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Management of Horticultural Genetic Resources in India: Recent Advances

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Horticultural crops comprise diverse economic species ranging from the fruits/nuts, vegetables, spices and condiments, ornamental plants, aromatic and medicinal plants. Besides the tangible materials, horticultural genetic resources (HGR) also encompass the indigenous knowledge accumulated over ages among gardeners, and which surround the use of such biological resources. Global climate change is causing challenges in productivity with the rise in global temperature and reduced amount of precipitation. It is crucial to develop strategies for effective conservation and judicious use of HGR to improve nutritional security and food safety for human health. This paper describes the present status of HGR in India, its scientific management aspects, including their diversity, conservation and sustainable use. It also addresses crucial concerns regarding conservation in India *vis-à-vis* recent advances in management of the HGR.

Key Words: Climate change/environmental stress, Conservation, HGR management, Horticultural crop diversity, Recent advances

Horticultural crops include fruits, vegetables, ornamentals and medicinal crops/species, and these species vary from place to place. 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), 118 of seeds and nuts (e.g., cashew, almond), medicinal plants (mint, liquorice, foxglove, cinchona, *Hyoscyamus* and others such as hops-*Humulus lupulus*). Thus, both indigenous (e.g., lemon, cucumber, lime, mango, muskmelon, eggplant) and well-adapted exotic species constitute a well-balanced matrix of crop diversity in India. The important fruit crops grown commercially in India are mango, banana, citrus, guava, grape, pineapple, papaya, sapota, litchi and apple which comprise more than 75% of total area under fruit cultivation. There are quite a large number of indigenous and underutilized fruit crops, which are being used by the local inhabitants. Some of the important vegetable crops grown in India are brinjal, tomato, chilli, sweet pepper, cabbage, cauliflower, knol-knol, okra, onion, garlic, long melon, muskmelon, snap melon, watermelon, cucumber, pumpkin, summer squash, bitter gourd, bottle gourd, ridge gourd, round gourd, snake gourd, sponge gourd, ash gourd, carrot, radish, turnip, broad bean, cluster bean, cowpea, lablab bean, french bean, peas, amaranths, beet root, fenugreek, spinach, lettuce, drumstick and curry leaf. In addition, there a several underutilized vegetables such as *Karemua*-water spinach (*Ipomoea aquatica),* asparagus (*Asparagus officinalis*), *chekurmanis* (*Sauropus androgynus*), *kachnar* (*Bauhinia purpurea*), poi (*Basella alba*), elephant foot yam (*Amorphophallus campanulatus*), pointed gourd (*Trichosanthes dioica*), snapmelon, sweet gourd; and underutilized fruits which have market value but not widely grown in the field and rarely found in the market include: jackfruit (*Artocarpus heterophyllus), bael* (*Aegle marmelos*), *jamun* (*Syzygium cuminii*), carambola (*Averrhoa carambola*), *aonla* (*Emblica officinalis*), *karonda* (*Carissa carandas*) and *phalsa* (*Grewia subinequalis, G. asiatica*) (Gupta and Yadav 2016; Rathore *et al*., 2005). The need for diversification to horticulture sector was acknowledged by the Government of India in mid-eighties by focussing its attention on investment in this sector. Presently horticulture has established its credibility in improving income through increased productivity, generating employment and in enhancing exports. Resultantly, horticulture has moved from rural confines to commercial venture.

Horticultural Diversity Across the Country

Horticulture is potential to raise the farm income, livelihood security and earn foreign exchange. There is

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a need to encourage diversification to high value crops (HVC) at the rate of 5% every year. According to the estimate, the share of the agriculture and allied sector in total GVA has improved to 20.2% in 2020-21 and 18.8% in 2021-22. Horticulture accounts for 30% of India's agricultural GDP from 8.5% of cropped area, and 52% of export earnings in agriculture. India is 2nd largest producer of fruits and vegetables in the world, and world's highest producer of onion, green peas, and cauliflower. India possesses 1000 wild edible plant species including 145 species of roots and tubers, 521 species of leafy vegetables/greens, 101 species of bulbs and flowers, 647 species of fruits, 118 species of seeds and nuts, 9,500 plant species of ethno-botanical uses, 7,500 for ethno-medical purposes, and 3,900 for edible uses of native tribals. A total of 583 species are cultivated, of which 417 belong to hort. crops. Cultivated species include 27 in fruits & nuts, 23 in vegetables, 15 in plantation and tuber crops and 16 in spices and condiments, and Wild relatives included 331 in fruits and nuts, 215 in vegetables, 154 in plantation and tuber crops and 161 in spices and condiments. Thus, the amount of species diversity available offers substantial genetic diversity to meet the future needs, particularly for the present scenario of climate change (Rathore *et al.*, 2005). Details of these diversity scattered in nineteen (19) regions of India, are stated below:

