Global interdependence for fruit genetic resources: status and challenges in India

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REVIEW

Global interdependence for fruit genetic resources: status and challenges in India

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Abstract

Sharing and exchange of germplasm within and beyond national boundaries generates opportunities to enrich the plant wealth of a country. India is the second largest producer of fruits and vegetables in the world. An analysis of the status of inflow and outflow of fruit germplasm in India was carried out to determine the extent of Indian national interdependence. The goal of this article is to promote the use of fruit genetic resources in crop improvement programmes. Our objectives are (i) to trace the history of domestication or introduction of important fruit crops in India and their subsequent adoption/ diffusion; (ii) to review the usage of exotic germplasm in India as well as Indian germplasm around the world; (iii) to discuss the important agreements/ actions to regulate international exchange of germplasm; (iv) to describe and analyse constraints in global exchange of germplasm; (v) to discuss the ways to strengthen international exchange and enhance utilisation of fruit germplasm. Methods used included retrieval of databases, literature review, communication with key informants, and crop pedigree analysis. India has been exchanging foreign germplasm since time immemorial but till late eighties, the germplasm flow was largely unregulated. Since the early nineties, a mechanism for import was in place. However, formal exchange was initiated in 1976 with the establishment of the Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR). Till date, ICAR-NBPGR has imported 9,684 accessions of fruit crops from over 40 countries. Using exotic germplasm, India has formally released over 100 varieties of fruit crops. Indian germplasm has also been utilised in international breeding of new cultivars or rootstocks, particularly in mango, citrus and banana. The development of Floridian mangoes in the USA, the use of Indian citrus rootstocks worldwide, and the use of Indian banana genotypes are classical examples of the international utilisation of Indian fruit germplasm. The regulated exchange of germplasm after the Convention on Biological Diversity plays a critical role in the sharing of germplasm worldwide.

Keywords Germplasm · Access · Exchange · Fruit crops · Utilisation · Exotic germplasm

1 Introduction and background

Biodiversity in general and Plant Genetic Resources (PGR) in particular are at the core of the wealth of a country. They constitute the foundations of food production and nutritional security. The germplasm wealth of a nation is composed of indigenous natural diversity as well as introduced diversity shared across national boundaries. Despite its wealth in indigenous genetic resources, no country is fully independent for its germplasm requirement and always looks for new germplasm sources. Since times immemorial, crop plants have travelled into new areas from their centres of origin through travellers, traders, invaders, explorers, and pilgrims. The history of crop domestication and global dispersal and adaptation suggests that diffusion of PGR (See Glossary) across borders has benefitted almost all countries around the world (Crosby, 1972, 1986; Diamond, 1997; Fowler et al., 2001; Halewood et al., 2014; Mann, 2011; SGRP, 2011; Galluzzi et al., 2016; Ghimiray & Vernooy, 2017). This trend seems to be increasing as a result of challenges such as growing population, food and nutritional requirements, climate change (Burke et al., 2009; Fujisaka et al., 2011; Jarvis et al., 2010; Lane & Jarvis, 2007; Ramirez-Villegas et al., 2013), as well as the

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evolution of food systems and diets (Khoury et al., 2014). While projecting the importance of germplasm introduction, Thomas Jefferson wrote: "*The greatest service which can be rendered any country is to add a useful plant to its culture…*" (Jefferson, 1800). Plant introductions are made either knowingly or unknowingly, but the plant wealth of any nation is the result of plant introductions over several centuries. Wheat, rice and maize, which respectively originated from Asia Minor and the Mediterranean region; from the Indian subcontinent, China and Sub-Saharan Africa; and from Mexico, are feeding the entire world today. A wide array of fruits and vegetables provide nutritional security globally, irrespective of their centres of origin. Today the world relishes mangoes and bananas originated from India, and in turn India enjoys the flavour of almost all varieties of fruits originated or domesticated elsewhere. The historic success of the global agricultural research system is undoubtedly attributable to scientists and scientific organisations sharing data, information, and materials across national boundaries, and the adoption of novel cultivated plants by farmers and fruit growers.

India has been, and continues to be, strongly involved in germplasm sharing with many countries. The development of the Indian fruit industry was dependent on indigenous variability for large-scale production until early 1800s. New crops were introduced by royalties, travellers or invaders, enriching the diversity. Selection from natural or introduced diversity was performed by local growers, often patronized by rulers of the time, continued over the years, and resulted in the development of several popular types in different fruits. Gradually, large amount of exotic germplasm was introduced, evaluated, adapted and utilised by breeders and adopted by farmers commercially, which helped in increasing the horticulture production in the country by the late 1990s. India has a single window system, which is operated by Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources (ICAR-NBPGR) for germplasm exchange. This concerns the import, export and quarantine of small samples, including those of transgenics, meant for research use.

The Convention on Biological Diversity (CBD), 1993; the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), 2004; and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilisation (NP), 2010 are the three international agreements that have a direct impact on the access, exchange, conservation, and utilisation of PGR (See Glossary) today. Countries that are signatory to the CBD (See Glossary) have developed regulations governing access to biological resources based on "prior informed consent" and "mutually agreed terms". All the 196 member parties of CBD (See Glossary) exchange germplasm under bilateral or reciprocal mode of exchange. The ITPGRFA (See Glossary) is the legal instrument for access and benefit sharing (ABS) in the case of Plant Genetic Resources for Food and Agriculture (PGRFA) for crops listed in Annex I of the Treaty. The NP (See Glossary) aims to provide a fair and equitable share of the benefits resulting from the use of all genetic resources. These policies have an obvious impact on the germplasm exchange patterns of member countries.

The present article is intended to document the extent to which India has sourced germplasm of fruit crops from foreign countries, as well as the extent to which international agriculture has benefitted of Indian germplasm.

The analyses include a retrospective element, which traces the history of domestication or introduction of key fruit crops in India and their subsequent diffusion; a present-day snapshot of important breeding achievements based on international exchanges; and an analysis of challenges and future action plans that are required to promote these exchanges. An analysis of the exchange and utilisation of germplasm of fruit crops in India may provide insights into our journey towards a Golden Revolution (Siddiqui et al., 2014; Dutt, 2016).

2 Data sources and methodology

The present study is based on; (i) actual data retrieved from databases of Germplasm Exchange and Policy Unit (GEPU) and PGR portal of ICAR-NBPGR (See Glossary); data from Agricultural and Processed Food Products Export Development Authority (APEDA); the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT); and Germplasm Resource International Network (GRIN) databases; (ii) a review of available literature and reports, (iii) communications with individual experts in the field of Horticulture, Plant Pathology and Quarantine and PGR for additional information. The review of literature included annual technical reports of various institutes, proceedings of conferences/symposia, newsletters, research articles, consultant reports, and textbooks. To the best of our knowledge, there have been no study regarding germplasm flows in fruit crops and their utilisation.

Released crop varieties in India at state or national level are used for the pedigree study. Review of country and crop-specific pedigree literature has been conducted in combination with personal interviews with end-users of germplasm: amateurs, breeders, researchers, students, and farmers involved in crop improvement programmes. The impact of inflow and outflow of germplasm is studied from interpretations of data on utilisation of germplasm. A slowdown of international exchanges of germplasm would be a critical blow to scientific progress in the world of plant breeding and crop improvement. The constraints which affect smooth germplasm flow among countries are described, and the way forward to enhance a more efficient international flow of germplasm is been presented.

3 Overview of fruit crop diversity in India

India, located between latitude 8°N-38°N and longitude 68°E-97°E and with altitudinal variations ranging from below sea level to over 3500 m above mean sea level, exhibits extreme diversity of edaphic and climatic conditions. It is unique and one of the most significant countries with respect to fruit genetic resources (FGR). Though over 300 species of fruits are grown in India, more than 75 percent of total area under fruit cultivation is occupied by mango, banana, citrus, guava, grape, pineapple, papaya, sapota, litchi and apple (Mitra et al., 2010). India is home to a number of fruit species of global importance including mango, banana, citrus (Table 1). The North Eastern (NE) region of the country, in particular, is endowed with a tremendous diversity of banana and citrus and a number of wild/minor species (Table 2). Several fruits such as *bael*, jack fruit, *karonda*, *lasoda* and *phalsa* exist in the wild or at local markets. The increasing health awareness makes these fruits becoming popular in large cities and are thus available in super markets. Promotion of these fruits can help in achieving nutritional security in diverse agro-climatic regions.

4 Status of fruit production in India

The context of horticulture in India is rapidly changing with changing lifestyle and health awareness. Horticulture generates about 24.5% of the agricultural GDP (See Glossary) from only about 16% of the total cultivated area. In the past two decades, the area and production of horticultural crops have increased from 12.8 to 25.4 million hectares; and from 95.6 to 311.7 million tons, respectively (Anonymous, 2018b). This results in part from a united approach of policy planners and researchers along with specialised organisations (e.g., NHB, ICAR, APEDA (See Glossary) and Agricultural Universities; Table 3). The availability of improved varieties and technologies is one of the reasons of this expansion (Fig. 1). India is proud to be the second largest producer of fruits and vegetables in the world, with a significant Indian presence in the global market (Table 4). The main fruits grown in India are mango (35.4% of total area under fruits), citrus (15.6%) and banana (13.5%) followed by other fruits such as apple, guava, pomegranate, grape, jackfruit, pineapple, papaya, sapota, *aonla* and others. India ranks first in the production of banana, mango and papaya in the world (Table 4). A number of new fruits such as kiwi, dragon fruit, blueberry, avocado, persimmon etc. have been introduced, becoming an integral part of the Indian fruit basket. Many fruits are exported to different countries, including grape, banana and mango.

Table 1 Fruit crops native to India

Sl. No	Common/ Vernacular name	Scientific name
1	*Amra*	*Spondias pinnata*
2	*Aonla* or Indian gooseberry	*Emblica officinalis*
3	*Bael*	*Aegle marmelos*
4	Banana	*Musa* spp.
5	*Ber*/ Indian jujube	*Zizyphus mauritiana*
6	Carambola	*Averrhoa carambola*
7	Citrus	*Citrus* spp.
8	Custard apple	*Annona squamosa*
9	Elephant apple/ *Chalta*	*Dillenia indica*
10	Fig	*Ficus carica*
11	Jackfruit	*Artocarpus heterophyllus*
12	*Jalpai*/ Indian olive	*Elaeocarpus floribundus*
13	*Jamun*	*Syzygium cuminii*
14	*Jumrool/Jamrul/Amrool*	*Syzygium samarangense (syn. Eugenia javanica)*
15	*Karonda*	*Carissa carandas*
16	*Khirni*	*Manilkara hexandra*
17	*Kokum*	*Garcinia indica*
18	*Lasoda*	*Cordia myxa*
19	*Latka*/ Burmese grape	*Baccaurea sapida*
20	Mango	*Mangifera indica*
21	Passion fruit	*Passiflora edulis*
22	*Phalsa*	*Grewia asiatica (syn. Grewia subinaequalis)*
23	*Sat Kara*/ *Kafir* lime	*Citrus hystrix*
24	Star *Aonla*	*Phyllanthus acidus*
25	*Tal*/ Palmyrah	*Borassus flabellifer*
26	Tamarind/ *Imli*	*Tamarindus indica*
27	Wood apple/*Kath Bael*	*Feronia limonia*

Source: Singh, 1969; Bose et al., 2001

5 Global genebanks for conservation of fruit genetic resources

Despite the existence of 1750 individual genebanks worldwide (FAO, 2010), very few are dedicated to the conservation of FGR (See Glossary). Storage of FGR seeds is difficult. Moreover, because most the fruit crops are cross pollinated, conservation of *true- to-the- type* genotype is possible only through vegetative propagule i.e. either in field genebanks or in vitro—derived shoot-tips and dormant buds conserved using cryopreservation. Throughout the world, conservation of FGR is mostly carried out as field collections (> 80%). Major genebanks involved in conservation of fruit germplasm include 11 USDA (See Glossary) repositories devoted to clonally propagated horticultural fruit and nut crops; APGRC (See Glossary), Sudan; ITC (See Glossary), Belgium; CePaCT (See Glossary), Fiji; EMBRAPA-CNPMF (See Glossary), Brazil; Seed Savers Exchange, USA; EURISCO (See Glossary); GFG (See Glossary), Germany; NARO (See Glossary), Japan etc.

