 2011, 2012)

Export of barley genetic resources is regulated by Biological Diversity Act (BDA), 2002.and ITPGRFA. The non-Indian entity need to take approval of NBA before accessing germplasm (apply in Form 1 with a prescribed fee), however, for non-commercial research/or for emergency purposes need to apply in form B along with an

undertaking for seeking approval of NBA. Export under collaborative research is exempted if the research project confirms to the policy guidelines issued by the Central Government or approved by the Central Government.

However, as barley is included in the multilateral system of the International Treaty on plant genetic resources for food and agriculture (ITPGRFA) and India has also designated 468 accessions to the MLS, the access to such designated accessions of barley is also made through the national focal point of the Treaty that is Department of Agricultural Cooperation and Farmers Welfare (DACFW). The access under the provisions of the Treaty is done

Table 1: Some major introductions of exotic barley germplasm through ICAR- NBPGR for research purposes (since year 2000) Registered cultivars and germplasm imported from USA

EC No.	Specific Traits
EC466352	Var- Garnet, good milling and breeding quality
EC473169	Consistent and highly resistant to barley stripe rust
EC473921	Large grain and high protein resistant to stripe rust
EC527044	Semi-dwarf, two rowed, spring, plump kernels, good malting quality, grain protein (11%av.) Resistant to barley stripe rust, lodging tolerant
EC533523	Superior malting quality, plump kernels, resistant to net blotch, spot blotch and stem rust
EC533524	Resistant to Fusarium head blight
EC 548849	Thrip resistant line
EC538157	Var. UC 933-Early maturing, resistant to stripe rust, barley yellow dwarf virus, leaf rust, powdery mildew net blotch and scald
EC538158	Var. UC 969- Early maturing, resistant to barley yellow dwarf virus, leaf rust, net blotch and scald
EC538159	Var. UC960- Resistant to BYDY, leaf rust, powdery mildew. Net blotch and scald
EC538160	Var.UC937-High yielding, resistant to stripe rust, BYDY, leaf rust, powdery mildew, net blotch and scald
EC540807	Var.Vivan- High yielding, shattering resistant , resistant to covered smut, false loose smut and common root rot , drought tolerant
EC586943	Var-Post 90, high yielding, widely adapted, resistant to all known greenbug biotypes, short statured, good straw quality and winter hardiness
EC586944	Var- Radiant proanthocyanidin free, potential malting barley and carry the gene that controls a high amount of thermostable b -amaylase
EC596667	Six rowed spring, high yielding, early maturing, resistant to net blotch or smut
EC596668	High beta-glucan content, low malt extract
EC607790	Low phytate, six rowed spring feed barley which provides phosphorus digestibility and mineral nutrition for human and non ruminant animals
EC631731	Variety Lentah-superior yield and test weight, most widely used as green feed
EC631732	Variety Clearwater-hull less, low phytate and high available (CV 335) phosphorus concentrations in the grain, superior feed quality
EC631946	Variety Tetonia-high yielding, resistance to spot blotch and net blotch
EC634221-27	Lines resistant to Russian wheat aphid, each line have a different source of resistance in malting barley cultivar backgrounds
EC698842	Cv Sidney a Russian wheat aphid resistant spring, two rowed feed barley
EC698843	Cv. Otis a spring barely well adapted to the high, dry plains, is susceptible to Russian wheat aphid
EC698889-698895	Germplasm STARS 0637B to 0643B, source of resistance resistance to Russian wheat aphid (*Diuraphis noxia*, (Mordvilko). They are comparable to their recurrent parents in yield, test weight, plant height, and heading date in the absence of Russian wheat aphid and superior in grain yield to their recurrent parents in the presence of Russian wheat aphid
EC894760-66	Wild species *Hordeum jubatum*
EC896486-86	Wild species *Hordeum lechleri*

Registered cultivars and germplasm imported from Canada

EC No.	Specific Traits
EC498168	Resistant to covered smut and loose smut
EC532339	Resistant to common root rot, lodging tolerant
EC532634	Six rowed, spring feed, high yielding, plump kernels, resistant to covered smut and immediate reaction to barley leaf scald and net blotch
EC548499	Var. Niobe-Early maturing, high yielding Resistant to surface borne smuts, spot form of net blotch and scald
EC570289	High grain and biomass yield, resistant to surface borne smut and true loose smut
EC570290	Yellow aleurone, lodging resistant, resistant to scald and covered smut
EC657889	Var. Ponoko- High yielding for both grain and biomass, good grain quality for malting , resistant to the spot form of net blotch, surface borne smuts and spot blotch
EC657888	Var. Manny- Six rowed, hulled, smooth-awned, spring feed barley, lodging resistance, higher plump seed percentage, good resistance to covered smut and false loose smut.
EC670538	Variety Bushy, two-rowed, rough-awned, feed barley, well adapted to the brown, black and gray soil, excellent disease resistance combined with good grain yield and feed quality, good lodging resistance and early maturing, low fibre content, resistant to the surface borne smut, and moderately resistant to the spot form of net blotch.