1. ***Western Himalayan Region:*** Region is inhabited by admixture of Indo-Aryan/Mongolian races. It is secondary centre of origin/ diversity of *Sorbus, Rubus, Prunus* Apple, pear, peach, plum, almond, apricot, cherry, walnut, and chilli, potato, pumpkin, and primary centres of *Allium* spp., brinjal, cucumber.
2. ***Eastern Himalayan Region:*** Most of Arunachal Pradesh and Sikkim, and northern tip of West Bengal (Darjeeling and Kalimpong); Tibetan culture, original inhabitants of Sikkim-Lepchas, Adi, Galo, Nishi, Khamti, Monpa, Apatani, and Hill Miris. It is centre of diversity of *Rhododendron, Primula, Pedicularis*, orchids, spices, *Prunus rufa,* Sikkim-special chilli locally '***Dalle Khorsani'***; *Catharanthus roseus*-anti-cancer/ diabetes; *Centella asiatica*-stomach disorders by different tribes. Wild relatives included *Luffa graveolens, Actinidia callosa, A. strigosa* (kiwi fruit), *Citrus reticulata* (wild forms), *Mangifera indica* var. *sylvatica.*
3. ***Brahmaputra Valley Region:*** Most parts of Assam, Meghalaya Plateau, NE Hills, Brahmaputra Valley. Bhutia and Bodo-the main tribes associated with agriculture, annual rainfall 1,600–2,000 mm with 270 days long growing period. Tea, cucumber, *Musa*, bamboo, brinjal, okra, *Abelmoschus pungens*, welsh onion (*Allium fistulosum*) of China extends up to the region. Ginger and turmeric- many local cultivars with desirable features, and in Citrus- *Citrus reticulata*. *Sonowal Kacharis* tribe uses *Allium sativum, Oryza sativa, Cassia sophera, Ricinus communis* and *Ananas comosus.* Variability in jackfruit (*Artocarpus heterophyllus*- although native of W Ghats), rich diversity found in Brahmputra valley, Bihar, Assam Jharkhand, WB, UP; rich in carbohydrates and Vit A.
4. ***Malwa Plateau Region:*** Western part of Madhya Pradesh and parts of SE Rajasthan. Opium (*Papaver somniferum*) is a traditional crop; wild relatives, like *Abelmoschus tuberculatus*, *A. manihot* ssp *tetraphyllus* var. *megaspermus* (large seed), *A. crinitus, A. ficulneus; Pusa Nasdar* in ridge gourd from a local landrace from Neemach; *Cucumis* spp.; *Chironji (Buchnania lanzan)*; *ber, bael, karonda, khirni,* and custard apple.
5. ***Bundelkhand Region:*** South of Yamuna between fertile Gangetic plains stretching across northern Uttar Pradesh & southern highlands of MP. Brinjal, *Ziziphus, bael* (*Aegle marmelos*)- traditional varieties such as Kagzi Etawah, a known landraces; *chironji* - diversity has been recorded for panicle, fruit size and quality kernels; diversity in *aonla, ber,* and *karonda***.**

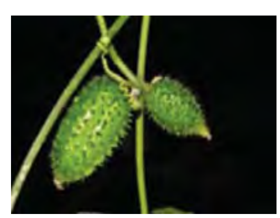
Bhut Jolokia **–the world's highest pungency; >1 million SHU.**