Table 2 Wild species of different fruit crops prevalent in India

Genus	Wild species	Area(s) of diversity
Mangifera	*M. sylvatica*	Andaman Islands
Musa	*M. arunachalensis*, *M. nagalandiana*, *M. kamengensis*, *M. puspanjalia*, *M. aurantiaca*, *M. manni*	North-Eastern states, Western Ghats, Eastern Ghats and the Andaman and Nicobar Islands, West Kameng District, Arunachal Pradesh, Nagaland
Citrus	*"Soh Nairiang"* a wild sweet orange, wild Indian mandarin (*C. indica* Tanaka), *C. assamensis*, *C. ichangensis* Swingle, *C. latipes* Tanaka and *C. macroptera* Mont.	Naga hills, Garo hills of Meghalaya and Kaziranga forests of Assam; NEH region
Malus	*M. baccata* (L.) Borkh., *M. baccata* var. *himalaica* (Maxim.) Schneid., *M. baccata* var. *dirangensis*, *M. sikkimensis* (Wenz.) Koehne ex Schneider	North-Western and Eastern Himalayan regions
Pyrus	*P. griffithi* Decne., *P. jacquemontiana* Decne., *P. khasiana* Decne., *P. pashia* Buch. & Ham. ex D. Don, *P. kumaonii* (Decne.) Stapf., *P. polycarpa* Hook. f., *P. pyrifolia* (Burm. f.) *Nakai* var. *culta* (Makino) *Nakai*, *P. serotina* Rehd., *P. thomsoni* King	North-Western and Eastern Himalayan regions
Sorbus	*S. aucuparia* L., *S. cuspidata* (Spach.) Hedlund., *S. foliolosa* (Wallich.) Spach., *S. granulosa* (Bertol.) Rehd., *S. insignis* (Hook. f.) Hedlund, *S. lanata* (D. Don) Schner., *S. microphylla* Wenzi g, *S. rhamnoides* (Decne.) Rehder	North-Western and Eastern Himalayan regions
Cotoneaster	*C. acuminata* Lindl., *C. acuminatus* Lindl., *C. bacillaris* Wallich ex Lindl., *C. buxifolia* Wall., *C. falconeri* Klotz., *C. frigida* Wall., *C. microphylla* Wall. ex Lindl., *C. multiflora* Bunge., *C. nummularia* Fish. & Mey., *C. roseus* Edgew., *C. rotundifolia* Moench., *C. vulgaris* Lindl	North-Western and Eastern Himalayan regions
Docynia	*D. hookeriana* Decne., *D. indica* Decne	North-Western and Eastern Himalayan regions
Pyracantha	*P. crenulata* Roem	North-Western and Eastern Himalayan regions
Prunus	*P. cerasoides*, *P. armeniaca*, *P. persica*, *P. cornuta*, *P. salicina*, *P. nepalensis*, *P. wallichi*, *P. jacquemontii*, *P. mira*	North-Western and Eastern Himalayan regions, Shillong plateau of Khasi hills in Meghalaya
Ribes	*R. alpestre*, *R. glaciate*, *R. griffithii*, *R. nigrum*, *R. rubrum*	North-Western and Eastern Himalayan regions
Rubus	*R. ellipticus*, *R. foliosus*, *R. fruiticosus*, *R. lasiocarpus*, *R. nepalensis*, *R. niveus*, *R. paniculatus*, *R. purpureus*, *R. hexagynus*, *R. ferox*, *R. calycinus*, *R. pungens*, *R. rosaefolius*, *R. saxatilis*, *R. macilentus*, *R. acuminatus*	North-Western and Eastern Himalayan regions
Vitis	*V. himalayana*, *V. lanata*, *V. latifolia, V. parvifolia*	North-Western and Eastern Himalayan regions
Fragaria	*F. nubicola*, *F. indica*	North-Western and Eastern Himalayan regions
Hippophae	*H. rhamnoides*, *H. salicifolia*, *H. tibetana*	North-Western and Eastern Himalayan regions
Viburnum	*V. corylifolium*, *V. cotinifolium*, *V. grandiflorum*, *V. jacquemontii*, *V. mullaha*	North-Western and Eastern Himalayan regions
Carissa	*C. congesta*, *C. grandiflora*, *C. spinarum*	North-Western and Eastern Himalayan regions
Elaeagnus	*E. angustifolia* L., *E. latifolia* L., *E. umbellata* Thumb	North-Western and Eastern Himalayan regions
Diospyros	*D. kaki*, *D. lotus*	North-Western and Eastern Himalayan regions
Corylus	*C. colurna*, *C. ferox*	North-Western and Eastern Himalayan regions
Viburnum	*V. corylifolium Hook. f., V. cotinifolium D. Don, V. grandiflorum Wall., V. jacquemontii Planch., V. mullaha Buch.-Ham.ex D.Don*	North-Western and Eastern Himalayan regions

Source: Sharma et al., 2005; Verma et al., 2006; Hellin & Higman, 2009; Diengngan & Hasan, 2015; Mitra et al., 2010

6 Conservation of fruit genetic resources in India

FGR (See Glossary) in India is conserved through a combined in situ approach, where the genetic resources are conserved in their natural habitat, e.g. gene sanctuary with an ex situ approach, which involves storing the seeds at 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. India has setup its first gene sanctuary in the Garo Hills of Assam for wild relatives of citrus. Efforts are also being made to set up gene sanctuaries for banana and mango. The ICAR-IARI, ICAR-IIHR, ICAR-CITH, ICAR-CISH, ICAR-CIAH (See Glossary) and other crop-based institutes (See Table 6) are the primary institutes

Table 3 List of organisations involved in research and development of horticulture in India

Acronym	Full name	Mandate
MoAFW	Ministry of Agriculture & Farmers Welfare, Government of India	MoAFW is the apex body for formulation and administration of the rules and regulations and laws related to agriculture in India. It consists of two departments: Department of Agriculture, Co-operation and Farmers Welfare (DACFW) and Department of Agriculture Research and Education (DARE)
ICAR	Indian Council of Agricultural Research	ICAR is an autonomous organization under DARE, MoAFW, Government of India. The council is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences with 101 ICAR institutes and 71 agricultural universities spread across the country
APEDA	Agricultural and Processed Food Products Export Development Authority	It is an apex body that promotes export trade of agricultural products in India
NHB	National Horticulture Board	The main objectives of the NHB are to improve integrated development of horticulture industry and to help in coordinating, sustaining the production and processing of fruits and vegetables
ATARI	Agricultural Technology Application Research Institute	Coordination and monitoring of technology application and Frontline Extension Education Programmes. Strengthening Agricultural Extension Research and Knowledge Management

involved in introduction and utilisation of fruit germplasm. In India ICAR-NBPGR (See Glossary) works along with its 7 regional stations and 10 National Active Germplasm Sites, which are designated field gene banks for introduction, evaluation, maintenance, and exchange of germplasm of specific crops with ICAR-NBPGR, New Delhi as the Nodal Agency (See Table 6). In vitro conservation and cryopreservation of vegetatively propagated species and prioritized tropical and temperate fruit crops in India is being carried out in multi-crop in vitro repository at TCCU (See Glossary), ICAR-NBPGR, New Delhi, which maintains about 400 accessions of *Musa* spp. and 300 accessions of temperate and minor fruits in its in vitro repository. Cryopreservation protocols are routinely developed for *Malus* spp., *Morus* spp., *Musa* spp., *Pyrus communis* and *Rubus* spp. Dormant-buds are one of the best explants for cryobanking of *true-to-the-type* cultivars of temperate fruits.

Table 4 India's position in world fruit production scenario

Crop	Area (m ha)	Production (m t)	Productivity (t/ ha)
Total fruits	2nd (6.50)	2nd (97.39)	2nd (14.96)
Apple	2nd (0.30)	5th (2.30)	9th (7.66)
Banana	1st (0.88)	1st (30.80)	4th (35.00)
Grape	10th (0.14)	7th (2.92)	1st (20.85)
Mango	1st (2.25)	1st (21.82)	5th (9.69)
Citrus	2nd (0.14)	3rd (12.54)	9th (89.57)
Papaya	1st (0.14)	1st (5.98)	6th (42.71)
Pineapple	2nd (0.10)	5th (1.70)	10th (17.00)

Source: APEDA, 2020; Anonymous, 2018b

7 Domestication/introduction of fruit crops in India: historical perspective

Shruti, Smriti and *Samhita* of the Vedic age bear clear testimony to the fact that the inhabitants of the towns of Mohanjodaro and Harappa used to cultivate fruits. Earthen vases shaped as pomegranate and coconut; and pendant shaped as lemon leaf suggest their presence in Harappa (Vats, 1940). The date is perhaps the oldest fruit known to ancient Indians (Hutchinson, 1974). The *Vriksh* Ayurveda, written by Kautilya in 300 B.C is one of the oldest known texts on fruit cultivation (www.shodhganga.inflibnet.ac.in). Medicinal uses of fruits such as *aonla* (*Emblica officinale*), *bael* (*Aegle marmelos* (L.) Corrêa), citrus, grape, hog plum, jackfruit, wild fig, monkey jack, *jamun* (*Syzygium cuminii* L.), *ber* (*Zizyphus mauritiana*), *karonda* (*Carissa carandas*), *khirni* (*Manilkara hexandra*), lemon, lime, mango, mulberry, orange, *phalsa* (*Grewia asiatica*), banana, pomegranate, wood apple etc. have been mentioned in *Charaka Samhita* and *Sushrut Samhita* (Chadha & Pareekh, 1993). References regarding *bael* is abundantly seen in *Yajurveda*, *Atharvaveda*, *Brahmanas*, *Kalpasutras* and *Puranas*; mangoes and date palms in the '*Ramayana'* and the *'Mahabharata'* (Shah, 2014; Singh, 1969). Hiuen Tsiang, the Chinese Budhist pilgrim, who came to India in 629 AD, noted the presence of mango, pomegranate and sweet orange everywhere (Singh, 1969).

