Collection and Utilization of Tropical and Subtropical Fruit Tree Genetic Resources for Breeding in India

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Abstract

India is the second largest fruit-producing country in the world. Mango, banana, citrus, guava, papaya, pineapple and grapes are the important tropical and subtropical fruit crops grown here. The overall productivity of various fruit crops grown in India is very low (9.75t/ha). The problems associated with successful growing of these crops include alternate bearing, malformation and spongy tissue formation (in cv. Alphonso) in mango ; bunchy top, panama wilt and burrowing nematode in banana ; dieback, tristeza, greening, bacterial canker, foot and root rot and nematodes in citrus ; wilt in guava ; frost, ring spot and leaf curl virus in North India in papaya, and anthracnose, downy and powdery mildews in grapes. Attempts have been made in the past and are continuing to collect both indigenous and exotic germplasm of various fruit crops for use in fruit improvement. These collections are being maintained mostly in field gene banks located at various research institutes of the Indian Council of Agricultural Research and different agricultural universities. These active collections are being evaluated from time to time. Extensive use of this vast germplasm has resulted in the development of 18 mango, 1 banana, 6 citrus, 5 guava, 11 papaya and 9 grape varieties.

Introduction

India is the second largest fruit-producing country in the world having an area of 3.29 million hectares under fruits with an annual production of 28.39 tons (Sharma and Dhal, 1993). The important tropical and subtropical fruits grown here are mango, banana, citrus, guava, papaya and grapes. However, the productivity of these crops is fairly low. A number of problems including diseases, insects, pests and various disorders are associated with fruit growing in India. Inferior quality of planting material and poor orchard management are some of the reasons for the low productivity. The present article describes the problems associated and the efforts made in the country to breed improved varieties of these crops.

Mango

Mango (*Mangifera indica*) is the most important fruit crop of India being cultivated here for over 4,000 years. It covers an area of 1,077 thousand hectares with an annual production of 8,752 thousand tons (Table 1). About 1,000 varieties are grown in differenct parts of the country, of which 18 are commercially important. These include the cultivars Dashehari, Langra, Chausa, Alphonso, Banganapalli, Mulgoa and Bombay Green. Andhra Pradesh, Uttar Pradesh (plains) and Bihar are important mango-growing states, though mango is cultivated throughout the country (Fig. 1). Main problems in mango cultivation are the alternate bearing, malformation and spongy tissue formation (in cv. Alphonso).

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Table 1 Fruit production in India and export (1991–92)*

Crop	Area (1,000 ha)	Production (1,000 t)	Productivity (t/ha)	Export (1,000 t)
Mango	1077	8752	8.12	47.55[FDP]
Banana	383	7790	20.34	0.65[FD]
Citrus	530	3760	7.09	8.27[FD]
Guava	94	1095	11.65	0.48[F]
Pineapple	57	768	13.48	0.14[F]
Papaya	45	805	17.88	0.30[F]
Grapes	32	668	20.88	11.15[F]

* Sharma and Dhal, 1993.
F=Fresh, D=Dried, P=Pulp.