6. ***Garo, Khasi and Jaintia Hills*****:** Centre of diversity of *Rhododendron, Schima*, Zingiberaceae spices, *Citrus, Garcinia;* Tura range (Garo Hills)- *Citrus* & *Musa* species diversity; brinjal, *S. khasianum* with resistance to stem and fruit borer, *S.kurzii*-endemic to Garo hills. In chilli, ***Bhut Jolokia*** with the highest pungency so far; bittergourd, ashgourd, bottlegourd, chow-chow, *Cucumis hardwickii* - the likely progenitor of cucumber; *Mangifera khasiana*-endemic, distinguishable from *M. sylvatica*; in *Citrus*, 8 of the 17 species reported from the NE Region *C. indica, C. macroptera, C. latipes* naturally occur, presenting rich genetic diversity; *Musa flaviflora* is localized with four additional species. *Artocarpus heterophyllus, Litchi chinensis, Malus, Pyrus, Prunus spp., Prunus persica, Rubus, Sorbus, Corylus, Castanea sativa, Prunus napaulensis, Pyrus cerasoides* while *Pyrus pyrifolia*, and *P. serotina* is grown semi commercially.
7. ***North-eastern Hills:*** Nagaland, Manipur, Mizoram and Tripura and Cachar. Brinjal, *Citrus, mango*, tropical and subtropical minor fruits, banana, pineapple, citrus, papaya, plum, peach, apple, cucumber with natural occurence of *Cucumis hardwickii, Cucumis hystrix, L. graveolens, M. cochinchinensis, Trichosanthes ovata, T. khasiana,* providing a reservoir of useful genes; brinjal with rich diversity*, S. torvum, S. indicum* and *S. khasianum* possess resistance to shoot and fruit borer, and root diseases; *Annona, Averrhoa ;* wild orange *C. indica* is found in the Naga Hills, whereas, lemon, *C. lemon,* is known with a large number of traditional cultivars, such as Hill lemon.
8. ***Arid Western Region and Semi-arid Kathiawar Peninsula:*** Western part of Rajasthan, parts of the south- western Haryana and Kathaiawar peninsula of Gujarat. Centre of diversity of *Citrullus, Cucumis melo* var *agrestis,* arid fruits, seed spices & *khejri (Prosopis cineraria),* marwar teak *(Tecomella undulata),* watermelon, *Citrullus lanatus, Cucumis melo* var. *momordica, Momordica balsamina,* mandarin *(Citrus reticulata),* kinnow mandarin, sweet orange *(C. sinensis), Ziziphus mauritiana-gola, seb* and *mundia; Punica granatum* –'Jodhpur Red' with wider spread, and Jalore seedless; guar, moth bean; and *Cucumis prophetarum* in Abu Road (Sirohi District) of Rajasthan.
9. ***Upper Gangetic Plains:*** Northern Punjab, most of Haryana and western, central and parts of eastern UP, spread from foothills of western Himalayas to Delta in West Bengal. Centre of diversity available are:*Benincasa hispida, Citrullus, Abelmoschus,* brinjal - *Ramnagar Baingan* (round green fruit type is suitable for Ganga River belt), *Dudhiya* (cluster), *Jethuwa*, *Kuchabuchia* (small clusters), *Jafrabadi,; Balfahwa Jathuwa Bhanta; petha* near Agra, *A. manihot* ssp. *tetraphyllus* (Rampur/Saharanpur), and *A. tuberculatus* (Saharanpur), mango- Bombay Green, *Dashehari, Fazli, Langra, Safeda* Lucknow, *Smarbehisht, Chausa*; aonla- *Hathijhool, Basanti* red, *Deshi, Chakaiya*; jamun, lemon; and water chestnut (*Trapa natans*)- excellent coolant for body, perfect food, high nutrient, low calorie, fat loss, helps in jaundice, thyroid gland, controls diarrhea.
10. ***Middle Gangetic Plains:*** Eastern UP and parts Bihar, either side of Ganga and Saryu (Ghaghara), and Himalayan foothills and Vindhya ranges. Centre of diversity of cucurbits- *parwal,* (*Trichosanthes dioica*)*, satputia (Luffa acutangula* var. *satputia*, also known as *Luffa hermaphrodita); Momordica;* in *Legeneria*- like *Rajendra Chamatkar* are developed through selection from local landraces; *Luffa echinata, Momordica cochinchinenesis, Momordica subangulata renigera M. dioica*, and more; brinjal, chilli, *Abelmoschus crinitus*; mangoes- *Bathua, Bombai, Himsagar, Kishen Bhog, Sukul, Langra, Sundar Pasand, Fazli, Gulabkhas, Mahmood Bahar* and *Zardalu'* litchi- North Muzaffurpur, Darbhanga is known for varieties, like *Bedana, Calcuttia, Purbi, Kasba, Desi, Early Bedana, Shahi*; bael, and *makhana (Euryale ferox).*