Many new fruits were introduced through Mughals, Portuguese, Spanish, French and Dutch (Table 5). Sultan Zain-ul-Abidin "Budshah" (1420–1470) imported many fruit crops from Central Asia. The sixteenth century was

Table 5 List of fruit crops domesticated/introduced in India

Common name	Latin name	Period of introduction	Entity or actor of the introduction/domestication	Reference(s)
Almond	*Prunus dulcis* (Mill.) D.A. Webb	sixteenth century	Persians	Ahmed and Verma (2009)
Apple	*Malus domestica* (Suckow) Borkh	nineteenth century	Britishers	Chadha and Patel (2005)
Annonas	*Annona* spp.	1590	Portuguese	Rajput (1985)
Arabian date palms	*Phoenix dactylifera* L.	early eighth century	at the time of the first Muslim invasion	Blatter (1926); Cooke (1908)
Avocado	*Persea americana* Mill.	1914	Lal Bagh Gardens, Bengaluru by American Missionary from Sri Lanka	Swamy (1967)
Black currant	*Ribes nigrum* L.	nineteenth century	Royal Agri-Horticultural Society, Kolkata	Randhawa (1982)
Blueberries	*Vaccinum* sp.	2006–07	Shimla Hills by ICAR-NBPGR RS, Shimla	www.tribuneindia.com
Cashew	*Anacardium occidentale* L.	16thcentury	Portuguese	Chadha & Patel, 2005
Custard apple	*Annona reticulata* L.	16thcentury	Portuguese	Verkataratanam and Satyanaranaswamy (1956)
Dragon fruit	*Selenicereus undatus* (Haw.) D.R. Hunt	1990s	-	Arivalagan et al. (2019)
Gooseberry	*Ribes uva-crispa* L.	nineteenth century	Royal Agri-Horticultural Society, Kolkata	Randhawa (1982)
Grape	*Vitis vinifera* L.	620 BC, 1300 AD	Not reported; subsequently by invaders from Persia and Afghanistan	Olmo (1976); Chadha and Pareek (1993)
Guava	*Psidium guajava* L.	seventeenth century	Portuguese settlers on Western Ghat regions	Dinesh and Vasugi (2010)
Kiwi fruit	*Actinidia chinensis* Planch.	1963	Plant Introduction Station	Pandey and Tripathi (2014)
Litchi	*Litchi chinensis* Sonn.	seventeenth century	Budhist Monks	Goto (1960); Knight (1980); Liang (1981)
Longan	*Dimocarpus longan* Lour.	18th Century	-	Nath et al. (2018)
Macadamia nut	*Macadamia integrifolia*	1980s	ICAR-NBPGR, New Delhi	Pradhan (2010)
Mangosteen	*Garcinia mangostana* L.	nineteenth century	Royal Agri-Horticultural Society, Kolkata	Randhawa (1982)
Malayan apple	*Syzygium malaccense*	16th Century	Portuguese in Goa region	Zich et al. (2020)
Monk fruit	*Siraitia grosvenorii* (Swingle) C. Jeffrey ex A.M.Lu & Zhi Y. Zhang	2018	ICAR-NBPGR, New Delhi	Shivani et al. (2021)
Papaya	*Carica papaya* L.	sixteenth century (1550)	Spanish	Singh (1969)
Passion fruit	*Passiflora edulis Sims*	early 1910s	British in Nilgiris, Coorg and Malabar regions	Tripathi (2018)
Persimmon	*Diospyros kaki* L.f	early twentieth century (1921)	European settlers	Thakur and Kashyap (2005)
Pineapple	*Ananas comosus* (L.) Merr.	sixteenth century (1548)	Portuguese	Collingham (2007)
Pineapple guava	*Feijoa sellowiana* (O. Berg) O. Berg	1950s	Plant Introduction Division, IARI	Bose et al., (2001)
Pomegranate	*Punica granatum* L.	first century AD	Mohanjodaro Civilization (Aryans)	Morton (1987)
Rambutan	*Nephelium lappaceum*	1950s	Amateur fruit growers of Kerala	Tripathi et al. (2020)

Table 5 (continued)

Common name	Latin name	Period of introduction	Entity or actor of the introduction/domestication	Reference(s)
Sapota	*Manilkara zapota* (L.) P. Royen	nineteenth century	Portuguese	Bhaskar et al. (2020)
Strawberry	*Fragaria × ananassa* (Duchesne ex Weston)	1815	Royal Botanic Garden, Kolkata	Randhawa (1982)
Wax apple	*Syzygium samarangense*	early twentieth century	Amateur fruit growers of Kerala, Karnataka and Tamil Nadu	Tripathi et al. (2019)
White currant	*Ribes rubrum* L.	nineteenth century	Agri-Horticultural Society, Kolkata	Randhawa (1982)

remarkable for plant introduction. The earliest in-depth description of mango, pineapple and custard apple are recorded in *Ain-i-Akbari*, an encyclopaedia written in 1590 AD (Chadha & Pareek, 1993; Rajan & Hudedamani, 2019). Mughal emperor Akbar who ruled northern India from 1556 to 1605 planted an orchard of hundred thousand mango trees near Darbhanga the *Lakhi Bagh* (Mehta, 2017) and many of these trees were found to be vigorous even 300 years later. Vavilov (1926) suggested that the Indo-Myanmar region was the centre of origin of mango based on the observed level of genetic diversity. Scientists of BSIP (See Glossary), Lucknow, have traced the origin of genus *Mangifera* from 60- million- year old fossil leaf imprints in the Palaeocene sediments near Damalgiri, West Garo Hills, Meghalaya (Mehrotra et al., 1998).

The period of British colonization (AD 1757—AD 1947) in India is also replete of references to fruits. This is the period when many exotic fruits such as apple, pear, grapes, strawberry were introduced/popularised (Table 5). Lord Auckland, Governor General during 1836–42, is said to have grown the first modern strawberries in India, but others were also trying across the subcontinent. Mr W.G. McIvor, began large scale cultivation of fruit plants in South India in 1855 and by 1859, he claimed to have 178 species and varieties, most of which were imported from England (Krishnamurthi, 1953). Apples were introduced by the Europeans in Ootacamund (Nilgris, Tamil Nadu) in 1850s. Captain R.C. Lee, Mr. Wilson, M. Ermens, Alexander Coutts, and M. Pychard are the pioneer in introducing apple to different parts of India. However, commercial apple production was given an impetus by Satya Nand (Samuel Nicholas) Stokes, who introduced 'Delicious' group of apples in the first quarter of the twentieth century at Kotgarh, Shimla Hills. Though Muhammed Bin Tughlaq introduced the grape cultivars Bhokri, Fakhri and Sahebi in Aurangabad (Daulatabad) as early as 1338, Punjab was perhaps the first state to engage into large-scale introduction and trials for testing the adaptability of grape varieties. The work though started at Lyallpur (now in West Pakistan) during 1928, the work initiated by Dr G.S. Randhawa and his co-workers during late fifties enriched the Indian grape germplasm wealth at IARI.

In the beginning of the twentieth century, emphasis was placed on the introduction of horticultural crops. In the 1950s the British introduced the green English and the coloured delicious varieties of apple (Singh et al., 2006). Research on temperate fruits was strengthened by the establishment of several research stations. Kiwi fruit or Chinese gooseberry was introduced in India in 1960 at Lal Bagh Gardens, Bengaluru, in 1960 and later in 1963 at the Phagli station of ICAR-NBPGR from the USA. The Kinnow mandarin was introduced from the USA by Dr J.C. Bakhshi (Gill & Mahindra, 2010) which became one of the most promising introductions in India.

8 Set-up of a single window system for exchange of plant genetic resources in India

Although exchange of germplasm has been a part of fruit research in India for a very long time, systematic efforts on germplasm diversity started after the establishment of the Botany Division of the Imperial Agricultural Research Institute in 1905. Further research was strengthened with the opening of a specific Plant Introduction Station in the Division of Botany at ICAR-IARI in 1946. In 1956, the Plant Introduction and Exploration Organisation (Botany Division, ICAR-IARI) was operational. An independent "Plant Introduction Division" was created at ICAR-IARI in 1961 followed by National Bureau of Plant Introduction in 1976 which was later renamed as National Bureau of Plant Genetic Resources in 1977.

Since 1976, the ICAR-NBPGR looks after the activities of germplasm exchange for research purpose within country as well as internationally. Since the late 1970s, the planned introduction of fruit germplasm has been undertaken through ICAR-NBPGR under a specific set of procedures. ICAR-NBPGR has enabled the introduction of 9684 accessions/varieties of fruit crops from over 40 countries under strict phytosanitary conditions. Some of the notable trait specific introductions made during the last 25 years are presented in Table 7.

ICAR-NBPGR has facilitated the import of germplasm of several new crops to the fruit basket of India (See Table 7). Crops such as blueberry, longan, mangosteen, rambutan, avocado, persimmon, macadamia nut, pineapple guava, opuntia pear, and others are being adapted and are awaiting commercialisation. Dragon fruit (*Selenicereus undatus*), dubbed "The Wonderous Fruit of the Twenty-First Century," was first introduced in India in the late 1990s (Arivalagan et al., 2019) and was reintroduced in 2014 through ICAR-NBPGR. Monk fruit (*Siraitia grosvenorii*), a potential crop for use as a natural sweetener, was introduced by ICAR-NBPGR in 2011, and again in 2018 and it is now well established under the Palampur conditions (Shivani et al., 2021).

9 Usage of exotic germplasm in crop improvement

Introduction is perhaps the easiest way to enhance crops with new alleles from exotic sources and wild species through introgression or incorporation. Introgression involves backcrossing a few chromosome segments with easily identifiable effects (often disease resistances) into elite cultivars; whereas, incorporation aims to produce new breeding populations that have very high proportions of unique, exotic-derived alleles in order to broaden substantially the crop's genetic base (Simmond, 1993).

9.1 Selection and release as variety

When a new germplasm is introduced, it is tested, and if well adapted and found suitable, it is directly released to farmers' access. This is known as Primary introduction. Some of the outstanding introductions in fruit crops directly released as variety (See Table 8) or released after evaluation and selection (See Table 9) are presented in tabular form. Because most fruit crops are perennial, exotic introductions have been and will continue to be preferred over selection and hybridisation programmes. Farmers are given new opportunities to grow a new crop/variety with increased market potential in this manner. Farmers have developed a number of grape varieties by selecting from exotic germplasm (See Table 9).

9.2 Hybridisation for specific traits

Exotic germplasm in fruit crops is best utilised by breeders through hybridisation followed by selection. Over 60 varieties have been released (See Table 10). The extent of reliance on exotic sources varies from crop to crop. Most of the commercial cultivars of apple, pear, cherry, plum, peach, apricot, persimmon and strawberry are of exotic origin; whereas some cultivars of walnut, sand pear and almond are selections from indigenous germplasm. However, in indigenous crops such as mango, banana, jackfruit, the reliance on foreign germplasm is lower; most of the cultivars are of indigenous origin. In citrus and banana, a number of interspecific hybrids have been developed using various exotic species.

10 Impact of exotic fruit germplasm on fruit production in India

In the 1960s, eating fruits was a status symbol; even a middle class family could not afford much fruits due to very low *per capita* access, *i.e.* 82 g/day (Fig. 1). Only mango, banana, citrus and minor fruits such as *bael*, *aonla* and *karonda* were available in the market for common people. Fruits such as apple and pomegranate were used only for sickness treatments. The growth of horticulture sector resulting from improved varieties and innovative technologies and their large scale adoption made India a leader in fruit production with per capita availability reaching 200 g/day (Fig. 1). The significant rise in productivity results from the continuous improvement work conducted by various institutions and farmers' adoption. Introduction of promising germplasm has played a significant role in crafting the current horticulture industry.

A good example of introduction is that of the dragon fruit, which was imported from Vietnam and Thailand and which used to be very costly in India. The introduction and adaptation of this crop in the North-East region of India and Maharashtra will make it affordable in large quantities. The examples of kiwi fruit and strawberry are similar. India has witnessed a sharp increase in area and production of banana, apple, grape, papaya and pineapple since the last 57 years (Figs. 2, 3, 4, 5, 6). Germplasm imported from other countries certainly has played an important role in this result. With the introduction of spur type and other coloured strains, apple production in Himachal Pradesh has increased dramatically with a high benefit-cost ratio (Fig. 7).

