CITRUS GENETIC RESOURCES IN INDIA

PRESENT STATUS AND MANAGEMENT

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The **National Bureau of Plant Genetic Resources** (NBPGR), is a nodal organization under the aegis of Indian Council of Agricultural Research (ICAR) for the management of plant genetic resources in India. NBPGR operates as per the mandate of the Government of India and actively contributes to the global efforts in ensuring food and nutritional security. The institute also recognizes the need to integrate *ex situ* and *in situ* conservation approaches in a network mode with all its stakeholders. NBPGR's mission is to ensure the country's agricultural growth and development by ensuring unrestricted availability of germplasm and associated information for use in research, development and utilization as per the national and international legislations.

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View of Nokrek Biosphere Reserve and wild & semi-wild species of Citrus

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Dr. K.C. Bansal
Director

Foreword

Citrus is the third most important fruit crop of India with several species recorded to have originated especially in parts of Northeast. India with World's third highest Citrus production after China and USA, is regarded as home of Citrus due to the presence of vast genetic diversity of important species. Citrus fruits are rich in antioxidants and have nutraceutical properties which make this fruit a prime choice of daily diet in developed countries. Low consumption of fruits and vegetables leading to increase in risk of various diseases in developing countries has now led to public awareness and search for nutritious fruits and juices. Quality planting materials and improved cultivars are the prime need of farmers to increase productivity and quality of citrus fruits. Genetic resources are the backbone of any crop improvement programme and for a diverse fruit like Citrus their importance is incredible. Hence, in the national context management of genetic resources of citrus assumes immense significance.

In the present publication, authors have provided the details of Citrus germplasm management undertaken for the past one and half decades at NBPGR and other institutions in India. The exhaustive survey and exploration to difficult areas of Northeast India for collection of Citrus diversity and wide range of wild and semi-wild species germplasm collected during these explorations is elaborated in this publication. The basic information on origin, distribution, threat perception, variability analyses, description of various species, presence of diverse indigenous and exotic cultivars along with traditional usages and socio-economic importance has been admirably compiled. Data generated in the field and during elaborate experiments undertaken in the laboratory for various cryobanking studies have been presented for several *Citrus* species.

The advent of Convention on Biological Diversity (CBD) and the FAO International Treaty on Plant Genetic Resources for Food and Agriculture

(ITPGFRA) has refocused national and international biodiversity conservation through *in situ* approaches and for economic plants on on-farm, field genebanks and traditional seed genebanks and cryogenebanks. With the realization of value of crop wild relatives (CWR) and landraces, with inherent ability to face vagaries of nature, the concept of handling of entire Crop Genepool rather than single genera and few related species has now advanced. Agrobiodiversity conservation with participatory approach of all stakeholders is still to take visible shape. Collaborative efforts and consultation with other institutions and departments during various PGR management activities have led to this publication on Citrus genetic resources and I congratulate the authors for an excellent compilation.

I am confident this publication would be a useful source of information to environmentalists, horticulturists, PGR workers, seed biologists, policy makers, faculty and students who wish to refer it for their research work. Geographical distribution of Citrus variability keenly surveyed and documented by the authors is a useful guideline for other explorers. Variability assessed as per characterised data represents genetic background for breeders to utilize and select elite types of mother plants for developing specific progenies. Complementarity of different conservation approaches is the need of the hour. The isolated activities of the different institutes spread over the country have been synthesised in this publication to project the overall national perspective. This is to maximise effectiveness of achieving the common goal of successful *in situ* and *ex situ* conservation and utilization of the Indian Citrus germplasm.

I compliment the authors for bringing out this informative publication on Citrus genetic resources reiterating the leading role of NBPGR in Indian PGR management and in this instance for Citrus, the most diverse horticultural crop of India.

(K.C. Bansal)

Preface

Citrus genetic resources spanning across 5 major groups namely, Acids, Oranges, Pummelo-grapefruit, Mandarins, Wild and semi-wild species and other related genera, hold great economic significance for Indian fruit industry. India, a natural home of several *Citrus* species harbours vast reservoir of diverse types/forms. Genetic diversity of Citrus is mainly concentrated in the Northeastern and Northwestern part of India. Study on genetic resources of *Citrus* in Northeastern India indicated the presence of 23 species, one subspecies and 68 varieties, thus according this area a special status as a treasure house of *Citrus* germplasm. Due to the long history of cultivation and natural interspecific crossing among the *Citrus* species vast variability has come up in nature. This caused an ambiguity in identification of different species, cultivars, hybrids, etc and presented a challenging task leading to initiation of deeper investigations. Documentation of present genetic resource status, traditional knowledge associated with these species and economic potential and threat perception of wild and semi-wild species of *Citrus* occurring in India especially in Northeastern parts were essentially required for designing a suitable genetic resources management strategy. Survey, exploration, sustainable utilization, conservation and preservation of invaluable Citrus germplasm have been the priority for NBPGR, India. To protect these invaluable genetic resources of citrus, NBPGR (ICAR) took initiative way back in 1981 by establishing the "Citrus Gene Sanctuary", probably first of its kind in the World, in the Garo hills of Meghalaya. It is endowed with highly specified microclimate and is a part of buffer zone of Nokrek Biosphere Reserve in Meghalaya. With only 12-13% of the earth's surface devoted to protected areas and other conservation areas, it is understandable that all species diversity cannot be secured in them. *Ex situ* conservation, with several options, are thus required to be adopted. Introduction of desirable Citrus germplasm into country by NBPGR and other organizations have enriched the diversity and strengthened the Indian Citrus Industry. With challenge of climate change looming large, wild and weedy relatives assume significance. Due to breadth of genetic diversity present in Citrus, which are adapted to a range of environmental conditions, they are likely to be needed more than ever before to maintain the adaptability of commercial Citrus cultivars. At NBPGR, New Delhi various Citrus accessions collected during explorations from field genebanks, farmer's fields, orchards and natural habitats have been characterised for leaf,