Date palm fruits in cluster


***Cucumis prophetarum* from Abu Road**


***Cucumis hardwickii* (2n=14); wild progenitor of Cucumber**


***Cucumis hystrix* (2n=24) amphidiploid**

11. ***Lower Gangetic Plain or Delta Region***: Parts of WB and Bangladesh where Ganges, Brahmaputra and Meghna meet into Bay of Bengal. *Ipomoea aquatica*, okra, *Momordica, Trichosanthes, Musa*, ornamentals, *parwal*, elephant foot yam, moringa, *kakoda, kostumbari* coriander, brinjal, okra- *Abelmoschus manihot, A. crinitus*; mango- *Bombai, Himsagar, Kishen Bhog, Langra, Malda*; jackfruit, and *karonda (Carissa carandus).*
12. ***Chhotanagpur Plateau:*** SE plateau of Jharkhand bordering Odisha, WB, Bihar and Chhattisgarh. Variability included in litchi, jackfruit, cucurbits, *Dendrobium* – a epiphytic orchids (over 10 species)*;* ginger- *Maran, Kuruppampadi, Ernad, Wynad, Himachal and Nadia;* mango- *Bathua, Bombai, Himsagar, Kishen bhog, Gopalbhog, Sukul, Ranipasand, Safed maldah, Chausa, Fazali, Zardalu,* etc. extending from middle and lower Gangetic plain; Jackfruit in the Santhal Parganas; litchi- *Shahi, Rose scented, China, Purbi, Early bedana, Late bedana;* and lac.

Momordica cochinchinensis

Winged bean

Areca nut in cluster

Carambola, *Kamrakh*

13. ***Bastar Region:*** Chhattisgarh including Dandakaranya, Bastar, Kanker, Dantewada, Bijapur, Narayanpur, and Abujhmarh. Inhabited by *Abujhmarhias, Gonds, Muria, Maria, Dhorla, Bhatra, Halba, and Dhurva* tribes. Mainly root and tuber crops, *Diospyros melanoxylon*; cassava, greater yam, aerial yam, sweet potato, elephant foot yam, *banda*, ginger, turmeric, wild tubers (*Dioscorea*), *pitkanda (D. dumetorum*), *kulihakanda* (*D. hispida*); other useful tubers- *tikhur* (*Zingiber roseum*), tannia, *vidarikand* (*Pueraria tuberosa*), making the region a very important centre of diversity for root and tuber crops; also *chironji; karonda-* rich diversity; melon, cucumber, bottlegourd, ridge gourd, smooth gourd, and a host of medicinal plants, including *keaukanda (Costus speciosus*) used to treat cancer.
14. ***Koraput Region:*** Southern-eastern Odisha and some districts of north-eastern Andhra Pradesh-Nizamabad, Vizagapatnam, Vijanagaram, Srikakulam. Inhabited by *Gonds, Khonds, Santhals, Lahqulas* and *Kinnaras.* Mainly root and tuber crops, cucurbits, *Luffa, Momordica,* yam, sweet potato, *Musa balbisiana*, jackfruit, mango, *aonla,* date palm, *karonda,* pomello, tamarind, *tejpat* (*Cinnamomum tamala*), turmeric, pepper, ginger, etc.; brinjal, chillies for fruit colour, shape, size and pungency. *S.indicum, S. incanum, S. surattense, S. pubescens*; *kundru*, *Cucumis hystrix, L. acutangula, L. graveolense, Luffa umbellata, Momordica balsamina, M. cochinchinensis, M. dioica, M. tuberosa, Trichosanthes bracteata, T. cordata, Trichosanthes multiloba* and *Trichosanthes himalensis*; okra- rich for fruit and plant types, *A. crinitus, A. ficulneus.* In root and tuber crops- *pitharu kanda* (*Dioscorea belophylla*), potato yam (*D. bulbifera*), *pitta kanda* (*D. glabra, D. wallichii, D. wightii*); Indian Kudzu vine (*Pueraria tuberosa),* and *Vigna vexillata.*
15. ***South Eastern Ghats:*** Dry areas of southern Andhra Pradesh and Karnataka. Mainly root and tuber crops; brinjal- *Sanna vanga, Saara vanga, Tella mulaka, Tella vanga* and *S. erianthum, S. nigrum, S. surattense* and in chillies for fruit colour, *Cucurbita pepo, Cucumis melo* var. *agrestis, C. pubescens, M. balsamina* and *M. tuberosa; Vigna hainiana,* elephant-foot Yams, *Amaranthus spinosus, A. tenuifolius, A. dubius;* variability in coriander, mango- *Banganpalli, Totapari, Cherukurasam, Himayuddin,* and *Suvarnarekha;* bael, palmyra palm (*Borassus flabellifer*), *karonda* (*Carissa carandus*), lime, *Commiphora caudata*, wood apple, *aonla*, *Phoenix*, clove, and *Ziziphus horrida, Morus alba*; and mulberry- powerhouse of nutrients, excellent source of proteins, reservoir of antioxidants, improves digestion, lowers cholesterol, promotes brain health, and improve immunity.
16. ***Kaveri Region**:* Kaveri delta of Tamil Nadu-Coromandel plains, South Arcot, North Arcot, Kolli