11 Diffusion and outflow of Indian fruit germplasm around the world: a historical perspective

India has shared its fruit diversity with other parts of the world since time immemorial. Mango and banana are few of the most important examples of outflow of germplasm from India to other parts of the world. The Chinese traveller Hiuen Tsang, who visited India between 632–645 AD, was the first to bring

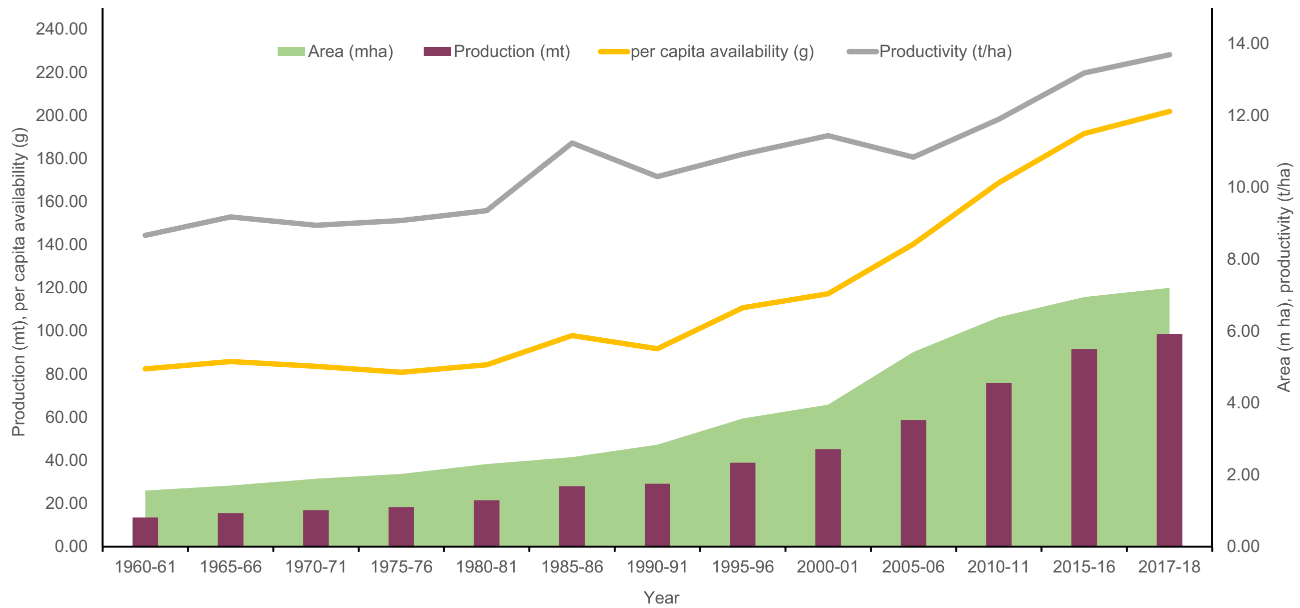

Fig. 1 Area, production and productivity and per capita availability trends of fruits in India in last five decades (Source: constructed by the authors from FAOSTAT, accessed on 02/11/2020)

mango to the notice of the outside world (Rajan & Hudedamani, 2019). Today mango is relished throughout the world and may be considered as one of the choicest Indian gifts to the world. It is believed that King Rana Bahadur Shah established a well-designed garden at *Sera Phant* (*Sera Bagaincha*) of Nuwakot focusing mango orchard for the first time in Nepal (Gotame et al., 2020). The earliest cultivation of banana is reported from India (Reynolds, 1951), however, it was Alexander's delectable dessert in 327 B.C. during his invasion of India that led to the fruit's widespread migration (www.news.un.org/en/story/2006/05/177262). Banana travelled from India to the Middle East, where it acquired its current name from the Arabic banan, or

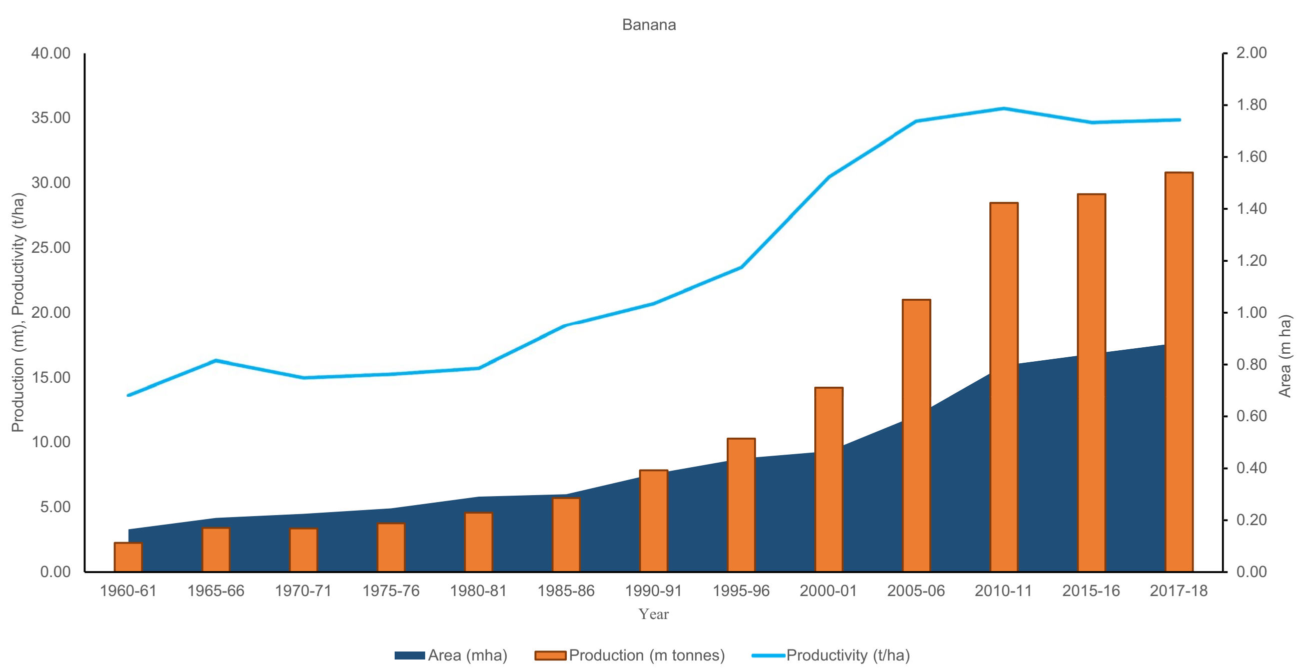

Fig. 2 Area, production and productivity trends of banana in India in last five decades (Source: constructed by the authors from FAOSTAT, accessed on 02/11/2020)

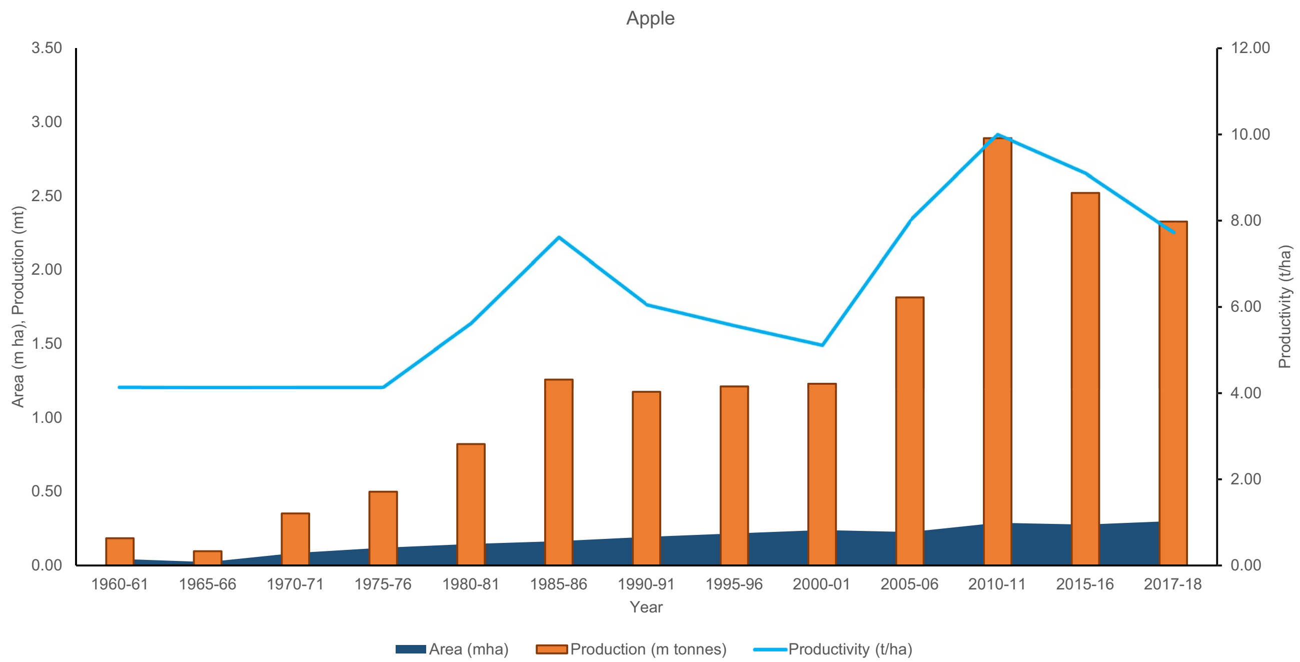

Fig. 3 Area, production and productivity trends of apple in India in last five decades (Source: constructed by the authors from FAOSTAT, accessed on 02/11/2020)

finger, and from there Arab traders took it to Africa, where the Portuguese transported it to the Caribbean islands and Latin American countries (Reynolds, 1951).

Although exchanges through travellers or pilgrims have historically been common practice, controlled exchanges started with the inception of ICAR-NBPGR under a set procedure for research use. Since 1976, a total of 937 accessions/varieties of fruit crops were exported to numerous countries (Gautam et al., 2000; Anonymous, 1995, 1996, 1997, 2000, 2001, 2002, 2003, 2004, 2010, 2012, 2015, 2017).

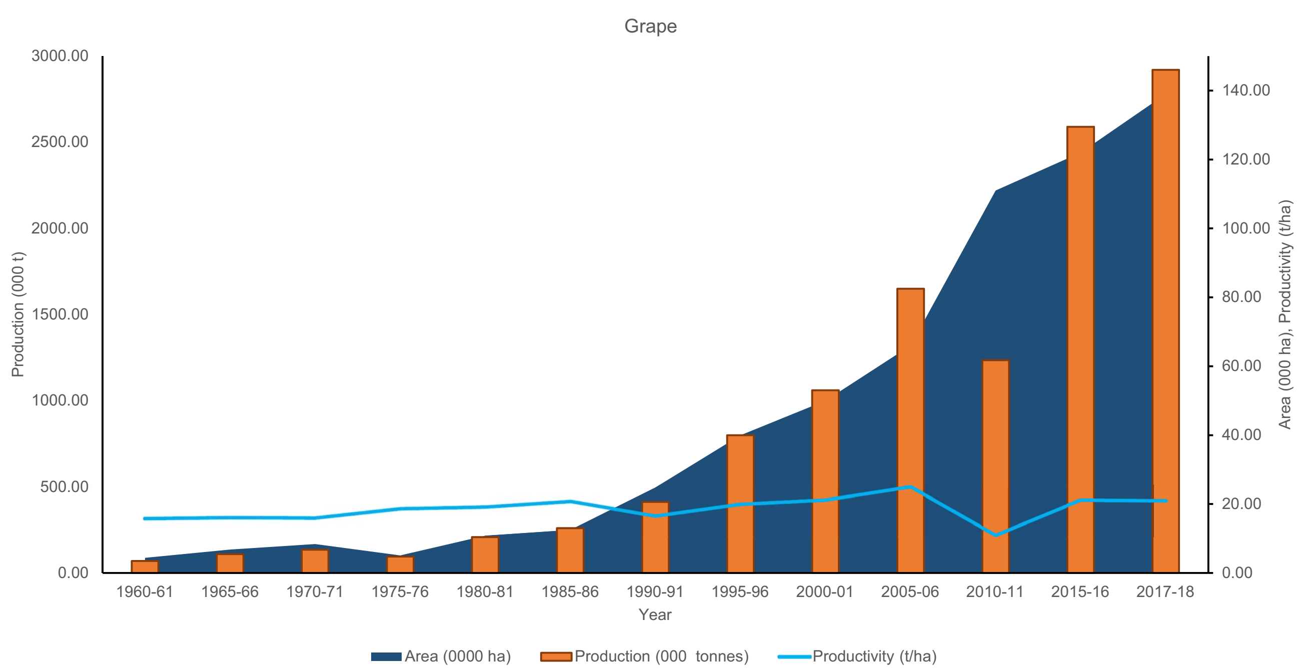

Fig. 4 Area, production and productivity trends of grapes in India in last five decades (Source: constructed by the authors from FAOSTAT, accessed on 02/11/2020)