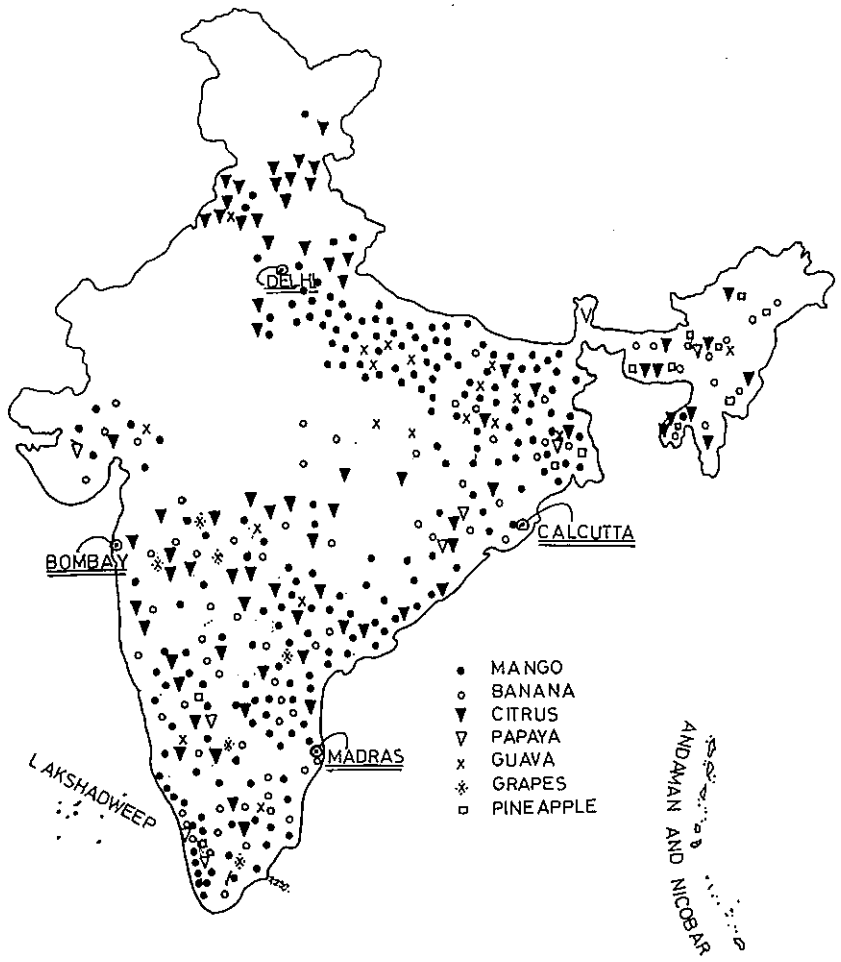

Fig. 1 Important tropical and subtropical fruit cultivation in India

1. Distribution of genetic resources

Six out of 41 species of *Mangifera* are native to India. *Mangifera indica* is economically the most important species of the genus. It is closely related to *M. longipes* and *M. sylvatica*. The species is native to India, many wild types occur, throughout the tropical and subtropical hilly forests and ravines up to 100 m above sea level and in the Andamans. Six zones of variability of wild *M. indica* have been recognized

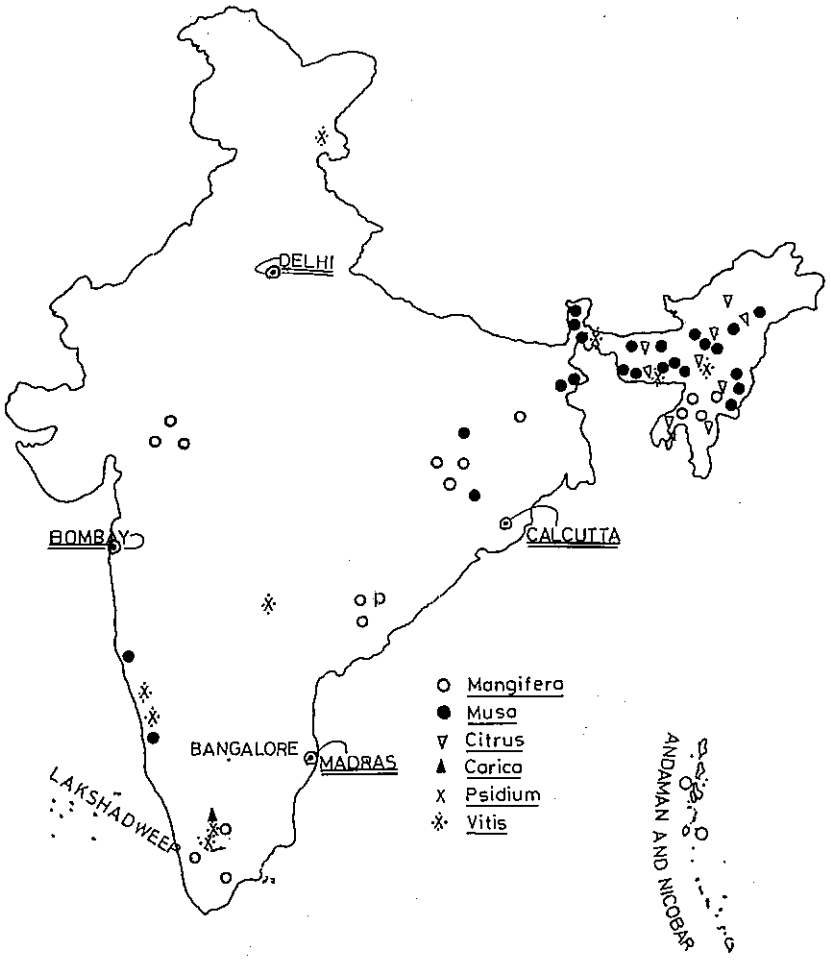

Fig. 2 Important tropical and subtropical fruit tree genetic resources in India.

(Fig. 2) (Yadav and Rajan, 1993).