malai, Pachamalai hills. Mainly *Trichosanthes,* Root and tuber crops, *Syzygium*, banana, bitter gourd, snake gourd, brinjal, chilli, *Canavalia,* moringa, *agathi*, *Cucurbita moschata, Cucumis melo* var. *anguria, Trichosanthes cucumerina* var. *cucumerina, Solanum nigrum, S. surattense, Momordica balsamina, M. tuberosa* and wild okra *Abelmoschus angulosus;* aroids, elephant foot yam, tannia, giant taro, mangosteen, wood apple, clove, mango- *Banganpalli, Bangalora, Neelum, Rumani, Mulgoa*; in banana- *Pachable, Karpurvalli, Monthan, Morris, Mysore poovan, Nendran, Pachanadan, Rasthali,* and Robusta.

17. ***North-western Deccan Plateau:*** Parts of NW Andhra Pradesh, Western Ghats, extending from Satpura-Mahadeo hills in the north to the Bellary-Dharwad. Mainly occur *Vigna* spp., *Citrus, Annona squamosa* (huge variability in custard apple), *Vitis vinifera, Tamarindus indica, Hibiscus cannabinus, H. sabdariffa;* sweet orange, *Flacourtia indica*, wood apple, jamun, grapes, mango- *Alphonso, Mankurad, Muloga, Pairi, Banganpalli, Totapari*; *Mosambi, Sathagudi, Malta*; sweet lime (*Citrus sinensis*); Nagpur mandarin, kagzi lime, and yam.

18. ***Konkan Region:*** Hot humid region of Western Ghats, coastal plains of Maharashtra, Goa, and Uttar Kannada. Centre of diversity of *Vigna* spp. *Vigna* species occur or cultivated in the region are *V. aconitifolia, V. angularis, V. dalzelliana, V. mungo, V. radiata* var. *setulosa, V. radiata* var. *sylvestris, V. sublobata, V. trilobata* var. *trilobata, V. trilobata* var. *pilosa, V. umbellata, V. vexillata, V. vexillata* var. *stocksii*, *V. khandalensis*, *V. unguiculata* ssp. *sesquipedalis,* offering valuable genetic diversity**;** spices, mango, *Garcinia, Artocarpus heterophyllus, A. hybridus, A. paniculatus, A. polygamus, A. spinosus;* bhindi, chillies, *kundru*, lablab bean, bottle gourd, bitter gourd, snake gourd, elephant-foot yam- *A. sylvaticus, A. konkanensis*, taro; yam, *Flemingia procumbens*, tapioca, pineapple, coconut, mango, strawberry, *Musa acuminata, M. sapientum*; jackfruit; arecanut, *Carum strictocarpum*, turmeric (*Curcuma inodora*), nutmeg, pepper, *Vanilla vatsalana, g*inger, harjodwa (*Cissus quadrangularis), Abelmoschus angulosus, A. ficulneus, A. manihot* ssp. *manihot, Cucumis ritchei, C. setosus, Momordica dioica, M. tuberosa, Mangifera sylvatica, tejpatta-C. tamala* and *C. goaense* etc.

