Genebank Standards – revised guidelines adopted by FAO

On 18 April 2013, the Commission on Genetic Resources for Food and Agriculture (CGRFA) of the United Nations Food and Agriculture Organization (FAO), endorsed and adopted the revision of the *Genebank Standards*, last published[1] in 1994. These standards are meant to ensure that plant genetic resources for food and agriculture (PGRFA) are conserved in genebanks under recognized and appropriate conditions, based on current technological and scientific knowledge. Simply defined, genebanks are places where either seeds are conserved at low temperature and moisture, or whole plants/plant propagules are conserved in field or culture vessels or in cryovials. Genebanks exist throughout the world and they collect, catalogue, store and protect as many species of plants and genepool of crops as possible. The idea is to conserve as much of diversity of plants as possible, so that it can be drawn appropriately for use. They are useful to plant breeders involved in research and/or breeding for developing new climate-resilient varieties, to respond to growing environmental pressures and to feed a rapidly expanding population. They can also provide a resource for restoration of key species after natural or man-made catastrophes.

Technical standards for genebanks were first developed by CGRFA in early 1990s. The CGFRA is a unique intergovernmental global forum, where countries that are donors or users of germplasm, funds and technology, deliberate matters related to genetic resources. The *Genebank Standards* were developed to respond to the need of appropriate standards for international *ex situ* conservation. They were published in 1994 and pertained solely with the storage of seeds of orthodox species[1]. The standards were non-binding and voluntary in nature. They emphasized the importance of striking an optimal balance between scientific considerations and the available personnel, infrastructural and financial resources[1].

However, due to advancement in technological and scientific knowledge (especially advances in seed storage technology, biotechnology and information/communication technology) and the changes in the policy issues related to genetic resources, especially adoption of international instruments such as the Convention on Biological Diversity (CBD, 1993), International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2001) and the International Plant Protection Convention (IPPC, 2005), a need was felt for revising the 1994 *Genebank Standards*. The CGRFA requested the FAO, in cooperation with competent institutes and bodies like the Consultative Group of International Agricultural Research (CGIAR) and its affiliated International Agricultural Research Centres (IARC), the Global Crop Diversity Trust (GCDT), the ITPGRFA, the IPPC, and other relevant institutions, to undertake this review.

The Bioversity International and FAO prepared a first draft version of the *Genebank Standards* together with GCDT, ITPGRFA and IPPC. An Expert Consultation Meeting was held during 6–8 September 2010 at Rome, where R.K.T. participated along with other genebank experts from many countries, besides experts from Bioversity International, GCDT and ITPGRFA. During the meeting the overall approach of the *Draft Updated Genebank Standards* and the underlying principles for maintaining genebanks were discussed. The consultation provided valuable inputs such that current scientific knowledge and changes in the conditions for *ex situ* conservation of orthodox seeds could be reflected in the revised version. Detailed deliberations for standards related to germplasm acquisition, processing, storage, viability monitoring, regeneration, characterization, documentation, distribution, personnel training and genebank security were held. Further, since significant progress had been made regarding the *in vitro* conservation and cryopreservation of vegetatively propagated crops and cryopreservation of recalcitrant species, it was agreed by all the experts that *Standards* should also be developed for *in vitro* genebanks, cryogenebanks and field genebanks to maintain the germplasm scientifically and uniformly all over the world. The revised draft was vetted and finalized by the Commission's 'Intergovernmental Technical Working Group on Plant Genetic Resources for Food and Agriculture' (ITWG-PGRFA). Finally, in the Fourteenth Regular Session of the CGRFA held during 15–19 April 2013, the document *Draft Genebank Standards for Plant Genetic Resources for Food and Agriculture*, was endorsed by the Commission, with several countries supporting the endorsement.

The most important feature of the revised *Genebank Standards* is that it covers crops with orthodox seeds, non-orthodox seeds and also vegetatively propagated species. Importantly, it presents one standard in contrast to the two levels, 'preferred' and 'acceptable' standards, used in the previous edition, mainly to avoid ambiguity or unnecessary duplications and to optimize the use of limited resources. The structure and presentation of the revised *Genebank Standards* have been greatly improved from the original *Genebank Standards*, for more specificity. The *Standards* contain four main sections: Introduction, Underlying Principles, Standards and Appendices. The 'Introduction' covers the context of the revision and scope of the *Standards*. It is followed by the 'Underlying Principles', which provide a framework for setting the *Standards* and encompass the overarching principles of genebank management. The section on 'Standards' provides the specificity to adhere to the underlying principles. The *Standards* are presented in a straightforward manner, followed by a narrative on technical aspects, contingencies and selected references. As in the earlier edition, these *Standards* are basically targets to aim for and remain non-binding and voluntary in nature.

