Introduction

The importance of horticulture in improving the productivity of land, generating employment, improving economic conditions of the farmers and entrepreneurs, enhancing exports and, above all, providing nutritional security to the people, is widely acknowledged (http://indiabudget.nic.in Economic Survey 2004-2005). In addition, more recently they have been shown to contribute significantly to environmental health as well, especially tree species (Guimarães et al. 2014. Vicente et al. 2016, Shrestha and 2016). Fruits, vegetables, and condiments add to the diversity of food. The problem of the lack of crop diversity leading to a loss of dietary diversity is not only a problem of the developing world but also of the industrialized world. Wallinga (2010) demonstrated the relationship between US cheap food policy, including subsidies for few commodity crops, and the replacement of hunger by obesity, and pleads for a more diverse farm policy to stimulate the production of vegetables and fruits. Horticultural crops, as high value crops, have an important role to play in revitalizing rural economies. In fact, five different major groups can be identified: fruit and nut crops, vegetables, food legumes, roots, and tubers, and lastly the ornamental and medicinal group. Horticultural production is dependent upon the optimization of diverse genetic resources to obtain uniform, high quality products and to adapt those products to changing environmental constraints and market demands. Untapped genetic resources also offer unique potential to develop new commercial opportunities, such as innovative crops or additional products within existing crops.

Brief Assessment of Global Horticultural Genetic Resources

Traditionally, horticultural crops include crops such as fruit, nut, vegetable, spices and condiments, beverages, and medicinal species, as well as ornamental plants. In some countries, especially Africa, SE Asia and South America, wild species contribute a significant source of food in addition to cultivated species. India is an important centre of origin and diversity of many horticultural crops including fruit crops like mango, citrus, and banana. Of course, some crops could have origins in more than one region in the world, evolving either simultaneously or at different times.

Europe

The highly intensive horticulture practised in Europe is the result of scientific and cultural innovations. The new tools developed in biology, chemistry, physiology, genetics, and biotechnology have driven dramatic advances in all areas of the fruit industry. Spurred initially by efforts in the public sector and more recently by input from the private, these innovations have brought about significant changes in field testing and orchard management and greatly enhanced both the expertise of growers and crop quality (Sansavini 2009). These improved tools helped to enhance better exploitation of HGR available to crop scientists. Examples of horticultural crops that either have their centre of origin or domestication in Europe include: currant, carrot, gooseberry, cabbage, parsnip, turnip, apple, endive, lettuce, pear, horseradish, grapes, radish, cabbage, cucumber, kale, dill, hops, chestnut, caraway.

Latin America and the Caribbean

The two centres of agricultural origin in LAC are Mesoamerica (Mexico to Panama) and South America (coastal regions). Many important horticultural crops have arisen from these centres;
examples include manioc (cassava), potatoes, sweet potatoes, oca, mashua, ulloco, arrowroot, yacon, tomato, chili pepper, avocado, cranberry, blueberry, cherimoya, papaya, passionfruit, pineapple, soursop, strawberry, melons, black walnut, Brazil nut, pecan, hickory nut, cashew, chocolate, canna, and vanilla. Numerous LAC horticultural species are currently underutilized and show potential for intensive cultivation, including many native fruit species – *Annonas* spp., mombin, sapote, mamoncillo, guava, etc. While these indigenous fruit species are cultivated in home gardens and available at informal markets, little effort has been invested in improving their production systems. The genetic diversity of crops originating in Latin America is an invaluable resource for breeders, both within the region and around the globe. Underutilized LAC tree fruits represent opportunities to generate new markets, like the creation of the “kiwi” market.