19. ***Malabar Region:*** Hot humid, southern part of Western Ghats and coastal plains ; Dakshin Kannada in the north to Kanyakumari in the south, including whole of Kerala, south of Karnataka. Primary centre of diversity of spices, *Syzygium, Garcinia, Artocarpus heterophyllus,* coconut, *M. dioica, M. tuberosa; Trichosnathes anamalayensis, T. cucumerina* var. *cucumerina*, winged bean (*Psophocarpus tetragololobus*) , yam bean, cardamom- 3 distinct types (*Malabar, Mysore* and *Vazhukka)*; wild relatives of *Amomum, Cinnamomum, Piper, Areca Catechu, Curcuma, Zingiber, Myristica* and *Vanilla* offer useful variability for use; banana-red skinned *Kappa,* large yellow skinned *Nedraka*, small yellow- *Kadali, Rasakadali, Poovan, Matti, Palayamkodan*; mango- *Mundappa, Plour, Pairi*; in jackfruit *Varikka* landrace has quality fruit;. Coorg Mandarin from Karnataka *Garcinia gummi-gutta - Kokam*; wild relatives of *Artocarpus, Diospyros, Garcinia, Syzygium, and Vitis* offer significant variability for use.

Vegetable and fruit crops are low in calories but contain high levels of vitamins and minerals (Janick, 2005), making them indispensable for balancing our daily diet. Although the supply of horticultural products is increasing, the diversity and nutritional value of the products are decreasing (Khoury *et al.*, 2014) . These decreases can be partially attributed to the narrow genetic diversity of horticultural crops resulting from domestication and breeding as well as reproductive barriers that inhibit genetic introgression from wild relatives (Kalloo, 1992). Therefore, the generation of genetic resources with diverse and desirable characteristics will be of great value for improving horticultural products. While the conventional approaches can be accomplished by the direct utilization of HGR in breeding program, recent advances in biotechnology have progressively used various tools (such as next generation sequencing, SNP genotyping array and genotyping by sequencing, genome-wide association studies-GWAS, MAS and genomic selection-GS) for selecting potential parents from germplasm collections.

Recent Advances

Horticultural crops are an excellent source of vitamins, antioxidants, and fibers that play an important role in human health. Highlighting the importance of horticultural crops and responding to the main challenges as well as the use of modern technologies in breeding is of paramount importance to meet the nutritional needs in the light of climate change and the trend for sustainable agriculture. The implementation of multi-omics approaches including genomics, epigenomics, transcriptomics, proteomics, metabolomics, and microbiomics is of great importance in order to reveal quality changes in horticulture crops.

Recent advances in automation and high throughput techniques used in decoding plant genomes play an important role to speed up the genomic research. With the establishment of genome and transcriptome sequencing for several horticultural crops, huge wealth of sequence information have been generated which have been used extensively for analysing and understanding genome structures and complexities, comparative and functional genomics and to mine useful genes and molecular markers. However, certain limitations present a number of challenges for the generation and utilization of genomic resources in many important crops. Given the development and advantages of genome-editing technologies, research that uses genome-editing to improve horticultural crops has substantially increased in recent years. With the advent of CRISPR/Cas9, the application of genome-editing to horticultural crops has greatly advanced. The goal of breeding is to harness genetic variations to introduce desirable traits. These genetic variations can arise in various ways, such as by spontaneous mutation, chemical mutagenesis, and physical mutagenesis (Chen *et al.*, 2018). Gene-editing could be regarded as biological mutagenesis. In comparison with other approaches, genome-editing technology is superior in terms of versatility, efficiency, and specificity. Through genome-editing, desirable traits can be directly introgressed into elite or heirloom lines without compromising other properties, and the resulting lines with targeted improvement will be ready for use in crop production (Zang *et al.*, 2016). The wild relatives of cultivated varieties are also potential materials for genome-editing because they generally present unique features in many important traits.