The revised *Genebank Standards* take into account the changes in *ex situ* conservation conditions, diversity in storage requirements, purpose and period of germplasm conservation, ranging from temperate to tropical provenances. Field genebanking is the most commonly used method for non-orthodox seed-producing plants, for plants that produce very few seeds, are vegetatively propagated and/or have a long life cycle, and their standards have been defined accordingly. The standards for *in vitro* culture and cryopreservation are broad and generic in nature, due to the marked variation among non-orthodox seeds and vegetatively propagated plants.

The new international standards are expected to help genebanks worldwide to conserve crop diversity in a more efficient and cost-effective manner. They provide a basis for establishing the norms and standards essential for the smooth operation of a genebank. They can be used by genebank curators as a source of guidance for developing standard operating procedures. They would also be helpful for developing quality management systems in genebanks. A systematic application of these standards will, however, require strong national, regional and global commitment and continuous financial support for capacity development and upgrading professional skills. After approval of the CGRFA, the *Genebank Standards for Plant Genetic Resources for Food and Agriculture* is expected to be published by the FAO and widely disseminated amongst decision-makers and relevant stakeholders. All genebanks are expected to adopt these standards, as far as possible, to ensure conservation of genetic resources under optimal conditions, for perpetuity. It is further expected that species-specific standards be developed in future for further fine-tuning of this endeavour.

FAO/IPGRI, *Genebank Standards*, Food and Agriculture Organization of the United Nations, Rome, International Plant Genetic Resources Institute, Rome, 1994, p. 12.

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RESEARCH NEWS

The fascinating story of boron–boron triple bond

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Modern chemistry has enriched human lives in innumerable ways. From medicine to materials, chemistry plays a key role in determining and manipulating their properties at the molecular level. Though these achievements may reflect our success in utilizing chemistry, we are yet far from understanding numerous fundamental aspects of the subject. The quest of chemists to answer numerous fundamental, unanswered questions seems to be an endless voyage to search for and reach new destinations. Here, we focus on one of the simplest questions for which the answer could finally be provided only very recently: *with only three valence electrons, can boron form a true boron–boron triple bond?*

The stability of homoatomic triple bonds[1] is beyond any question for carbon and nitrogen. Triple bond-containing alkynes form a distinct class of numerous stable organic compounds and are regarded as an indispensable part of synthetic organic chemistry. The triple bond in dinitrogen is one of the strongest bonds in nature and as a result, dinitrogen is used to provide inert environment in laboratories. However, the stability of the triple bond does not apply in the case of other main group elements. Extreme steric protection is essential to stabilize homoatomic triple bonds in low-valent main group elements. Even if the synthetic difficulties can be overcome, they are often severely trans-bent, reducing their triple bond character[2,3].

Boron, however, is unique in this regard (Figure 1)[4]. Having only three valance electrons, it lacks the ability to attain a closed-shell noble-gas electronic configuration in its trivalent state. Three coordinate organoboron compounds like boronic acids gain their stability from extensive B–O p_π–p_π overlap which diminishes the reactivity of the boron centre[4e,4g]. Kinetic stability in triorganyl boranes can also be achieved using bulky aryl substitutions. The sterically protected empty p_π orbital greatly influences the optoelectronic properties of triarylboranes, which makes them potential candidates for electroluminescent materials and a receptor for smaller anions[4b-f,4j]. Boron can also be stabilized in the organic backbone via chelation in borate form. The chelation process not only stabilizes the boron centre, it also assists to rigidify the organic moiety, forming highly emissive dyes. The BODIPY dyes must be mentioned in this context[4c], as they have been extensively studied in recent years and have already been commercialized in biomedical applications. In elemental form, boron forms icosahedral clusters[4a,4i] (Figure 2) and this tendency is also manifested in carboranes which are promising candidates in medicinal chemistry as delivery agents in BNCT (boron–neutron capture therapy)[4h].

Boron forms a wide range of sigma bonds with other elements. Apart from conventional B–X sigma bonds, it also forms three-centre-two-electron B–H–B bonds in B_2H_6 which is an extreme example of the high electron deficiency of the element. Boron–boron σ-bonding in stable molecules is well known. Similar to boron-clusters and carboranes, B–B single-bonded compounds such as bis-(pinacolato)-diboron (Figure 2) or tetrachlorodiborane can be easily handled in general laboratory conditions. However, due to its highly electron-deficient nature, boron resists multiple bonding[5] and rarely forms B–B π-bonds. Successful attempts to prepare stable homoatomic multiple-bonded group 13 element compounds have been based on populating the empty π-bonding orbital between the atoms. In 1992, Moezze *et al.*[6] were able to form a B=B for the first time in anion-stabilized 'diborenes', which was described as a diborane dianion analogue of substituted ethylene (see below).

A B–B triple bond in compounds like LBBL (L = substituent) seems to be rather far-fetched as boron has only three valence electrons (Figure 3) available for bonding. In 2002, the B_2 entity could be isolated in an argon matrix at 8 K by stabilization with Lewis base CO in the form of OCBBCO[7] (Figure 3). It was found to be a neutral molecule with some boron–boron triple bond character. In