'Busby' barley (EC670538), a high-yielding general purpose feed variety

Variety 'Ponoko' of barley from Canada (EC570289)

Variety 'Manny' of barley from Canada (EC570290)

[Photo Courtesy: Field Crop , Development Centre, Alberta Agriculture and Rural Development, Lacombe, Canada]

after signing the Standard Material Transfer Agreement (SMTA), ensuring that the material accessed under the MLS of the treaty shall be freely available to others for use in research, breeding and training provided the third and subsequent parties are bound by the same conditions of the SMTA. Intellectual Property Rights (IPRs) cannot be claimed by the recipients on the material received from the MLS and if any commercial utilization is done, the benefits would be deposited in a trust fund of the Treaty.

3. CGIAR centres and import of international nurseries

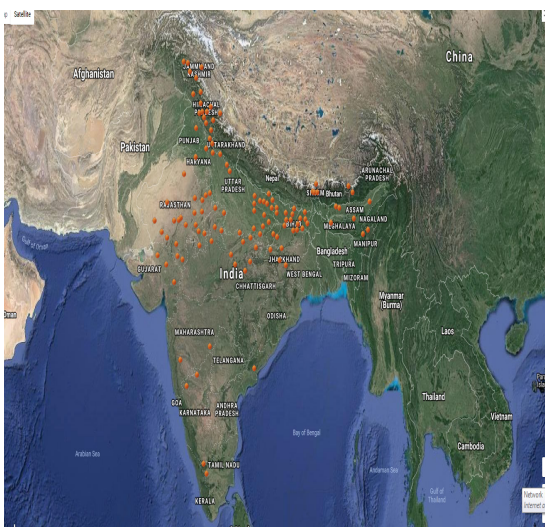
International Centre for Agricultural Research in Dry Areas (ICARDA) has the global mandate for the improvement of barley and is engaged indoing prebreeding activity in barley, the variability generated is made available to various usersand in the form of various nurseries and trials. India receives such germplasm from these institutions as the international nurseries and trials provide an opportunity to get new form of variation in exotic material.

The information on various nurseries and trials constituted by these centers are published every year. An indent is placed for the consolidated demand. The number of sets to be introduced from each nursery depends on the demand of indigenous users. A field- day during the crop season provides access to exotic germplasm and it has served a great deal in vitalizing barley breeding through selection by large number of breeders. Exotic materials grown at various institutes are monitored at appropriate plant growth stages by a team of breeders and pathologists to isolate most promising lines. These lines are later on included in Elite International Germplasm Nurseries.

After the crop is harvested, the data booklets complete in all respects are received back from the co-operators for onward transmission to ICARDA. Considering the performance of test entries across the locations, the superior genotypes are identified. Many genotypes showed promise when compared with existing checks across the test sites. Taking the advantage of summer nurseries, the selected entries are screened against rust diseases in off-season nurseries. The most promising entries are used in preparing the International Germplasm Nurseries and exposedto large number of beneficiaries.

4. Status of conservation in long term storage

The National Genebank at ICAR-NBPGR holds a total of 8558 accessions of barley germplasm, which has been received and conserved over a period of thirty years. Amongst this collection, 1537 accessions are of exotic origin and have been imported mostly from USDA, USA and CG genebanks (CIMMYT and ICARDA). The 7021 indigenous accessions in the long term storage consist of 778 landraces, 74 released cultivars, 178 trait-specific genetic stocks and 53 wild genotypes. The wild species represented in the national genebank are *Hordeum himalayense, Hordeum vulgare ssp. distichon, Hordeum bulbosum, Hordeum hexastichum, Hordeum lechleri, Hordeum marinum, Hordeum spontaneum, Hordeum brevisubulatum.* In the cultivated species (*Hordeum vulgare),* around 450 accessions are two-row barley genotypes and the rest are six-row types. There are white, yellow, purple and black seeded genotypes. The trait specific genetic stocks developed and submitted by various research organizations are available in NGB and can be supplied, based on indents, for utilization in barley breeding programmes. Some of the unique genetic stocks conserved are, multi pistillate genotype (four ovaries), six-rowed and two-rowed GMS lines, CGMS lines with desirable traits, lines with excellent malt quality, high protein line, several rust resistant lines etc.



Recently, the entire collection of barley germplasm was characterized at ICAR-NBPGR and the wide variability in multiple traits has been documented. The information will be uploaded on the institute portal.