1) Humid subtropical region comprising Manipur, Tripura, Mizoram and South Assam.
2) 1) Chota Nagpur plateau and trijunction of Madhya Pradesh, Bihar and Orissa.
   2) Santhal Pargana (Rajmaha hills).
3) South Madhya Pradesh, adjoining Orissa and Andhra Pradesh.
4) Dhar plateau of Madhya Pradesh and adjoining South Rajasthan and Gujarat.
5) Humid tropical South peninsular India.
6) Andaman and Nicobar islands.

Mangifera sylvatica occurs in Sikkim, Himalayas (up to 1300 m), Darjeeling district, Khasi hills, upper Assam, Surma valley and Andaman islands. It bears small edible fruits in clusters twice a year. *M. khasiana* is endemic to India (Khasi hills). It is a rare and insufficiently known species distributed in Andaman islands. *M. andamanica* is another endemic species distributed in Andaman islands, it is an endangered species and resembles *M. monandra*.

2. Collection, conservation and evaluation of germplasm

A number of exploration trips have been made during the past ten years and variability available in Orissa, Uttar Pradesh, Madhya Pradesh and Maharashtra has been collected. Both indigenous and exotic germplasm collections numbering 1,461 are being maintained in field gene banks at 32 centers (Table 2). These germplasm collections are being described and evaluated for various characters including resistance to pathogens, insect pests and various disorders. Gangolly *et al.* (1957) have described 210 impor-

tant varieties of mango for various characters. Cultivars Neelum, Bangalora and Totapari Red Small are regular bearing ; out of these cultivars Neelum has been found to be the best combiner. The regularity of bearing of the other two cultivars is closely linked to poor fruit quality. Leaf flavor has been found to show a direct correlation with the fruit flavor. Emergence of new vegetative growth simultaneously with fruiting or immediately after harvest indicates regularity of bearing and lower stomatal density indicates dwarfness. Cultivar Dashehari has been found to be excellent for nectar making. Cultivar Sukul is outstanding for juice making and cv. Mallika is ideal for canning (slices) purposes. Cultivars Lord and Navneetam have been found to be tolerant to mango hoppers *Amaritodus atkinsoni*. Cultivars Azam-us-Samar, Chambalwali, Chausa, Karnuli, Mulgoa, Totapari and Vanraj are tolerant to sooty mould (*Meliola mangiferae*). Cultivars Vanraj, Rajapuri and Azam-us-Samar are tolerant to *Phyllosticta*. Cultivar Bhadauran is the only one which is free from malformation, however, it has a low fruit quality.

3. Utilization

Mango breeding is being conducted at eight different locations spread all over the country. The main emphasis has been to develop regular bearing, colored varieties and to avoid the formation of spongy tissue in cultivar Alphonso (an export variety). Cultivar Neelum has been used to impart regular bearing habit, cv. Vanraj for colored skin character and cv. Banganapalli to avoid spongy tissue formation. As a result of massive hybridization programs, 18 mango varieties have been developed, including Amrapali (dwarf, regular bearing), Mallika (regular bearing, processing) and Ratna (regular bearing, free from spongy tissue). Three more colored hybrids Arka Arun, Arka Puneet and Arka Anmol have been developed, which are free from fibers and spongy tissue. Variety Sindhu is a recently developed hybrid with papery and soft stone (Table 3).

Banana

Banana is the second most important fruit crop of India covering an area of 383 thousand hectares with an annual production of 7,790 thousand tons of fruits (Table 1). There are about 300 varieties of banana in India, out of these 35 varieties are grown commercially. These include cultivars Robusta, Dwarf Cavendish, Poovan, Rasthali, Chini Champa, Rasa Bale, Monthan and Nendran. Maharashtra, Tamil

Table 2 Number of accessions and major locations for preservation of important tropical and subtropical fruit germplasm in India

Crop	No. of accessions	No. of preservation locations	Major preservation locations
Mango	1,461	32	CIHNP, Lucknow FRS, Sangareddy HRI, Saharanpur IIHR, Bangalore
Banana	296	13	IIHR, Bangalore TNAU, Coimbatore
Citrus	600	13	IIHR, Bangalore
Guava	153	17	IIFHR, Bangalore HETC, Basti CIHNP, Lucknow
Papaya	58	9	IIHR, Bangalore TNAU, Coimbatore CIHNP, Lucknow
Pineapple	33	2	KAU, Trichur
Grapes	980	16	IIHR, Bangalore