**North America**

The diversity of horticultural products grown in the USA is extensive, cool valleys are excellent for apples, cabbage, sweet corn, and muscadine grapes. Coastal Plains are ideal for most vegetables and fruits, including tomatoes, peppers, watermelons, and squash (Arteca 2015). Usually, North America is not considered as a major centre of origin or domestication of food crops. However, it does have many horticultural species originating, although some of these may be common with South and Central Americas. Examples include blackberry, Jerusalem artichoke, blueberry, cranberry, black and white walnuts, American ginseng (*Panax quinquefolius*), chives, sage, American grape, American plum and, pumpkin. In the USA, which probably leads in plant genetic resources conservation activities, especially ex situ, conserves horticultural genetic resources in various USDA managed centres. These include: Davis, California - grape, stone fruits, walnut, almond, pistachio, persimmon, olive, fig, pomegranate, mulberry, kiwi; Geneva, New York - grape, apple; Miami, Florida, and Mayaguez, Puerto Rico - banana, mango, avocado, Brazil nut, Chinese date, jujube, coffee, cacao, soursop, bamboo, sugarcane, cassava, tropical yam, cocoyam; Orlando, Florida – Citrus; Hilo, Hawaii - macadamia, guava, passion fruit, Barbados cherry, breadfruit, jackfruit, pineapple, papaya, lychee, *Canarium* (pili nut), *Guiliema* (peach palm), *Nephelium* (rambutan, pulasan), carambola.

**North Africa and Middle East**

Despite that desert comes to mind when one thinks about this region, it is a remarkably heterogeneous area characterized by a great diversity of agroclimatic zones, allowing to produce many crop species and supporting a considerable richness in dietary diversity, especially of fruits and nuts and indigenous species of regional interest (USAID 2005). The Fertile Crescent in the Middle East has been considered as one of the centres of origin of agriculture and agricultural crops, including horticulture. Historically, the gardens around temples in Egypt might be the beginning of horticulture. Some examples of horticultural crops that have origin in the Middle East include: cherry, asparagus, fig, beet, grape, celery, olive, cress, plum, lettuce, onion, pea, radish, spinach, almond.

**Asia**

Asia is the centre of origin and diversity of many of the world’s major horticultural crops. Examples include Azuki bean, brinjal, yams, blackcurrant, cabbage, Chinese mulberry, Mandarin melon berry, silkworm thorn, or zhe, Citrus, jujube, winter melon, gojo berries, apple, coconut, durian, Kiwifruit, or Chinese gooseberry, *Lansium*, longan, litchi, mango, mangosteen, rambutan, rhubarb etc. Much of this germplasm has not yet been characterized and little effort is currently extended to preserve genetic resources and protect local cultivars from extinction. Conservation of genetic resources is critical, both for the improvement of economically important crops and for the possible introduction of new crops into international markets. Farmers throughout ANE have extensive knowledge of indigenous crop varieties and their utilization, as well as familiarity with the wild relatives of cultivated horticultural...
crops, but most of their knowledge has never been systematically assessed. The germplasm and knowledge are a latent resource, which may prove essential for the future of the industry. The range of germplasm in ANE covers many fruit and vegetable species; this region is particularly rich in species with medicinal or pharmaceutical properties as well as many herbs, spices, and flowers. The region has a strong cultural history of employing herbs, spices, and medicinal plants. Consequently, there is a wealth of ethno-botanical knowledge and a long oral and written history of uses of these plants. Much of the ANE region lacks adequate systems and mechanisms for protecting indigenous germplasm and the associated intellectual property rights.

**Australia and the Pacific (A&P)**

Australia’s horticulture industry comprises fruit, vegetables, nuts, flowers, turf, and nursery products. The industry operates in a highly competitive domestic and international market, is labour intensive and mostly seasonal ([http://www.agriculture.gov.au/ag-farm-food/hort-policy/horticulture_fact_sheet on 25/09/2017](http://www.agriculture.gov.au/ag-farm-food/hort-policy/horticulture_fact_sheet)). Main horticulture crops include: banana, pineapple, mandarin, avocado, mango, fresh tomato, capsicum, pears, apple, cucurbits (rock melons, watermelons, pumpkins), with a growing “rare and exotic fruit” industry producing fruits such as abiu, carambola, durian, jackfruit, mangosteen, pitaya, rambutan, and amarillo; nut crops grown throughout Australia include almonds, cashews, chestnuts, hazelnuts, macadamias, peanuts, pecans, pistachios, and walnuts. Although the fruits of Australia were eaten for thousands of years as bushfood by Aboriginal people, they have only been recently recognized for their culinary qualities by non-indigenous people. Many are regarded for their piquancy and spice-like qualities for use in cooking and preserves. Some Australian fruits also have exceptional nutritional qualities, including high vitamin C and other antioxidants. These include: Atherton raspberry, black apple, blue tongue, bolwarra, broad-leaf bramble, cluster and desert figs, common apple-berry, Davidson's plum, desert lime (*Citrus glauca*), finger lime (*C. australasica*), lady apple (*Syzygium suborbiculare*).