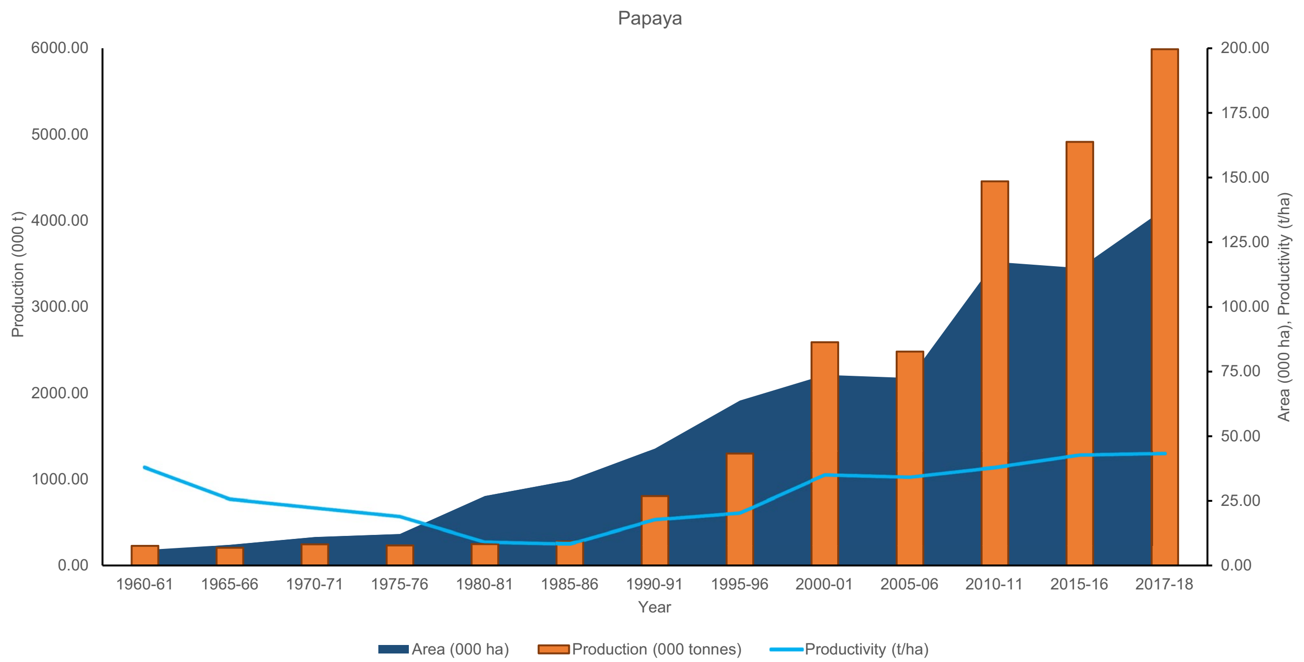

Fig. 5 Area, production and productivity trends of papaya in India in last five decades (Source: constructed by the authors from FAOSTAT, accessed on 02/11/2020)

12 Usage and impact of Indian germplasm around the world

The Indian FGR (See Glossary) are being utilised in numerous countries either directly as a variety or as parents in hybridisation programme. Some of the important fruit germplasm from India being maintained or utilised in breeding programmes worldwide are presented in Table 11. The Indian subcontinent has made an enormous contribution to the global genetic base of mangoes and bananas. The impact of Indian mango 'Mulgoba' in Florida mango industry is a good example. Indian mango varieties are very well placed in the commercial growing of several countries. Out of the 260 mango varieties reported in Pakistan, 10 Indian varieties are reported to be commercially

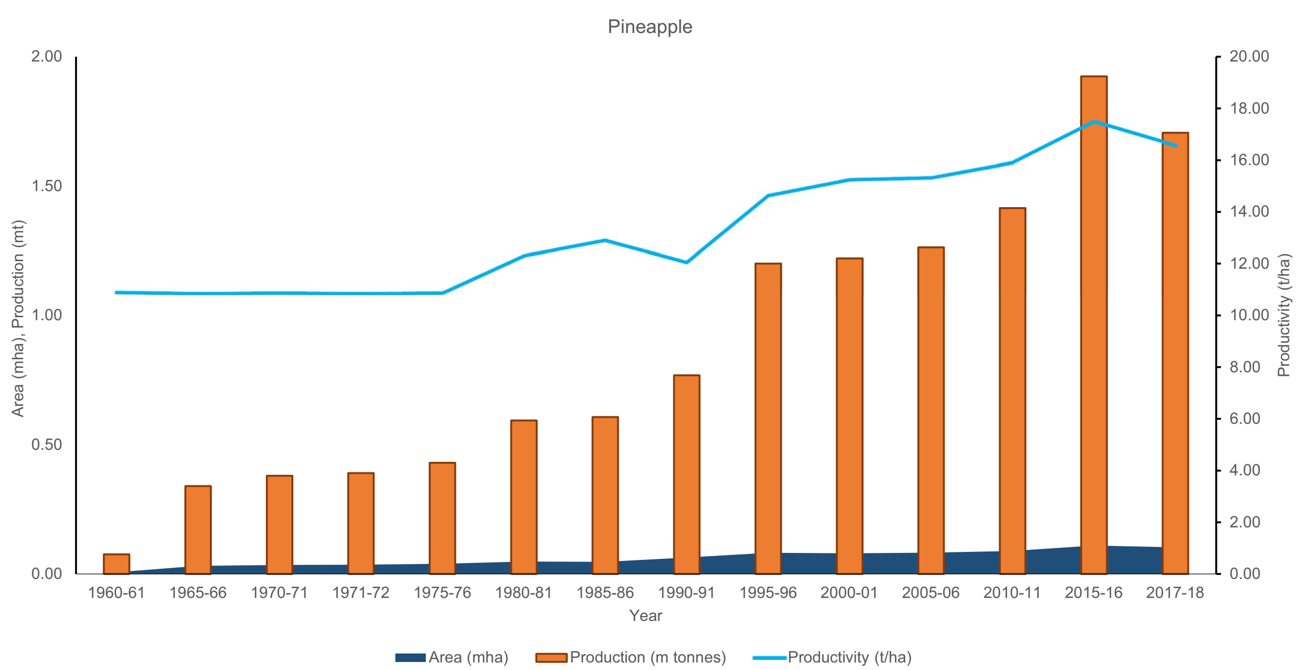

Fig. 6 Area, production and productivity trends of pineapple in India in last five decades (Source: constructed by the authors from FAOSTAT, accessed on 02/11/2020)

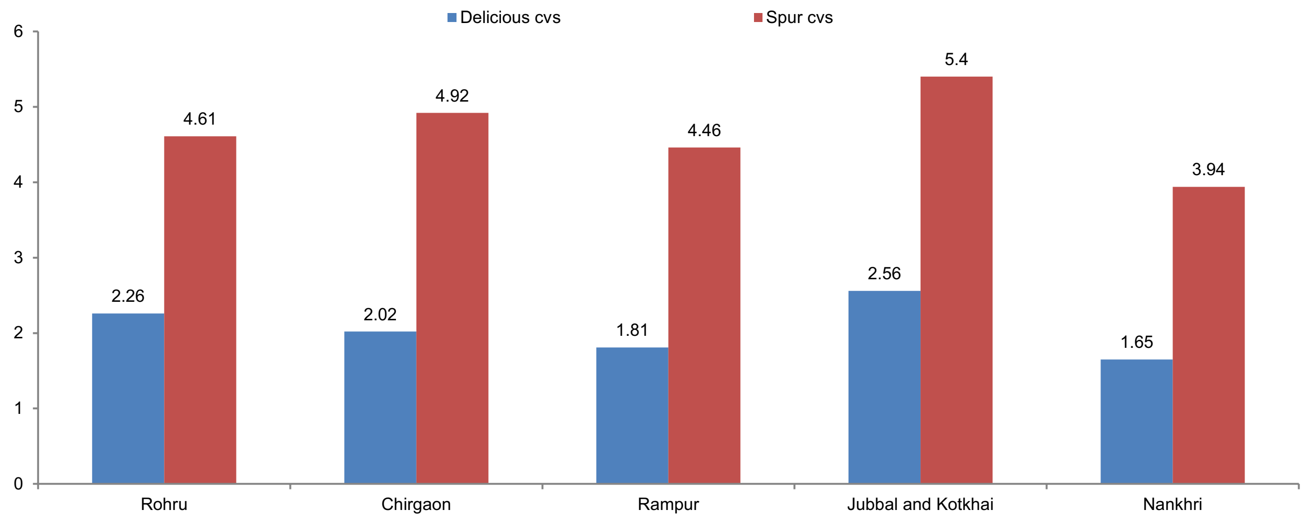

Fig. 7 Benefit: Cost ratio of spur type and delicious cultivars of apple growing in different blocks of Shimla (Source: ICAR-ATARI, Ludhiana, 2019)

important (Amin & Hanif, 2002), with three Indian varieties being the leading export varieties (Nafees et al., 2013). Eight Indian varieties are commercially grown in Bangladesh and 7 in Egypt (See Table 11). Five mango varieties in Brazil and 6 in USA have been released utilising Indian mango germplasm (See Table 12).

Most of the cultivars of tropical fruits grown in Nepal are introduced from India. A number of accessions/varieties of citrus, *aonla*, apple and kiwi fruit were supplied from India and being maintained in Nepal (Gautam & Gotame, 2020). Indian papaya varieties Pusa Dwarf and Farm Selection-1 are reported to be the most preferred genotypes in Nepal (Chaudhary et al., 2012). Farmers are particularly interested in Indian and Thai varieties that produce very large and tasty fruits (Kalinganire et al., 2008; Kone et al., 2009).

13 Challenges of germplasm exchange and utilisation

There are several challenges in sharing germplasm beyond boundaries and in their proper and effective utilisation. Some of these are discussed below.

13.1 Perishable nature of planting material and maladaptation

Except for few fruits such as papaya, citrus rootstock, and macadamia nut, which are propagated through seeds, the majority of fruits are propagated through bud woods, cuttings, and tissue cultured plantlets. These require special handling and maintenance. Furthermore, the introduced germplasm often fails to establish and adapt in new environment due to maladaptation. As a result, a single variety/genotype often needs to be reintroduced several times for its successful introduction.

13.2 Introduction of invasive pests and diseases

The introduction of new genetic material is frequently associated with the risk of introducing exotic pests and diseases. A slew of new diseases and pests have emerged over the years, wreaking havoc (See Table 13). The quarantine examination ensures that no pests or diseases escape when introductions concern small samples and introductions for research purposes; however, commercial imports of fruit crops in large quantities pose a risk of such escape. Furthermore, online web sites and large-scale business nurseries that are importing large number of exotic planting material and are selling plant material directly to growers represent possible route for the introduction of pathogens and pests. One famous example is the spread of *Phylloxera*, when a North American aphid was accidentally introduced into continental Europe around 1865 and devastated much of Europe's grape-growing regions. This led to the establishment of first international plant protection convention, namely *Phylloxera* Convention signed by five countries in 1881.

13.3 Challenges of regulatory mechanism

The complex web of MTAs (See Glossary), licences, contracts, patents, and phytosanitary restrictions that surround the exchange of plant germplasm today restrain exchanges among plant breeders and farmers worldwide (Luby et al., 2015). Most elite material is now proprietary, limiting plant breeders' access to diverse cultivars and the traits they contain, impacting exchange of germplasm, thus affect development of new cultivars. Over the last decade, India has gradually replaced licencing and discretionary import controls with deregulation and simplified import procedures. Most import items are subject to India's EXIM (See Glossary) Policy regulation of Open General License, which states that they are freely importable without restrictions or a licence, except to the extent that they are regulated by existing policy's provisions or any other law.