Table 3 Important fruit varieties developed in India

Name	Year	Origin	Characteristics
Mango			
Ratna	1970	Neelum × Alphonso	Regular bearing, free from spongy tissue
Mallika	1979	Neelum × Dashehari	Regular bearing, suitable for canning
Amrapali	1979	Dashehari × Neelum	Regular bearing, dwarf
Arka Arun	1993	Banganapalli × Alphonso	Regular bearing, dwarf, colored skin, free from spongy tissue
Arka Puneet	1993	Alphonso × Banganapalli	Regular bearing, red skin, deep orange flesh, free from spongy tissue, good keeping quality
Arka Anmol	1993	Alphonso × Banganapalli	Late season, golden yellow fruits, free from spongy tissue
Sindhu	1993	Ratna × Alphonso	Fruits in cluster, red skin, fibreless, firm, deep orange flesh and soft papery stone
Banana			
CO-1	–	(Ladan × *Musa balbisiana*) × Kadali	Good flavour
Citrus			
Kagzi lime Pramalini	1985-86	Clonal selection	Fruits in clusters
Vikram	1985-86	Clonal selection	30-35% higher yield
Chakradhar	1989	Selection from Kagzi lime	Thornless, thin rind, seedless, 60-66% more juice
Guava			
Sardar	1927	Selection from Allahabad Safeda	Large fruit, white flesh, high TSS
Safeda Jam	–	Allahabad Safeda × Kohir	Large fruit, few soft seeds, medium-sized tree
Kohir Safeda	–	Kohir × Allahabad Safeda	Large tree, big fruits, soft seeds
Allahabad Surkha	1991	Selection from Allahabad Safeda belt	Pink fruit skin, deep pink pulp
Papaya			
Coorg Honey Dew	1959	Selection from Honey Dew	Gynodioecious, large fruits, high TSS
Pusa delicious	1982	Sib-mating and selection from local types	Gynodioecious, deep orange flesh, high TSS
Pusa Nanha	1982	Sib-mating and selection after irradiation	Dwarf, dioecious, red orange flesh
CO-3	1982	CO-2 x Sunrise Solo	Vigorous, gynodioecious, red flesh, high TSS, table purpose
CO-5	1985	Selection from Washington	Large fruit, dioecious, high papain, suitable for processing
Grape			
Arkavati	1980	Black Champa × Thompson seedless	High yield, all buds fruitful, seedless
Arka Kanchan	1980	Anab-e-Shahi × Queen of the Vineyards	High yield, good for head system, golden yellow berries
Arka Shyam	1980	Bangalore Blue × Black Champa	High yield, high TSS, suitable for table purpose and wine making
Arka Hans	1980	Bangalore Blue × Anab-e-Shahi	Good for head system, suitable for wine making

Nadu, and Gujarat are the important banana-growing states though banana is cultivated throughout the country (Fig. 1). Banana bunchy top, Panama wilt (*Fusarium oxysporum*) and burrowing nematode (*Radopholus similis*) infestation are the main problems in banana cultivation. In South India fruits of cultivar Poovan occasionally develop seeds rendering the fruit inedible (Agarwal, 1988a).

1. Distribution of genetic resources

Malayan region is the primary center of origin of banana, but at present the greatest diversity occurs in New Guinea. The center of origin of AAB and small group of AB hybrids lies in India. South India is also the major center of origin of ABB group. About 14 species of *Musa* have been recorded in India of which 3 to 4 are cultivated as ornamentals. *Musa acuminata* occurs in India in Assam and parts of peninsular India. Both seedless and seeded forms occur as normal diploids and triploids. *M. balbisiana* occurs in Assam, Sikkim and South India. Among other species *M. cheesmanii*, *M. manii*, *M. sanguinea* and *M. velutina* occur in Assam, Khasi, Mikir and Mariani hills and Manipur; *M. itinerans* in Manipur; *M. nagensium* in Nagar hills; *M. sikkimensis* in Sikkim, North Bengal, Khasi hills and Manipur; *M. ornata* in Sikkim, North Bengal, Chota Nagpur, Orissa and Konkan hills; *M. superba* in western ghats and Assam; *M. glauca* in Khasi hills and *M. agharkarii* in Chittagong hills (Fig. 2) (Anonymous, 1962).

2. Collection, conservation and evaluation of germplasm

Three exploration trips have been made by the author in collaboration with the National Bureau of Plant Genetic Resources (NBPGR), India to collect variability in *Musa* from northeastern India. Twenty two wild germplasm samples have been collected from Meghalaya, 31 from Arunachal Pradesh and 26 from Cachar and Jayantia hills (Fig. 3). Presently 296 accessions of *Musa* are being maintained at 13 centers in field gene banks (Table 2). One hundred and twenty accessions are also being stored *in vitro* at 25 °C (Anonymous, 1992b).