**India**

The Indian subcontinent is very rich in biological diversity, harbouring around 49,000 species of plants, including about 20,500 species of higher plants. The Indian gene centre holds a prominent position among the 12 mega-gene centres of the world. It is also one of the Vavilovian centres of origin and diversity of crop plants. Four out of the 34 global hotspots of biodiversity, namely the Indo-Burma and Western Ghats/Sri Lanka, are located here. India possesses about 12 per cent of world flora with 5,725 endemic species of higher plants belonging to about 141 endemic genera and over 47 families. About 166 species of crops including 25 major and minor crops have originated and/or developed diversity in this part of the world. Further, 320 species of wild relatives of crop plants are also known to occur here.

- Primary centre of diversity for crops: Jackfruit, banana, mango, *Syzygium cumini*/*jamun*, large cardamom, black pepper and several minor millets and medicinal plants like *Rauwolfia serpentina and Saussurea costus*.
- Secondary centre of diversity for African crops: Cowpea, cluster bean (transdomesticate), okra, tomato, muskmelon/*Cucumis* species, pumpkin/*Cucurbita* species, chayote / chou-chou, chillies and *Amaranthus*; and
- Regional (Asiatic) diversity for crops: Cucumber, bitter gourd, bottle gourd, snake gourd and Tribe *Brassicae*.

In India, horticultural crops include 145 species of root and tuber (e.g. potato, onion, yam, taro), 521 of vegetables/greens (e.g. beans. peas, carrot, brinjal, cauliflower, cabbage, carrot and tomato, amaranth, palak), 101 of buds and flowers (e.g. apple, pear, grapes, cherry, peach, and apricot) and 118 of seeds and nuts (e.g. cashew, almond). Medicinal plants include mint, liquorice, foxglove, *Cinchona*,...
Hyoscyamus (herbane) and others such as Humulus lupulus (hops). Thus, both indigenous (e.g. lemon, cucumber, lime, mango, muskmelon, eggplant) and well adapted exotic set of materials constitute a well-balanced matrix of crop diversity in India. In addition, there are several underutilized fruit he more familiar ones include: jackfruit (Artocarpus heterophyllus), bael (Aegle marmelos), jamun (Syzygium cumini), carambola (Averhoa carambola), aonla (Emblica officinalis), karonda (Carissa carandas) and phalsa (Grewia asiatica); vegetables such as water spinach (Ipomoea aquatica (Akthar et al. 2012) Kahtthi Metthi (Oxalis corniculata), kohar (Bauhinia purpurea), poi (Basella alba) (Gupta and Yadav 2016), drum stick, snapmelon, sweet gourd (Peter 2008).

The Indian gene centre has strong linkages and contiguity with other regions of diversity of crop plants such as the Indo-Chinese-Indonesian, Chinese-Japanese and the Central and West Asian regions. Further the influx of germplasm in distant past from the Mediterranean, African and tropical American regions, has built up enormous locally selected diversity. Apart from the crop plants and their wild relatives, enormous diversity occurs in natural habitats in medicinal and aromatic plants and forage grasses and legumes. Some of the medicinal plants diversity such as Rauwolfia serpentina, Ocimum and Cymbopogon spp., Emblica officinalis, Swertia chirayata, Podophyllum hexandrum and Nardostachys jatamansi are of industrial use. The diversity in wild forage plants is largely distributed in the Western Ghats, Eastern Ghats, North-Eastern region and in the Himalayas.