14 Strengthening international exchange of fruit germplasm

The access and use of FGR (See Glossary) worldwide need to be strengthened to contribute more to global food and nutritional security. This is discussed below.

14.1 National and international agreements

International agreements have facilitated international exchanges of germplasm. India has ratified all three treaties (CBD, ITPGRFA and NP) and also enacted its own Biological Diversity Act (BDA), in 2002 that governs the ABS (See Glossary) mechanisms of genetic resources held within its political boundaries. The NBA (See Glossary) serves as the nodal body for granting permission to foreign researchers for use of Indian biological resources. CBD's 196 members exchange germplasm in a bilateral or reciprocal exchange. ICAR-NBPGR being the nodal agency for the management and exchange of PGR (See Glossary) for research purposes in India, coordinates the supply of PGRFA (See Glossary) of Annex 1 crops including fruit crops such as *Artocarpus* (breadfruit), *Citrus*, coconut, strawberry, apple, banana/ plantain and their facilitated exchange for research, breeding and training purposes under the conditions of an SMTA (See Glossary).

14.2 Adoption of biosafety protocols

The adoption of biosafety protocols such as the SPS Agreement formulated under IPPC (See Glossary) facilitates the global movement of plants and plant materials and encourages WTO (See Glossary) members to base their phytosanitary measures on IPPC standards. The Cartagena Protocol on Biosafety, a supplementary agreement to the CBD (See Glossary), was adopted in 2000 and is designed to protect biological diversity from potential risks posed by LMO (living modified organisms). Regulations and legislations for GMO (genetically modified organisms) vary from country to country.

14.3 Introduction & conservation of crop wild relatives

Exchange of CWRs (See Glossary) among countries will enhance the sharing of germplasm. India's wealth in wild species (Table 2), is yet to be utilised by researchers in India and in the world. Efforts have been initiated to tag the holdings of CWR (See Glossary) in national and international genebanks and prioritisation of future collection efforts (Castañeda-Álvarez et al., 2016). The Crop Trust has established pre-breeding projects to collect crop wild relatives of 29 priority crops including apple and banana among fruit crops to ensure their long-term conservation and their enhanced utilisation in breeding programs (Crop Trust, 2020).

14.4 Germplasm management using modern tools and techniques

Novel methods for linking traits to genebank accessions can enhance the efficacy of genebanks, which in turn may lead to better and more efficient trait-specific exchange of germplasm. Tools, such as the Focused Identification of Germplasm Strategy (FIGS), combine environmental and plant characteristics. This will facilitate the identification of germplasm with traits of potential interest for specific environments (Khazaei et al., 2013). New generation breeding techniques such as cisgenic and genome editing could be used for shortening the breeding period in fruit crops and also addressing the issues related with animal and plant sources of gene(s).

15 Conclusion

Enhanced utilisation and smooth flow of germplasm around the world is necessary for conservation and sustainable utilisation of genetic resources for food and nutritional security, both in India and across the world. The present germplasm flows are not restricted to their centres of diversity, but are based in international and national genebanks and breeding programs, which are based in various parts of the world. India has been and continues to be highly interconnected for germplasm share with a number of countries. In the last twenty-five years, India developed work plans for the exchange of germplasm with many institutions and countries. India is party to various treaties and these instruments facilitate better collaboration on exchanges. Addition of more crops to the list of Annex I crops may facilitate better exchange of germplasm for research use. India is looking forward for enriching its fruit basket with introductions of new crops and germplasm, which may add diversity and help to achieve food and nutritional security.

Annexures

Table 6 List of centres/institutes working on the collection, conservation and improvement of various fruit crops in India

Acronym	Full Name	Mandated fruit crop(s)
ICAR- NRCB	ICAR-National Research Centre for Banana, Trichy	*Musa* spp.
ICAR- NRCG	ICAR-National Research Centre for Grapes, Pune	*Vitis* spp.
ICAR- NRCL	ICAR- National Research Centre on Litchi, Muzaffarpur	*Litchi chinensis*
ICAR- NRCP	ICAR- National Research Centre on Pomegranate, Solapur	*Punica granatum*
ICAR-CIAH	ICAR-Central Institute for Arid Horticulture, Bikaner	Horticultural crops of Arid and semi-arid region viz., *Ziziphus* spp., *Punica granatum*, *Emblica officinalis, Phoenix dactylifera, Aegle marmelos, Opuntia ficus indica*, *Grewia subinaeqaualis*, *Ficus carica*, *Morus alba*, *Citrus sinensis*, *Carrisa congesta*, *Cordia myxa*, *Feronia limonia*, *Capparis decidua*, *Syzygium cumini*, *Mangifera indica*, *Psidium guajava*
ICAR- CISH	ICAR- Central Institute for Subtropical Horticulture, Lucknow	*Mangifera indica*, *Psidium guajava*, *Syzygium cumini*
ICAR- CITH	ICAR- Central Institute of Temperate Horticulture, Srinagar	*Malus* spp., *Cydonia oblonga*, *Prunus amygdalus*, *Prunus domestica*, *Prunus armeniaca*, *Prunus avium*, *Prunus persica var. nucipersica*, *Pyrus communis*, *Juglans* spp.
ICAR- IIHR	ICAR- Indian Institute of Horticultural Research, Bengaluru	*Mangifera indica*, *Punica granatum*, *Vitis vinifera*, *Artocarpus heterophyllus*, *Psidium guajava*, *Syzygium cumini*, *Achras sapota*, *Carica papaya*, *Annona squamosa*, *Citrus* spp., *Aegle marmelos*, *Garcinia indica*
ICAR- IARI	ICAR- Indian Agricultural Research Institute, New Delhi	*Mangifera indica*, *Vitis* spp., *Psidium guajava*, *Carica papaya*, *Citrus* spp.
ICAR- CCRI	ICAR- Central Citrus Research Institute, Nagpur	*Citrus* spp.
ICAR-NBPGR (7 regional stations)	ICAR-National Bureau of Plant Genetic Resources (RS Shimla, Bhowali, Thrissur, Jodhpur, Srinagar, Ranchi, Shillong)	*Actinidia deliciosa*, *Aegle marmelos*, *Artocarpus* spp., *Averrhoa carambola*, *Capparis decidua*, *Carissa carandas*, *Citrus* spp., *Cordia myxa*, *Cotoneaster horizontalis*, *Feijoa sellowiana*, *Ficus benjamina*, *Diospyros kaki*, *Fragaria ananassa*, *Garcinia* spp., *Juglans regia*, *Malus* spp., *Mangifera indica, Morus* spp., *Musa* spp., *Passiflora edulis*, *Phoenix dactylifera*, *Phyllanthus emblica*, *Prunus* spp., *Psidium guajava*, *Punica granatum*, *Pyrus* spp., *Rubus idaeus*, *Simmondsia chinensis*, *Syzygium cuminii*, *Tamarindus indica*, *Vitis* spp., *Zizyphus mauritiana*
AICRP-F (30 State Agricultural Universities, 14 ICAR-Institute, 4 Central Agricultural University, one private center in Pune and one under the Government of Arunachal Pradesh)	ICAR- All India Coordinated Research Project- Fruits (50 centers)	*Artocarpus heterophyllus*, *Achras sapota*, *Carica papaya*, *Citrus* spp., *Mangifera indica*, *Musa* spp., *Litchi chinensis*, *Psidium guajava*, *Vitis vinifera*

Table 7 Some of the trait specific germplasm/ varieties introduced/reintroduced in India through ICAR-NBPGR

Crop	Variety/ germplasm	Trait(s)	Reference
Almond	Ferragnes	Large size, late flowering and smooth skinned	Anonymous (2017)
	Ferralise	Large size, late flowering and smooth skinned	Anonymous (2017)
	Tardy Large	Large size, late flowering and smooth skinned	Anonymous (2017)
Apple	Red Spur, Oregon Spur, Well Spur	Early, suitable for high density planting	Gautam et al. (2000)
	Mollies Delicious	Suitable for mid hill areas	Gautam et al. (2000)
	Merton 779	Recommended as commercial rootstock for apple in Kumaon hills	Ghosh (2012)
	EMLA-111	Rootstock suitable for drought prone areas	Ghosh (2012)
	EMLA-9	Rootstock suitable for high density planting on irrigated deep soils	Ghosh (2012)
	Anna	Apple scab, powdery mildew, cedar apple rust and fire blight resistant	Ghosh (2012)
	MM-111, M-9, M-26, M-4, M-7, MM-106	Dwarfing rootstock	Ghosh (2012)
	G-41	Fire blight and *Phytophthora* resistant	Anonymous (2019)
	MM-111	Excellent anchorage, no staking required, drought tolerant, resistant to collar rot and woolly aphids and moderately resistant to fireblight	Anonymous (2019)
	EC971990-97199	Resistant to fire blight and phytophthora, resistant to collar rot, woolly aphid and drought tolerant	Anonymous (2019)
Avocado	Pollock	Low oil content	Anonymous (2009)
	Pinkerton	Excellent peeling	Anonymous (2009)
	Bacon, Zutano, Reed, Pinkerton, Duke 7, The Sharwill, Ettinger, Lam Hass, Toro canyon	Improved varieties	Anonymous (2020)
	Gwen	Dwarf variety	Anonymous (2020)
	Fuerte	Cold tolerant	Anonymous (2020)
Banana	EC160160	Resistant to bunchy top virus	Gautam et al. (2000)
	Musa textilis	Wild banana	Anonymous (2019)
	Musa jackeyi	Wild banana	Anonymous (2019)
Blueberry	EC562075-78	Firm fleshed, good flavour, vigorous, resistant to cracking, early ripening	Anonymous (2002)
Babaco (*Carica pentagona*)	EC407405	High yielding type	Anonymous (1997)
Cranberry	EC562097	Prolific bearer, good keeping quality, resistant to leaf hopper	Anonymous (2005)
	EC562086	Resistant to blunt nose leaf hopper and false blossom	Anonymous (2005)
Ficus	EC390352-59	Large fruits	Gautam et al. (2000)
	EC167661-77	Seedless type	Gautam et al. (2000)
Grape	EC873363- 75	Resistant to cracking, large clusters, hardy vine with bunch-rot disease resistance	Anonymous (2017)
	EC881483-537	Large and deep purple-red; very sweet, virtually seedless; double flowered	Anonymous (2017)
	Vitis gigas, V. caribbeana, *V. munsoniana, V. smalliana, V. cineraria*, *V. shuttleworthi*, *V. arizonica* and *V. monticola*	Resistant to biotic (downy mildew, powdery mildew and anthracnose) and abiotic (salinity, drought) stress tolerance	Singh and Rana (1993)
Grapefruit	Star Ruby	Very deep red fleshed, with red blush on fruit surface	Anonymous (2018a)
Guava	EC147033-038	Seedless	Gautam et al. (2000)
	EC256005	Very large sized fruits	Gautam et al. (2000)
	EC313012	Seedless large fruit	Gautam et al. (2000)

Table 7 (continued)