The geographic sources from where barley germplasm has been received for long term conservation in National Genebank is depicted below-

5. Conclusions

The responsibility for import and export of plant genetic resources for research purposes has been delegated by the Ministry of Agriculture and Farmers Welfare to the Indian Council of Agricultural Research (ICAR)/ Department of Agricultural Research and Education (DARE). ICAR- NBPGR is the nodal agency recognized for PGR exchange within the country as well as outside the country. After enactment of the Biological Diversity Act, Protection of Plant Varieties and Farmers Rights Act (PPVFRA) and ratification of The International Treaty on Plant Genetic Resources for Food and Agriculture by India, ICAR-NBPGR has to follow new rules for exchange of plant genetic resources for food and agriculture (Tiwari, 2006) . The import of barley germplasm for research purposes and bulk imports of seeds for multiplication or grains for consumption are regulated under the provisions of PQ Order, 2003.

Regulation of access to barley germplasm and information under the new regime in India has to take into account the established institutional mechanism and various acts in force relating to agro- biodiversity. The requests of indenters are to be dealt with depending on the status of requesting party and the conditions for access under different categories. ICAR-NBPGR is the nodal agency for facilitating the proposals for export under the collaborative research programmes based on projects approved by State Government Department or Central Government, or MoU/ Work plan and other relevant agreements as per the Guidelines issued by the Ministry of Environment, Forests and Climate Change (MoEFCC).

6. References

1. Bhalla S, V Celia Chalam, Arjun Lal and RK Khetarpal. 2009. Practical Manual on Plant Quarantine. NBPGR, New Delhi, India, 204 p+ viii.
2. Das S, Tyagi V and Kaul J. 2008. Germplasm Introduction in Cereals: Achievements and Opportunities In Training Manual on Germplasm

Exchange: Policies and Procedures in India November 17-26, 2008. NBPGR, New Delhi 302-320 pp.

3. Dhillon BS , SK Pareek, BM Singh and K Srinivasan. 2001. NBPGR: Past and Present. In: *National Bureau of Plant Genetic Resources: A compendium of achievements*. BS Dhillon, KS Varaprasad, K Srinivasan, Mahendra Singh, Sunil Archak, Umesh Srivasatava and GD Sharma (eds),NBPGR, New Delhi, India, pp1-30.
4. Khetarpal RK, KS Varaprasad, Arjun Lal, PC Agarwal and B Lal. 2001. Plant Quarantine of germplasm under exchange. In: *National Bureau of Plant Genetic Resources: A compendium of achievements*. BS Dhillon, KS Varaprasad, K Srinivasan, Mahendra Singh, Sunil Archak, Umesh Srivasatava and GD Sharma (eds),NBPGR, New Delhi, India, pp 90-115.
5. Mathur VK and Arjun Lal. 1996. Plant Quarantine Activities at NBPGR (1976-1996). *NBPGR Sci. Monog.* No. 6, 96p.
6. Parakh DB and PL Gautam.1999. Role of quarantine in prevention of diseases of horticultural crops. In: *Diseases of horticultural crops – fruits*. LR Varma and RC Sharma (eds.), Indus Publishing Co., New Delhi, India, pp. 668-689.
7. Plant Quarantine (Regulation of Import into India) Order 2003 and its amendments. The Gazette of India. Extraordinary, Part II Section 3 subsection (ii), No 1037, 2003 published by the Ministry of Agriculture (Department of Agriculture and Cooperation); Notification dated 18th November, 2003.
8. Ram Nath. 1996. India's Plant Quarantine System Works to Thwart Potentially Devastating Crop Losses. *Diversity* 12 (3): 49-50.
9. Tiwari SP. 2006. Regulatory and operational mechanisms as related to agro- biodiversity, Second and Revised Edition, NAARM (ICAR) Publication, PP 1-216 + xiii.
10. Tyagi V, D Chand, IP Singh, SP Singh, SS Ranga (2007) Guidelines for exchange of Transgenic Planting material In: *Cartagena Protocol on Biosafety: Decisions to diagnostics* Gurinderjit Randhawa, Shashi Bhalla, V Celia Chalam and S K Sharma (eds), NBPGR, New Delhi, India, pp74-81.
11. Tyagi V, A Lal, V Joshi, P Brahmi, N Verma, AK Yadav, Anitha P, SP Singh and S Singh. 2011. Important Crop Germplasm Introduced in Field crops in India during 2009*Indian Journal of Plant Genetic Resources* 24 (1): 27-30
12. Verma RPS, SS Malik, B Sarkar and S Nagarajan. 2006. Barley In Plant Genetic Resources: Foodgrain Crops.Dhillon BS, S Saxena, A.Agrawal and RK Tyagi (eds), NBPGR, New Delhi, India, pp 137-159