The horticultural crop management is a fit case for using disruptive technologies. Robotics, AI, and IoT are all technologies that have the potential to radically transform the way we grow food. These are poised to revolutionize horticulture as we know it. Robotics can take over many of the tasks currently performed by human workers, from transplanting and watering to harvesting and packaging. AI can be used to monitor crops and optimize conditions for maximum yield. And IoT devices can provide real-time data on everything from soil moisture levels to pest infestations. Drones or Unmanned Aerial Vehicles (UAV) with sensor and imaging capabilities can play an increasingly role in identifying and reducing crop damage. In India, over 80 per cent farmers are small and marginal (<1 ha), it is difficult to manage invasive pests. If one field is sprayed, the pests shift to the neighbouring fields. Parameters related to drone-based spraying such as nozzle type, droplet size, drone-type, spread, density, uniformity, deposition, and penetrability should also be a factor during implementation of mitigation strategies. It can be employed in several field operations and is an excellent tools for rapid, reliable, and non-destructive detection of field problems. Not only will these make our crop production more efficient and sustainable, but it will also free up farmers. In combination with vertical farming, these technologies could increase the efficiency and quality of horticultural products. The entire growth process could be digitized and made available in the form of algorithms. This would allow tech companies to get into the food-growing business. And they could probably do it much cheaper and faster.

Although the supply of horticultural products is increasing, the diversity and nutritional value of the products are decreasing. These decreases can be partially attributed to the narrow genetic diversity of horticultural crops resulting from domestication and breeding as well as reproductive barriers that inhibit genetic introgression from wild relatives. Therefore, the generation of genetic resources with diverse and desirable characteristics will be of great value for improving horticultural products.

Future Perspective

There is tremendous scope for enhancing the productivity of Indian horticulture which is imperative to cater to the country's estimated demand of 650 mt of fruits and vegetables by the year 2050.

1. Some of the new initiatives like focus on planting material production, cluster development program, credit push, promotion of FPOs are the right steps in this direction. An integrated holistic approach is needed to increase horticultural productivity by adoption of growth enhancing technologies, pest management systems and 'precision farming', automation (can reduce over-

application of agrochemicals), vertical farming, soil-less horticulture, protected cultivation (better dividends, also brings pride to the profession by attracting youth including women as well). At present, only ~50,000 ha are under protected cultivation in India, whereas China has 2 m ha. There is need to increase 4 times the area (~2,00,000 ha) in the next 4-5 years. It not only provides high water and nutrient use efficiency but it can easily increase the productivity by 3-5 folds over open field cultivation (GoI, 2019).

2. One of the major components in precision agriculture in crop health monitoring, which includes irrigation, fertigation, pesticide sprays, and timely harvest of the crop. In order to accomplish above operations, drones are highly useful for on-site detection of problems so as to act instantly for corrective measures. As labour availability and technical manpower are meagre, drones are gaining popularity. In India, over 80 per cent farmers are small and marginal (<1 ha), it is difficult to manage invasive pests. If one field is sprayed, the pests shift to the neighbouring fields. Parameters related to drone-based spraying such as nozzle type, droplet size, drone-type, spread, density, uniformity, deposition, and penetrability should also be a factor during implementation of mitigation strategies. It can be employed in several field operations and is an excellent tool for rapid, reliable, and non-destructive detection of field problems.