Crop	Variety/ germplasm	Trait(s)	Reference
Kiwi fruit	Bliss Yellow	Yellow flesh colour, high TSS	Anonymous (2020)
	Bliss Red	Dark yellow flesh	Anonymous (2020)
	Nugget	Flesh dark yellow with white core colour	Anonymous (2020)
	El dorado	High TSS	Anonymous (2020)
	Blade	High TSS	Anonymous (2020)
	Tomuri	Suitable as male parent	Anonymous (2020)
Macadamia nut	EC896466-78	Early, heavy bearer, anthracnose resistant, large clusters of uniform well shaped nuts	Anonymous (2017)
	EC884114	Drought resistant	Anonymous (2017)
	EC884116	Rust resistant	Anonymous (2017)
Olive	EC206629	Oil variety, small size fruit, frost resistant, very tall	Gautam et al. (2000)
	EC206630	Table variety, medium size fruit, low in oil, frost susceptible	Gautam et al. (2000)
	EC206631	Table variety, best for pickling (green table olives), very large fruit low in oil content (16–22%), frost resistant	Gautam et al. (2000)
Strawberry	Arking	Leaf spot, leaf scorch, powdery mildew and red stele resistant	Anonymous (2007)
	Belrubi	Large fruits	Anonymous (2007)
	Tyee	Resistant to spotted spider mite	Anonymous (2007)
	Vesper	Large fruits	Anonymous (2007)
	Vantage	Resistant to *Verticillium* wilt, leaf scorch and powdery mildew	Anonymous (2007)
	Senga sengana	Good freezing quality	Anonymous (2007)
	Sumas	Early ripening, resistant to red stele races A-1, A-3, A-4 and tolerant to fruit rot	Anonymous (2007)
	Joliette	Adapted to heavy soil, low temp tolerant, powdery mildew, leaf scorch, leaf blight and leaf spot resistant	Anonymous (1997)

Table 8 Some outstanding examples of primary introduction in fruit crops/varieties in India

Crop	Variety	Source country	Year of release
Banana	Lady Finger	Australia	-
	Grand Nain M.S	France	-
	Valery	West Indies	-
Papaya	Sunrise Solo	USA	-
Pomegranate	Shirin Anar	USSR	-
	Wonderful	USA	-
Jacoticaba (*Myrciaria cauliflora*)	Sahara Blanc M 8962	USA	-
Apple	Vered	Israel	-
	Delicious-II	USA	-
	Red Baron	USA	-
	Mollies Delicious	USA	-
	Skyline Supreme Red Delicious	USA	-
Pear	Flemish Beauty	USA	-
	Max Red Bartlett	Italy	-
	Devoe	USA	-
	Manning Elizabeth	USA	-
Peach	Stark Early Glo	USA	-
	Candor	USA	-
	Flordasun	USA	1976
	Earli Grande	USA	1976
Plum	Methley	Kenya	-
	Kanto-5	USA	-
Apricot	Nugget	USA	-
	Coninos	Italy	-
Almond	Non Pareil	USA	-
Walnut	Lake English	USA	-
	Hansen	USA	-
	Payne	USA	-
	Tutle 31	USA	-
Pecan nut (*Carya illinoensis*)	Mahan	USA	1932
Kiwi fruit	Allison, Bruno, Abbott, Monty, Hayward	New Zealand	-
Pineapple guava (*Feijoa sellowiana*)	Nikitsky	USSR	-
Pineapple	Kew	USA	-
Grape	Perlette	USA	1958
	Thompson Seedless	Australia	1936
	Muscat of Hamburg (Gulabi)	Australia	1936
	Kishmish Chorni	USSR (Uzbekistan)	1964
	Beauty Seedless	USA	1964
	Flame Seedless	Australia	1993
	Red Globe	USA	1985
	Crimson Seedless	USA	2002
	Italia	Originally from Italy but introduced from USA	2002
	Cabernet Sauvignon	France	1982

Table 8 (continued)

Crop	Variety	Source country	Year of release
	Chenin Blanc	France	1987
	Sauvignon Blanc	Blanc	1987
	Shiraz	France and Australia	1993
	Zinfandel	France	1995
	Malbec	France	1995
	Ugni Blanc	France	1995
	Grenache	France	1995
	Centennial Seedless	USA and Australia	1985
	Fantasy Seedless	USA	2001

Source: Singh et al., 2009; Mitra & Dinesh, 2019; Chadha & Pareek, 1993

Table 9 Utilisation of exotic germplasm in varietal development through selection/ mutation

Crop	Variety	Exotic germplasm utilised	Method of breeding	Releasing institute/ Farmer's name	Year of release
Apple	Chaubattia Agrim	Early Shanburry	Mutant of Early Shanburry	HETC, Ranikhet, Uttarakhand	1984
Apricot	Chaubattia Alankar	(Kaisha x Charmagz) budwood irradiation with gamma rays	Induced mutation	HETC, Ranikhet, Uttarakhand	1984
	Chaubattia Madhu	(Turkey x Charmagz) budwood irradiation with gamma rays	Induced mutation	HETC, Ranikhet, Uttarakhand	1984
	Chaubattia Kesri	(St Ambroise x Charmagz) budwood irradiation with gamma rays	Induced mutation	HETC, Ranikhet, Uttarakhand	1984
Mango	Pusa Surya	Eldon	Selection	IARI, New Delhi	2002
Grape	New Perlette (HS 37–6)	Perlette	Natural sport	HAU, Hisar	1976
	Pusa Seedless	Thompson Seedless	Clonal selection	IARI, New Delhi	1970
	Sonaka	Thompson Seedless	Clonal selection	Late Nanasaheb Kale, Nanaj, Solapur, Maharashtra	1977
	Manik Chaman	Thompson Seedless	Clonal selection	Mr. T.R. Dabade, Nannaj, Solapur, Maharashtra	1982
	Tas-a-Ganesh	Thompson Seedless	Clonal selection	Mr. Vasant Rao Arve, Tasgaon, Sangli, Maharashtra	1976
	Monika	Thompson Seedless	Clonal selection	Mr. A.G. Meher, Narayangaon, Pune, Maharashtra	1980
	Maruti Seedless	Thompson Seedless	Clonal Selection	Mr. Maruti Ramchandra Mali, Miraj, Sangli, Maharashtra	1993
	Manjari Naveen	Centennial Seedless	Clonal selection	NRCG, Pune	2008
	Manjari Kishmish	A mutant selection from Kishmish Rozavis	Mutant selection	NRCG, Pune	2017
	Madhu Angoor	Carolina Black Rose	Clonal selection	ANGRAU, Hyderabad	1998
	Sharad Seedless	Kishmish Chorni	Bud sport of Kishmish Chorni	Nanasaheb Kale, Nanaj, Solapur	1980
	Mahadev Seedless	Kishmish Chorni	Bud sport of Kishmish Chorni	Mr. Gausmohammed Saipan Shaikh, Boramani, Solapur	2006
	Sarita Seedless	Sharad Seedless	Clonal selection	Mr. Dattatraya Nanasaheb Kale, Nanaj, Solapur	1996
	Nanasaheb Purple	Sharad Seedless	Clonal selection	Mr. Dattatraya Nanasaheb Kale, Murajipeth, Nanaj, Solapur	1998
	Nath Jambo	Sharad Seedless	Clonal selection	Mr. Vithal Nivrutti Thorat, Kalamb, Tal. Ambegaon	2006
	Krishna Seedless	Sharad Seedless	Clonal selection	Mr. Narayan Sangapa Mali, Sangli	2006
Papaya	CO5	Selection from Washington	Selection	TNAU, Tamil Nadu	1985
	Punjab Sweet	Selection from germplasm from Kenya	Selection after sib-mating	PAU, Ludhiana	-
	Coorg Honey Dew	Selection from Honey Dew	Selection	IIHR, Bengaluru	-

Source: Singh et al., 2009; Mitra & Dinesh, 2019; https://nrcgrapes.icar.gov.in

Table 10 Utilisation of exotic germplasm of fruit crops in varietal development through hybridisation in India

Crop	Variety/Hybrid	Exotic germplasm utilised	Releasing institute	Year
Apple	Lal Ambri	Red Delicious x Ambri	SKUAST (K), Srinagar, J&K	1973
	Sunehari	Ambri x Golden Delicious	SKUAST (K), Srinagar, J&K	1973
	Akbar	(Golden Del. x Rome Beauty) x *M. floribunda*	SKUAST (K), Srinagar, J&K	1987
	Firdous	Ambri x Cox's Orange Pippin	SKUAST (K), Srinagar, J&K	1984
	Shireen	Lord Lamborne x Melba XR-12740-7A	SKUAST (K), Srinagar, J&K	1984
	Ambred	Red Delicious x Ambri	YSPUH&F, Nauni (Mashobra), HP	1978
	Ambrich	Richard x Ambri	YSPUH&F, Nauni (Mashobra), HP	1978
	Ambstarking	Starkign Delicious x Ambri	YSPUH&F, Nauni (Mashobra), HP	1978
	Ambroyal	Starking Delicious x Ambri	YSPUH&F, Nauni (Mashobra), HP	1986
	Chaubattia Anupam	Early Shanburry x Red Delicious	HETC, Ranikhet, Uttarakhand	1984
	Chaubattia Princess	Early Shanburry x Red Delicious	HETC, Ranikhet, Uttarakhand	1978
	Chaubattia Swarnima	Benoni x Red Delicious	HETC, Ranikhet, Uttarakhand	1978
	Chaubattia Anurag	Esopus Spitzenberg x Red Delicious	HETC, Ranikhet, Uttarakhand	1984
	Chaubattia Alankar	Fanny x Red Delicious	HETC, Ranikhet, Uttarakhand	1986
	Pusa Gold	Golden Del. x Tydeman's Early Worcester	IARI, RS, Shimla	-
	Pusa Amartara Pride	Royal Delicious x Prima	IARI, RS, Shimla	-
Custard apple	Arka Sahan	Island Gem (*Anonna atemoya*) x Mammoth (*A. squomosa*)	IIHR, Bengaluru	1995
Peach	Saharanpur Prabhat	Sharbati x Flordasun	FRS, Saharanpur	1988
	Shan-i-Punjab	(South Island) F_3 x Springtimes	PAU, Ludhiana	
Mango	Pusa Arunima	Amrapali x Sensation	IARI, New Delhi	2002
	Pusa Pratibha	Amrapali x Sensation	IARI, New Delhi	2011
	Pusa Shreshth	Amrapali x Sensation	IARI, New Delhi	2011
	Pusa Lalima	Dashehari x Sensation	IARI, New Delhi	2011
	Pusa Deepshikha	Amrapali x Sensation	IARI, New Delhi	2020
	Konkan Samrat	Alponso x Tommy Atkins	RFRC, Vengurle	2014
Papaya	Co3	Co2 x Sunrise Solo	TNAU, Tamil Nadu	1983
	Co4	Co1 x Washington	TNAU, Tamil Nadu	1983
	Arka Surya	Sunrise Solo x Pink Flesh Sweet	IIHR, Bengaluru	1994
	Arka Prabhath	(Surya x Tainung-1) x Local Dwarf	IIHR, Bengaluru	-
	HPSC-3	Tripura Local x Honey Dew	ICAR RC-Tripura Centre	1995
	RCTP-1	Tripura Local with different genotypes including Honey Dew	ICAR	2014
Pomegranate	Solapur Lal	Bhagawa x [(Ganesh x Nana) x Daru]	NRC Pomegranate, Solapur	2017
	Solapur Anardana	Bhagawa x [(Ganesh x Nana) x Daru]	NRC Pomegranate, Solapur	2017
Grape	Pusa Navrang	Madeleine Angevine x Rubi Red	IARI, New Delhi	1997
	Pusa Urvashi	Hur x Beauty Seedless	IARI, New Delhi	1997
	Pusa Aditi	Banqui Abyad x Perlette	IARI, New Delhi	2018
	Pusa Trishar	(Hur x Bharat Early) x Beauty Seedless	IARI, New Delhi	2018
	Pusa Swarnika	Hur x Cardinal	IARI, New Delhi	2018
	Arkavati	Black Champa x Thomson Seedless	IIHR, Bengaluru	1980
	Arka Kanchan	Anab-e-Shahi x Queen of Vineyards	IIHR, Bengaluru	1980
	Arka Chitra	Angur Kalan x Anab-e-Shahi	IIHR, Bengaluru	1994
	Arka Majestic	Angur Kalan x Black Champa	IIHR, Bengaluru	1994
	Arka Neelmani	Black Champa x Thompson Seedless	IIHR, Bengaluru	1991
	Arka Soma	Anab-e-Shahi x Queen of Vineyards	IIHR, Bengaluru	1994