The indigenous plant wealth has been supplementing by introduction of species and forms that have greatly enriched the local flora. These introduced species also diversified in India due to isolation over time and space, and diversity in climate and human intervention. The geographical proximity with the Indo-Chinese-Indonesian, the Chinese - Japanese, the Central and West Asian centres of diversity has helped in considerably augmenting our crop plants resources. The influx of genetic material from other parts of Asia, Africa, Americas, and Europe in the past, has also resulted in accumulation and diversification of enormous genetic variability. The ancient travellers, traders and religious missionaries contributed significantly towards enriching the agro-biodiversity in the Indian gene centre. Presently, India has > 480 species of agricultural crops as native and introduced species.

Home gardens and traditional agro-forestry systems with complex structure and multiple functions are the important sites for in situ/on-farm conservation of land races, wild potential species and wild relatives of crops. Inventoring the wild and domesticated plants valued for human use has been done in different parts of the country.

The wild relatives of cultivated plants constitute a rich reservoir of genetic variation in the gene centre and this diversity is of immense value to breeders. Among the 320 species about 60 are endemic/rare taxa belonging to different economic crop groups. Based on economic importance in different agricultural and horticultural crops, diversity in wild relatives has been grouped as cereals and millets legumes, fruits, vegetables. Around 70% of India’s medicinal plants are found in tropical areas mostly in the various forest types spread across the Western and Eastern Ghats, the Vidhya, Chotta Nagpur plateau, Aravalli& Himalayas. Although less the 30% of the medicinal plants are found in the temperate and alpine areas and higher altitudes they include species of high medicinal value. Macro studies show that a larger percentage of the known medicinal plant occur in the dry and most deciduous vegetation as compared to the evergreen or temperate habitats (Anonymous,2000).

Conservation of HGR

Efforts on Conservation of HGR in India

The concept of ‘National Collection Centres’ was introduced by the ICAR for various fruit crops for augmentation, conservation and utilization of germplasm. This concept has developed into a system
operated by ICAR-NBPGR (ICAR-National Bureau of Plant Genetic Resources), the Indian National Plant Genetic Resources System (IN-PGRS), which networks 30 National Active Collection Sites in various Agri- horticultural crops. Many of the landraces and primitive cultivars have already vanished and some are on the verge of it due to their abandonment by farmers in lieu of high yielding varieties. The remaining ones are genetically deteriorating gradually due to hybridization, selection or genetic drift. It is, therefore the immediate requirement to assess, collect and maintain them in suitable environments and conserve in National Gene Bank. Attention needs to be paid on the vanishing landraces in crops native to the Indian region about their availability and those that are most vulnerable to modern agricultural practices.

The two approaches to PGR conservation are *ex situ* and *in situ*. *Ex situ* approach generally involves storing the seeds in low temperatures, maintaining plants in the field genebank or clonal repositories, botanical gardens and maintaining, cells, tissue, or pollen *in vitro* and in liquid nitrogen and DNA storage, all of which are outside the natural habitat/environment of the plants concerned. In contrast, *in situ* approach is conserving genetic resources in the plants’ natural habitat. HGR are maintained in reserves/protected areas, on farm, and in home gardens. We present here a summary of different methods and their recent developments before taking up the question of using them in developing complementary conservation strategies.

**Ex situ conservation**

Efforts have been made here to deal in detail with the *ex situ* conservation of seed germplasm of agri-horticultural crops. The National Bureau of Plant Genetic Resources (NBPGGR) has taken a lead in this direction. A National repository for plant germplasm resources has been set up and conservation activities are being coordinated. For horticultural crops, IIHR is the nodal centre for conservation & management of genetic resources, coordinating activities with various crop based institutions. *Ex situ* conservation is a set of conservation methods that focus on the transfer of a target species/genotype/landrace away from its normal habitat. The main objectives of *ex situ* conservation are the rescue and preservation of threatened genetic material and use of the material for different purposes.