3. Use of plastic mulch (25% more yield than no mulched), crop cover or low tunnels (for early crop and protection from low temperature), walk-in tunnels (for temperate region off-season vegetables), naturally ventilated polyhouses (tomato, cucumber, tomato, flowers), net houses (for large number of vegetables and ornamental plant nurseries), environment-controlled greenhouses (healthy nursery and foliage plants), vertical farming of lettuce, strawberry etc., soil-less farming (hydroponics and aeroponics for vegetables), and vegetable grafts, are some important technological interventions that need to be scaled up and adopted more widely. The use of vertical farming (growing low crops in multiple layers, mostly inside buildings) and urban/peri-urban farming (the growing of plants within and around cities) which contributes for increasing access to food, advancing livelihoods and improving the environment (waste management, reduce CO_2 emissions) combined with technologies such as hydroponics, allows us to make efficient use of space and reduce the distance our food travels to get to consumers. Designing of improved management (storage, packaging, processing and local marketing) will be crucial from a value-chain perspective would create new opportunities for job and income creation, and is also crucial for generating access to fresh and nutritious food to a wider urban population. Another new and interesting development in Japan uses a biopolymer for 'film-farming', which uses 90% less water than conventional farming and offers a viable alternative to resource-intensive horticulture. Promotion of cold-chain management, harvest and post-harvest management would require cluster identification of horticulture produce and creation of infrastructure for aggregation of the produce, pre-conditioning-cleaning, sorting, grading, packaging, transport and/or storage facilities, processing and market linkages. *Mandis* need to have pledged facilities to avoid distress sale. To enhance the delivery effectively, there is a need for innovations to be scaled in PPP mode for better adoption in horticulture. Involvement of youth for technical backstopping, input supply will be helpful. Further, a thrust on secondary agriculture would be beneficial, as farmers can fetch higher price for their produce subjected to value-addition.

4. R&D for using cutting-edge technologies like genomics, proteomics, metabolomics, phenomics for genetic improvement need to be adequately funded. Concerted efforts need to be made to reorient breeding programs to target the traits like enhanced productivity, seedlessness, canopy architecture, nutrient use efficiency, biotic/abiotic stress resistance, shelf-life improvement, and biofortification, etc. Dryland/arid horticulture needs to be given focused attention for which new varieties/hybrids and related cultivation technologies need to be developed on priority.

5. GoI's Mission for Integrated Development of Horticulture (MIDH) is required to address all the activities starting from cultivation till the produce reaches to the consumers in an acceptable form. There is need to establish functional block level resource centres, including facilities for low-cost value-addition (secondary agriculture). Processing

of fruits and canning of vegetables can multiply their value 50 to 500 times. This would not only save post-harvest losses but also add to employment generation at the local level by engaging youth (including women) and creating village level entrepreneurs. Effective coordination is needed among MoA&FW, Ministry of Food Processing Industries and Ministry of Commerce and Industry. For aggregation of farm produce, there is a need for decentralization and modernization of market yards, railway freight operations need to be strengthened through temperature-controlled containers along with loading and unloading facilities, to reduce post-harvest losses and connect land-locked states to export markets. Private entrepreneurs should also be incentivized to establish small farm implement mechanization hubs for every 1,000 ha and big machinery hubs for every 5,000 ha of cultivated area.

Thus, HGR impacts as well as gets impacted by climate change. Crop diversity regimes, especially landraces and farmers' varieties, which must sustainably increase productivity, resilience (adaptation), mitigation (removal of GHG) and biodiversity conservation are needed. These outcomes and the related activities interact in a complex manner and cut across a number of stakeholders, seeking synergistic integration of gene smart, water smart, soil and nitrogen smart, energy smart, carbon smart, weather smart, and knowledge smart development pathways to green the economy. Investment in PGR conservation and its utilization in climate smart agriculture (CSA) should be suitably enhanced and linked with an effective monitoring, evaluation and impact mapping system. Innovative approaches to social safety-nets, including new insurance products, will be needed to augment house hold resilience. The science-policy interface is necessary to sensitize policy makers. As we move towards an Evergreen Economy, crop diversity should be mainstreamed into the national and international policies in mutual harmony with CSA. For increasing production, let us pledge to develop varieties/ hybrids/ transgenics that help increasing production by 25% from current levels; varieties and technologies that use fewer resources but permit acceptable or relatively better output; improve profitability of farming and living conditions of farmers; and involve women and rural youth in agri-horticulture. Feeding hungry is our duty. If we fail to feed the present generation due to pre-conceived fears of frontier technologies, then there would probably increase hunger and under-, malnutrition in future generations. Emerging technologies including biotechnology are not the enemy but hunger is real enemy that affects around one billion and starvation that causes millions of deaths every year. Without adequate food supplies at affordable prices to needy, we cannot expect world health or peace. Judicial blending of traditional and responsible frontier technologies is our future.

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