Table 10 (continued)

Crop	Variety/Hybrid	Exotic germplasm utilised	Releasing institute	Year
	Arka Trishna	Bangalore Blue x Convent Large Black	IIHR, Bengaluru	1994
	Arka Shyam	Bangalore Blue x Black Champa	IIHR, Bengaluru	1980
	Arka Shweta	Anab-e-Shahi x Thompson Seedless	IIHR, Bengaluru	1994
	Arka Hans	Bangalore Blue x Anab-e-Shahi	IIHR, Bengaluru	1980
	Arka Krishna	Black Champa x Thompson Seedless	IIHR, Bengaluru	1994
	Manjari Medika	Pusa Navrang x Flame Seedless	NRCG, Pune	2017

Source: Singh et al., 2009; Singh & Sharma, 1996; Chadha & Pareek, 1993

Table 11 List of important fruit germplasm from India being maintained/utilised/cultivated in different countries

Crop	Indian germplasm/ variety	Country	Reference
Mango	Bombay Green, Bombay Yellow, Maldahiya, Dashehari, Calcuttia, Mallika, Amrapali, Chausa, Gola, Jarda, Shilhat, Alphonso, Anupati, Bhadaiya Maima, Fazli, Gulab Khas, Jardalu, Sukul, Sukhtara, Anarbahartal, Bathuwa, Kishnabhog, Langra, Ladbi Midhuwa, Lal Maldahiya, Maghukupia, Sipiya, Safeda Maldahiya, Radi, Neelam, Gulab Bhog, Hattijhul, Suvarnarekha, Kapari, Gurkha, Kalepad, Late Green, Malewa Safeda, Mombasa, Sukhia, Totapuri	Nepal	Kaini (1994); Gotame et al. (2014)
	Anwar Ratole, Dushehri, Samar Bahisht Chaunsa, Langra, Neelam, Fajri, Ratole No. 3	Pakistan	Riaz et al. (2018)
	Mulgoba, Alphonso, Suvarnrekha, Sendura, Galour, Kesar, Pairi, Ratna, Sindhu, Dolores, Brindibani, Himsagar	Israel	Sherman et al. (2015)
	Alphonso	Japan	Yamanaka et al. (2019)
	Mallika, Langra Benarasi, Alphonso, Royal Special and Totapuri	Florida	Warschefsky and Wettberg (2019)
	Fazli, Gopal Bhog, Himsagar, Khirsapati, Langra, Kishanbhog, Kohinoor, Mohan Bhog	Bangladesh	www.mangifera.res.in
	Alphonso, Bullock's Heart, Hindi Be Sennara, Langra, Mabrouka, Taimour, Zebda	Egypt	www.mangifera.res.in
	Amrapali, Mallika	Brazil	Pinto et al. (2004)
Banana	Harichhal, Chinia Champa	Nepal	Kaini (1994)
	Calcutta-4	Nigeria	Khokher (2015)
	Poovan, Calcutta	Brazil	Khokher, 2015
	Malbhog	Nepal	Gotame et al. (2020)
Guava	Lucknow-49 and Alahabadi Safeda	Nepal	Kaini (1994)
Litchi	Early Seedless, Early Large Red, Late Large Red, Rose Scented, Raja Saheb, Dehraduni, China, Calcuttia, Patharia Red, Shahi, Bambai, Muzaffarpuri, Maclean, Seedless, Early Green, Koshelia, Rose Scented, Dehara Rose, Bombay Red, Bedana, Deharadun, Late Large, Phash, Ujali, Purbi, Deshi	Nepal	Kaini (1994); Bose (2001); Gautam et al. (2020)
	Bombai, Muzaffarpuri, Bedana and China Number Three	Bangladesh	Bose (2001)
Citrus	*Citrus* x *paradisi* 'Chakotra' Lour, *Citrus jambhiri* Lush. cv '*Jatti khatti*', *Citrus* x *reticulata* 'Nagpuri santra	Pakistan	Shahzadi et al. (2016)
	Rangpur lime, Sour orange	Turkey	Cimen and Yesiloglu (2016); Yesiloglu et al. (2017)
Guava	Allahabadi, Allahabad Safeda, Chittidar, Chinese Guava, Lucknow-49, Lalguda, Seedless, KG-1	Nepal	Gotame et al. (2020)
Bael	Five accessions	Sri Lanka	Pathirana et al. (2020)
	Narendra Bael-5, Narendra Bael-7, Narendra Bael-9, Narendra Bael-17	Nepal	Gautam et al. 2020
Ber	Kaithal, Umran, Gola	Mali	Kalinganire et al. (2012)
	Banarasi, Gola, Umran, Jingzhao, Chuizhao	Nepal	Gotame et al. (2014)
Phalsa	Faizabadi	Nepal	Gotame et al. (2014)
Apricot	Blenheim Indian, Shakarpara, Tilton Indian,	Nepal	Gotame et al. (2014)
Aonla	Chakaiya, Kanchan NA-4, NA-6, NA-7, NA-10	Nepal	Gotame et al. (2014)
Jackfruit	Khajawa, Rasdar	Nepal	Gotame et al. (2014)

Table 12 Mango varieties released in other countries utilising Indian germplasm

Sl. No.	Variety	Indian germplasm utilised	Releasing Institute/country	Ref
1	Embrapa Roxa 141	Amrapali x Tommy Atkins	CARC, Brazil	Pinto et al. (2000)
2	Embrapa Alfa 142	Mallika x Van Dyke	CARC, Brazil	Pinto et al. (2000)
3	BRS Beta	Amrapali x Winter	CARC, Brazil	Pinto et al. (2000)
4	Embrapa Lita	Amrapali x Tommy Atkins	CARC, Brazil	Pinto et al. (2000)
5	BRS Omega	Amrapali x Tommy Atkins	CARC, Brazil	Pinto et al. (2000)
6	Bailey's Marvel	Haden x Bombay	Florida, USA	Schnell et al. (2006)
7	Anderson	Sandersha x Haden	Florida, USA	Schnell et al. (2006)
8	Haden-JIRCAS	Mulgoba x Turpentine	Florida, USA	Campbell (1992); Knight et al. (2009); Schnell et al. (2006)
9	Haden-OPARC	Mulgoba x Turpentine	Florida, USA	Campbell (1992); Knight et al. (2009); Schnell et al. (2006)
10	Jacquelin-OPARC	Haden x Bombay	Florida, USA	Schnell et al. (2006)
11	Jacquelin-JIRCAS	Haden x Bombay	Florida, USA	Schnell et al. (2006)

Table 13 Diseases/ pests of fruit crops introduced in India from other countries

Sl. No	Disease/ pest	Scientific name	Host	Date of first record	Introduced from
1	Wooly apple aphid	*Eriosoma lanigerum*	Apple, pear	1909	England
2	San Jose scale	*Quadraspidiotus perniciosus*	Apple	1900	Italy
3	Downy mildew of grape	*Plasmopora viticola*	Grape	1910	Europe
4	Fluted scale	*Icerya purchase*	Citrus	1928	Sri Lanka
5	Crown gall	*Agrobacterium tumefaciens*	Apple, pear	1940	England
6	Hairy root of apple	*Agrobacterium rhizogenes*	Apple	1940	England
7	Bunchy top	*Bunchy top of banana virus*	Banana	1940	Sri Lanka
8	Fire blight of pear	*Erwinia amylovora*	Pear	1940	England
9	Apple canker	*Sphaeropsis malorum*	Apple	1943	Australia
10	Banana mosaic	*Banana mosaic virus*	Banana	1961	-
11	Apple scab	*Venturia inequalis*	Apple	1978	UK
12	Codling moth	*Cydia pomonella*	Apple	1989	Pakistan and Afghanistan
13	Banana bract and streak virus	*Banana bract and streak virus*	Banana	1995	Sri Lanka
14	Coconut eriophid mite	*Aceria gurreronis Keifer*	Coconut	1997	South America
15	Papaya Mealy bug	*Paracoccus marginatus*	Papaya	2008	Central America
16	Banana mealy bug	*Pseudococcus jackbeardsleyi Gimpel and Miller*	Banana, papaya, custard apple	2012	Neotropical
17	Woolly whitefly	*Aleurothrixus floccosus*	Guava, *Citrus* species	2019	Neotropical
18	Neotropical white fly	*Aleurotrachelus atratus*	*Cocos nucifera* and *Dypsis lutescens*	2019	Neotropical

Source: Paroda et al., 1987; Khetrapal and Gupta 2007; Muniappan et al., 2008; Vijay Laxmi et al., 2014; Gupta et al., 2019; Shivakumara et al., 2020; Latha & Sathyanarayana, 2013; Khan et al., 2017; Singh et al., 2020

Glossary

ABS Access and benefit sharing
AICRP-F All India Coordinated Research Project-Fruits
ANGRAU Acharya N. G. Ranga Agricultural University
APEDA Agricultural and Processed Food Products Export Development Authority
APGRC Agricultural Plant Genetic Resources Conservation and Research Centre
ATARI Agricultural Technology Application Research Institute
BARC Bangladesh Agricultural Research Council
BDA Biological Diversity Act
BSIP Birbal Sahni Institute of Palaeobotany
CARC Cerrados Agricultural Research Center
CBD Convention on Biological Diversity
CCRI Central Citrus Research Institute
CePaCT Centre for Pacific Crops and Trees
CES Citrus Experiment Station
CIAH Central Institute of Arid Horticulture
CISH Central Institute of Sub-tropical Horticulture
CITH Central Institute of Temperate Horticultural
CWR Crop Wild Relatives
EMBRAPA-CNPMF Embrapa Mandioca e Fruticultura Tropical
EMLA East Malling Long Ashton
EURISCO European Search Catalogue for Plant Genetic Resources
EXIM Export and Import Policy
FAO Food and Agriculture Organization
FIGS Focussed Identification of Germplasm Strategy
FRS Fruit Research Station
GDP Gross Domestic Product
GEPU Germplasm Exchange & Policy Unit
GFG German Fruit Genebank
GRIN Germplasm Resources Information Network
HAU Haryana Agricultural University
HETC Horticultural Experiment and Training Centre
IARC International Agricultural Research Centres
IARI Indian Agricultural Research Institute
ICAR Indian Council of Agricultural Research
IIHR Indian Institute of Horticultural Research
IITA International Institute of Tropical Agriculture
IMTP International Musa Testing Programme
INIBAP International Network for Improvement of Banana and Plantains
IPPC International Plant Protection Convention
ITC International Musa Germplasm Transit Center
ITPGRFA International Treaty on Plant Genetic Resources for Food and Agriculture
KVK Krishi Vigyan Kendra
MoAFW Ministry of Agriculture & Farmers Welfare
MTA Material Transfer Agreement
NARO National Agricultural Research Organisation
NBPGR National Bureau of Plant Genetic Resources
NHB National Horticulture Board
NP Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilisation
NPGS The US National Plant Germplasm System
NRC National Research Centre
NRCB National Research Centre for Banana
NRCG National Research Centre on Grape
NRCL National Research Centre on Litchi
NRCP National Research Centre on Pomegranate
PAU Punjab Agriculture University
PGRFA Plant Genetic Resources for Food and Agriculture
RAAS Russian Academy of Agricultural Sciences
RFRC Regional Fruit Research Centre
RC-Tripura Regional Centre, Tripura
SKUAST (K) Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir
SMTA Standard Material Transfer Agreement
TNAU Tamil Nadu Agricultural University
USDA United States Department of Agriculture
YSPUH&F Dr. Yashwant Singh Parmar University of Horticulture and Forestry
WTO World Trade Organisation

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