One hundred and seventy accessions of banana have been described by the author for 52 characters (Agarwal, in press). None of the banana varieties has been found to be resistant to banana bunchy top disease. Variability, however, exists with regard to susceptibility to burrowing nematode (*Radopholus similis*) and Panama wilt pathogen (*Fusarium oxysporum*). Cultivars Attikol, Adakka Kunnan, Ayiranka Poovan, Elakki Bale, Kunnan, Pacha Chingan, Padali Moongil, Poovan and Thatilla Kunnan are resistant to burrowing nematode (*R. similis*). Cultivar Basrai is immune to Panama wilt pathogen whereas, cultivars Poovan, Moongil, Pey Laden, Raja Bale and Vamankeli are resistant.

3. Utilization

Spontaneous mutations are very frequent in banana. A number of interesting mutants have been obtained, among which Mott Poovan a plump fruited mutant of cultivar Poovan, Ayiranka Rasthali a mutant of cv. Rasthali without male flowers and bearing fruits up to the inflorescence tip, Venkadali a green-red fruited mutant of red fruited cultivar Chenkadali. Not much work has been done for the varietal improvement of banana mostly because of the lack of diploid fertile varieties. Cultivar Matti (AA) has been used frequently as female parent in breeding programs as it yields a large number of hybrids. Only one hybrid Co-1 (Ladan × *M. balbisiana*) × Kadali) has been released for local use which, when grown on plains, gives the characteristic flavor of hill banana (Table 3).

Citrus

In India citrus occupies an area of 530 thousand hectares with an annual production of 3,760 thousand tons of fruits (Table 1). Commercially important citrus types include sweet oranges, mandarins, acid limes, lemons and Kinnow. Sweet oranges are grown in the states of Maharashtra, Andhra Pradesh, Tamil Nadu, Punjab, Haryana and Rajasthan. Important cultivars are Mosambi, Sathgudi, Malta, Malta Blood Red and Pineapple. Mandarins are grown in Maharashtra, northeastern India and Coorg in Karnataka. Important mandarin cultivars are Nagpur Santara and Khasi mandarin. Kinnow (King × Willowleaf mandarin) is a recent introduction and is grown in Punjab. Limes are grown all over the country, important cultivars are Kagzi and seedless limes. Lemons, grape fruits and pummelos are grown over a

limited area. Important lemon varieties are Galgal, Italian, and Seville and grapefruit varieties are Duncan and Marsh Seedless. Major problems in citrus growing in India include greening in sweet oranges and mandarins and tristeza and citrus bacterial canker disease (*Xanthomonas campestris* pv. *campestris*) in acid lime. Phytophthora foot/root rot and citrus nematode (*Tylenchulus semipenetrans*) are major rootstock problems.

1. Distribution of genetic resources

Citrus occurs naturally from India and south China to northern Australia and Caledonia. Only two types are considered to have originated in India : lime in northern India and adjoining parts of Burma and citron in sub-Himalayan regions of northeastern India and upper Burma. Some consider that Indo-China is the area of origin of mandarins (Agarwal, 1988 b). Bhattacharya and Dutta (1956) considered that at least five species *C. indica* (Tan.), *C. assamensis* (Dutta and Bhattacharya), *C. ichangensis* (Swing.), *C. latipes* (Tan.) and *C. macroptera* (Mont.) are indigenous to Assam. Thirty one species of citrus are distributed all over India (Fig. 2).

2. Collection, conservation and evaluation of germplasm

Bhattacharya and Dutta (1956) had collected a large number of citrus germplasm and maintained it in a field gene bank in Assam. However, due to disease and dieback problems these collections have disappeared. Some of the collections duplicated elsewhere are however, surviving. A citrus gene sanctuary has recently been established in Garo hills (Singh, 1981). In recent years during three exploration trips the author, in collaboration with NBPGR, India, has made 15 wild germplasm collections from Arunachal Pradesh, 21 from Meghalaya and 10 from Cachar and Jayantia hills (Fig. 4). A total of 600 accessions of citrus and allied genera are being maintained at 13 different research centers (Table 2).