*Ex situ* conservation methods include:

- Whole plants in the field (field genebank/clonal repository)
- Orthodox seeds in clod stores (seed genebank)
- Clonally propagated plants as tissue cultures under slow growth (*in vitro* genebank) conditions
- Non-orthodox seed and vegetatively propagated plants, pollen and DNA under cryopreservation (Cryogenebank).

**In situ/on-farm conservation**

The conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties. *In situ* conservation is one of two basic conservation strategies, alongside *ex situ* conservation. Article 8 of the Convention on Biological Diversity (CBD) specifies *in situ* conservation as the primary conservation strategy, and states that *ex situ* measures should play a supportive role to reach conservation targets. It aims to enable biodiversity to maintain itself within the context of the ecosystem in which it is found. Traditionally, protected areas are the cornerstone of *in situ* conservation. Conservation approaches that are more adaptable to individual situations and applicable beyond protected areas, are being increasingly applied. The emphasis is on sustaining the use itself for the benefit of the various stakeholders (Freese, 1997). Hutton and Leader-Williams (2003) point out that objectives could be the conservation of the species (or its populations), the ecosystem in which they occur, or the livelihoods.
that depend on the exploitation. The involvement and acquiescence of local inhabitants, farmers, officials and other interested parties is crucial for the successful implementation of in situ conservation projects in most cases (Damania, 1996).

Future Needs and Priorities

- **Identification of gaps in management of HGR:** The HGR conservation efforts need to be system (within the national or global PGRFA system) and managed accordingly. This will require evaluation of present system/programme, identification of gaps or shortcoming and redressing them to make the conservation and use of HGR more efficient and effective.

- **Increased focus on in situ/on farm conservation of HGR:** This will require an assessment of diversity in farming systems using dynamic analysis of land use patterns and cropping patterns; in crop diversity within a crop species through genetic diversity analysis; and an assessment of changes in wild and weedy relatives at in situ level.

- **Meeting the increasing demand:** There is the steadily rising requirements of low-cost, year-round supply of premium quality fruit and vegetables especially in developing countries (Sharma and Alam 2013). This demand can be met partly through efficient and increased production practices. However, such efforts will be sustainable overall if the available HGR searched for more efficient plant materials and used in improvement and general cultivation.

- **HGR for nutrition and health:** Fruit and vegetable production, along with herbal products, has been gaining momentum in the past 2-3 decades. Part of this growing demand can be satisfied with existing portfolio of plant species that are cultivated, but surely there are more possible species and varieties hidden in the vast array of HGR available. New ways to screen and identify those with potential to meet this increasing demand is the need of the hour.

- **Product development:** One of the major issue that haunts horticulture is shelf life of the produce. Hence developing products that can be preserved for longer periods will help in making the benefits of fruits and vegetables available through the lean periods and to populations far removed from production areas. Studies have shown that there is variation within a species for both shelf life and appropriate product (Dash et al. 2014,) and hence growing through physico-chemical properties of HGR will help efforts in this direction.

### Table 1. Genetic Resources of Horticultural Crops in Horticultural Institutes

<table>
<thead>
<tr>
<th>Crops</th>
<th>Total accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits and nuts</td>
<td>7,084</td>
</tr>
<tr>
<td>Vegetables (including onion &amp; garlic)</td>
<td>20,053</td>
</tr>
<tr>
<td>Ornamentals (including orchids)</td>
<td>3,499</td>
</tr>
<tr>
<td>Spices (including seed spices)</td>
<td>8,785</td>
</tr>
<tr>
<td>Plantation crops (including oil palm &amp; cashew)</td>
<td>2,709</td>
</tr>
<tr>
<td>Medicinal &amp; Aromatic plants+ RET species</td>
<td>2,570</td>
</tr>
<tr>
<td>Tuber crops &amp; potato</td>
<td>10,094</td>
</tr>
<tr>
<td>Mushrooms</td>
<td>2,692</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>57,486</strong></td>
</tr>
</tbody>
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(Ganeshan, 2015)