Evaluation of germplasm has shown a high degree of resistance to citrus nematode (*Tylenchulus semipenetrans*) in Flying Dragon and Argentina strains of trifoliate orange (*Poncirus trifoliata*). Three rootstock hybrids CRH-3, CRH-5 and CRH-41 developed at IIHR, Bangalore have been found to be highly resistant to this nematode (Reddy *et al.*, 1987). Hybrids CRH-3, CRH-12, CRH-19, and CRH-141 are resistant to *Phytophthora* (Anonymous, 1992a). A hybrid of *Citrus limonia* and *Poncirus trifoliata* with a short juvenility has been identified (Agarwal, 1988c). Out of eleven rootstock hybrids (*Citrus* × *Poncirus*) Swingle Citrumelo has been found to be the most vigorous rootstock (Agarwal, 1987).

3. Utilization

Hybrid Kinnow (King × Willowleaf) has been the most important introduction. This cultivar is very high-yielding and has occupied large areas in Punjab. Most of the improvements have been made by selection of spontaneous mutants. Sweet orange Yuvraj Seedless is a seedless early maturing mutant of Blood Red. Three Kagzi lime varieties Pramalani, Vikram and Kasi Pentla have been developed by clonal selection. They bear fruits in clusters and give 30-35% more yield than the existing cultivar. Chakradhar is another thornless and seedless selection made from cultivar Kagzi lime having round fruits, thin papery rind and 60-66% juice content, it has a high vitamin C content and is high-yielding (Table 3). In mandarins a seedless mutant Mudkhed Seedless has been isolated from Nagpur mandrin.

Guava

Guava (*Psidium guajava*) is another important fruit crop of India covering an area of 94 thousand hectares with an annual production of 1,095 thousand tons of fruits (Table 1). It is grown throughout the country up to 1300 m altitude (Fig. 1). It exceeds most other fruit trees in productivity, hardiness and vitamin C content. There are twenty six varieties in India of which 10 are commercially important. Allahabad Safeda and Sardar are the leading varieties of guava. Guava cultivation is currently being threatened by wilt caused by *Fusarium* spp.

1. Distribution of genetic resources

Guava originated in tropical America. In India it was introduced by the Portuguese in the 17 th cen-

tury. *Psidium guineense* syn. *P. molle* Berd. grows wild in Agartala (Tripura), it is a very hardy species and has a long flowering duration (Fig. 2).

2. Collection, conservation and evaluation of germplasm

Propagation by seeds during early days has given rise to considerable variability in growth habit, shape and size of the fruit, pulp texture, flavor and seediness. One hundred fifty three genotypes are being maintained at 17 different research centers (Table 2).

Cultivar Apple Colour has bright red skin with cream-colored flesh. Cultivar Red Flesh has red-colored flesh and saffron yellow fruit skin. Seedless guava is triploid (3 n=33) with one or two seeds. Philippine guava has been found to be resistant to wilt pathogen. *P. guajava* and *P. chinensis* are crossable. *P. guajava* as female parent, is incompatible with *P. molle*. *P. chinensis* as female parent is compatible with *P. molle*.

3. Utilization

Cultivar Sardar is a large fruited, high-yielding selection from Allahabad Safeda. Two varieties Safed Jam and Kohir Safeda have been developed by hybridization. Safed Jam has bigger fruits than Allahabad Safeda and few soft seeds. Variety Kohir Safeda is a high-yielding cultivar and has large fruits with few seeds and white flesh. A new selection Allahabad Surkha has been made in Allahabad guava belt. The skin and the pulp of the fruits are pink (Nand *et al*., 1991) (Table 3). Hybrid, a cross between Seedless and Allahabad Safeda and Hybrid 16-1, a cross between Apple Colour and Allahabad Safeda have recently been developed (Subramanyam and Iyer, 1993), the former has fruits with high TSS and good keeping quality and the latter has a bright red fruit skin with high TSS, good keeping quality and few soft seeds.

Papaya

In India, papaya (*Carica papaya*) is grown over 45 thousand hectares of land with an annual production of 805 thousand tons of fruits (Table 1). Karnataka, Gujarat, West Bengal, Orissa, Assam and Kerala are the important papaya-growing states (Fig. 1). In North India varieties Pusa Delicious and Pusa Majesty are grown, in South India varieties Coorg Honey Dew and Co-2 are popular. Papaya cultivation is not very successful in North India because of the susceptibility to frost, papaya ring spot and leaf curl virus infestation. Interestingly the plants in South India are not affected by this virus.

1. Distribution of genetic resources

Carica papaya is indigenous to tropical America. It was introduced to India in the 16 th century. *Carica candamarcensis* grows in a semi-wild state in the Nilgiris at elevations between 1,400 and 2,100 meters (Figs. 2, 5).

2. Collection, conservation and evaluation of germplasm

Most of the Indian collections are exotic in nature. Fifty eight genotypes are being maintained and evaluated at nine research centers (Table 2). *Carica cauliflora* and *C. candamarcensis* are resistant to ring spot virus. *C. candamarcensis* is also resistant to frost. Cultivars Coorg Honey Dew and Pink Flesh Sweet are good donors for yield, whereas Pink Flesh Sweet, Sunrise Solo and Waimanalo have been identified for quality characters like TSS and fruit cavity index.

3. Utilization

Papaya improvement work is being conducted mainly at Bangalore, Pusa, Coimbatore and Lucknow. Coorg Honey Dew was selected as a gynodioecious variety from Honey Dew, a dioecious cultivar. Pusa Delicious, Pusa Dwarf and Pusa Majesty are the selections made after sib-mating of local types. Pusa Delicious is a gynodioecious variety with deep orange flesh, Pusa Dwarf is a dwarf variety with medium-sized fruits and Pusa Majesty is a gynodioecious high-yielding variety. These varieties are suitable for northern India. CO-1 is a dwarf selection from cultivar Ranchi, CO-2, CO 5 and CO-6 are selections with

a high papain content from local types, cultivar Washington and cultivar Pusa Majesty, respectively. A number of hybrids have also been developed, including CO-3 (CO-2 × Sunrise Solo), a red flesh table purpose variety and CO-4 (CO-1 × Washington) a vigorous yellow flesh variety. Pusa Nanha a dwarf variety has been developed by 15 Kr gamma treatment (Table 3).

Grapes

In India grapes are grown over 32 thousand hectares of land with an annual production of 668 thousand tons (Table 1). Grape productivity in India is the highest (21 t/ha) in the world. Grapes are mainly grown in the states of Maharashtra, Karnataka, Punjab and Andhra Pradesh. Important table varieties are Anab-e-shahi, Perlette, Thompson Seedless, Beauty Seedless and Bangalore Blue (Fig. 1). Grapes are grown mostly for table purpose. In South India, with a tropical climate, two crops can be obtained in a year as the vine growth is continuous without a pronounced dormant period (Randhawa *et al*., 1982), whereas, in North India, only one crop is obtained as the vines remain dormant during the winter season. Anthracnose (*Elsinoe ampelina*), downy mildew (*Plasmopara viticola*) and powdery mildew (*Uncinula necator*) are the most important diseases of the grapevine. Their control by the use of fungicides makes grape growing a costly affair.

1. Distribution of genetic resources

Grape is considered to have originated between the Caspian and Black seas. In India, grapes were introduced about 2,600 years ago. *Vitis araneosus* is found in the Western ghats of the Konkan, Nilgiri, Palni, Anamalai and Shevaroy hills up to an altitude of 1350m. *V. indica* is found on the western coast and ghats from Konkan Southwards up to 900m altitude. *V. latifolia* occurs throughout the greater part of India up to an altitude of 1200 m in the Himalayas. *V. barbata* is found in the hills of North Bengal, parts of Assam and Khasi hills up to 1200m elevation. *V. lanata* is found throughout the greater part of India ascending up to 2100m in the Himalayas. *V. parviflora* is found in Northwest Himalayas from Kashmir to Nepal at an altitude between 600-1800m. *V. tomentosa* is found throughout the greater part of the Deccan peninsula. Fruits of *V. barbata*, *V. lanata* and *V. parviflora* are edible, whereas plant parts of *V. araneosus*, *V. indica*, *V. latifolia* and *V. tomentosa* are of medicinal value. Apart from these 7 species of *Cissus*, 6 of *Tetrastigma*, 3 of *Cayratia* and one of *Parthenocissus* also grow in different parts of the country up to an altitude of 3000m (Fig. 2) (Anonymous, 1976).

2. Collection, conservation and evaluation of germplasm

Both indigenous and exotic collections have been made in *Vitis* and allied genera/species. Presently 980 accessions including 31 species of *Vitis*, 14 of *Cissus*, 5 of *Leea*, 2 of *Cayratia* and one each of *Tetrastigma* and *Ampelocissus* are being conserved at 16 research centers (Table 2).

Chadha and Randhawa (1974) have described 130 varieties of grapes for vegetative, floral and fruit characters. Out of 30 varieties of grapes, the variety Blank Champa has been found to be suitable for double cropping (main season and off-season) in South India (Randhawa *et al*., 1982). Cultivars Angur Kalan, Karachi Gulabi and Niagra have been found to be resistant to anthracnose (*Elsinoe ampelina*). Black Champa and Bangalore Blue are resistant to downy mildew (*Plasmopara viticola*) and Red Sultana, Saint George and 1613 have been found to be highly resistant to powdery mildew (*Uncinula necator*).

3. Utilization

Grape breeding in India is being done mainly at IIHR, Bangalore. Introduction of variety Anab-e-Shahi from the middle East in about 1890 revolutionized the grape cultivation in India. It is a very prolific bearing seeded variety. Important selections made in grapes include Cheema Sahebi an open-pollinated seedling from male sterile varieties. Tas-a-Ganesh is a selection from Thompson Seedless with elongated berries. Sonaka and Manik Champa have also been selected from Thompson Seedless. Sonaka has much more elongated berries than Tas-a-Ganesh. Dilkush is a bud sport of Anab-e-Shahi having golden yellow elongated berries. Four improved grape hybrids have been developed at IIHR, Bangalore and released (Table 3) (Negi and Randhawa, 1980). These include Arkavati a prolific bearing, large clus-

tered seedless variety with thin skin and high TSS (23° B). It is suitable for table and raisin purposes. Arka Kanchan is also a prolific hybrid bearing golden-yellow seeded berries having muscat flavor. It is suitable for table and wine purposes. Arka Shyam is a black, seeded variety with high TSS (24° B), suitable for table and wine purposes. Arka Hans is another prolific bearing variety with yellowish green seeded berries suitable for wine making. Apart from these a number of other grape hybrids are currently under final evaluation.

Conclusions

1) In mango, the problem of alternate bearing has been solved by developing regular bearing cultivars. A number of colored mango varieties have also been developed. Presently the emphasis is on the development of malformation-resistant varieties with colored skin for export purpose.
2) In banana, bunchy top is the most important problem in India. None of the commercial cultivars are resistant to this virus. We are looking for resistance to bunchy top in wild types for transfer to commercial cultivars. Though a tremendous amount of variability is present in Indian bananas, we do not have many fertile diploids required for banana breeding. There is, therefore, a need to introduce fertile diploids from exotic sources.
3) In citrus, we have been able to produce a number of rootstock hybrids resistant to *Phytophthora* and citrus nematode (*Tylenchulus semipenetrans*) which are being further evaluated for compatibility, etc. A couple of high-yielding acid lime varieties have also been developed. Attempts are being made to develop bacterial canker (*Xanthomonas campestris* pv. *campestris*) − resistant acid limes. There is a further need to take up improvement of sweet oranges, mandarins and acid limes for resistance to greening and tristeza.
4) In guava, a number of high-yielding, good quality as well as colored (skin and pulp) varieties have been developed, but wilt remains the major problem in this crop. Efforts, therefore, need to be directed towards breeding wilt-resistant varieties of guava with a good keeping quality.
5) In papaya, a number of varieties have been developed which show a better fruit quality for table purpose and papain content or are dwarf. There is a strong need for developing papaya varieties resistant to cold, ring spot and leaf curl diseases which are very severe in North India.
6) In grapes, although all the varieties developed so far display improved fruit and bunch characters, they are susceptible to various diseases. Emphasis needs to be placed on the development of grape varieties resistant to anthracnose, downy and powdery mildews which will contribute not only to reducing the cost of cultivation but also to saving the environment.

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Discussion

Uritani, I. (Japan): Could you indicate how fruit tree genetic resources are being maintained? Are they preserved as trees, tissue cultures or seeds?

Answer: Most of the tropical and subtropical fruit crops are being maintained as field gene banks, including mango, banana, citrus, guava, grapes, pineapple and papaya. Citrus species native to northeast India are being conserved in gene sanctuaries. Efforts are being made to conserve banana and citrus *in vitro* and by using cryopreservation.

Comment: Tandon, P. (India): I agree with Dr. Agarwal that conservation of plants requires careful studies. In my opinion, the various methods of preservation like field genebanks, *in vitro* methods and cryopreservation have certain limitation. It is important to understand the materials before attempting to conserve them. For example in the case of mango, attempts are being made to use tissue culture in India. Conservation is a global problem and it requires concerted efforts of all concerned.

Comment: Renveni, O. (Israel): In addition to India, it should be emphasized that *Citrus* is being conserved in Spain. *Musa* is conserved *in vitro* in Belgium, at IITA in Nigeria and *in situ* in Honduras and the Philippines. There are very promising results in the cryopreservation of *Musa*. More effort should be made to adapt the techniques, which requires funding. Before conservation, it is essential to evaluate the specific plants. Indeed it is important to determine the reason why a specific material should be conserved.