fruit and seed characters using IPGRI descriptors to define range of diversity present and to classify the variability for more than 600 accessions.

It has been pointed out that erosion of genetic resources of *Citrus* due to various biotic and abiotic factors have resulted in loss of gene pools from nature and as well as from different centers of collections. Conservationists face the task of deciding how to best conserve these large *Citrus* species complex. Seed banking is one of the most powerful and practical *ex situ* conservation tools available to combat the loss of biodiversity while complementing the *in situ* conservation. NBPGR has thus worked with integrated approach by cryobanking of seeds, embryos and embryonic axes and a cryobase collection of about 700 accessions has been successfully established. Investigations on 29 species for their seed storage behaviour led to decision making for handling and processing for storage using desired methodology. Accessions wise data of each *Citrus* species for exploration and characterization is provided in this publication. It is important to provide a coherent, coordinated and complementary approach to conservation and utilization of Citrus genetic resources. This publication entails the efforts made by NBPGR for PGR management of Citrus taking into consideration a truly complementary conservation decision making in consultation with other stakeholders and especially in coordination with NRC Citrus, Nagpur, Field Genebanks of SAU's, State Horticulture Stations and most valued Citrus farmers in various parts of India. We gratefully acknowledge everyone who had contributed and assisted whole heartedly in preparation of this publication. We profusely thank all the past Directors of NBPGR who encouraged us to undertake these activities. Authors welcome any valued suggestion from the readers for the improvement of the presented information.

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Contents

1. Introduction

Rich genetic diversity of fruits exists across the tropical and sub-tropical regions of the world, with more than 500 species of fruits estimated to be found in Southeast Asia alone (Rao and Bhag Mal, 2002). The South and Southeast Asia represents above 300 species of native minor fruits (Arora, 1995). This area has been the center of origin of a number of tropical and temperate fruit species, most of which are still growing in wild or semi-wild state and exhibit a sizable variability. India is endowed with a rich genetic diversity of fruits. Tropical fruits constitute a major proportion of the spectrum of fruit diversity available in India. Important tropical fruits mango, banana, citrus, papaya and guava alone are grown in 4.29 m ha out of the total area of 6.32 m ha under fruit crops and account for 81 percent of the total annual fruit production (Anonymous, 2010). These and several other tropical fruit species not only meet the needs of local and export markets for fresh fruit but also contribute substantially to the fruit processing industry. Mango, citrus, banana and guava due to the presence of vast diversity and liking flavour and taste were supported and improved by local fruit growers and horticulturists for wide adoption. The genetic diversity of tropical fruit trees is increasingly threatened; in the case of cultivated species by specialization of production systems in a few varieties only linked to market demand and also by land use changes, and in the case of natural wild species and wild relatives due to habitat loss. The recognition of the value of the genetic diversity of tropical fruits trees in the World and the threats that it faces has led to increasing efforts for their genetic resources management by countries within the tropical and sub-tropical regions (Bhag Mal *et al*., 2011). Tropical fruit basket of India include good number of nutritious fruits namely banana, citrus, mango, pineapple, papaya, guava, jackfruit, litchi, longan, tamarind and custard apple (Singh and Chadha, 1993; Arora and Rao, 1995), with predominant fruits being banana, mango, citrus, papaya and guava. Citrus is the third most important fruit crop of India, with diverse Citrus fruits forming part of daily diet of vast Indian population in one or other way. Starting from common lime and lemon to sweet oranges and mandarins Citrus fruits have become a house hold requirement.

India is one of the 12 mega diversity rich countries of the World possessing three hot spots of biodiversity (Conservation International-Biodiversity hotspots:

http://www. biodiversityhotspots.org). Northeast India falls under the "Indo-Burma Region" of hot spot of biodiversity, which is the richest and one of the most threatened places for plant life on the earth. Several Citrus species and their natural hybrids have been reported to originate and exist in this area, however, this vast indigenous Citrus diversity of India has not been used to its full potential for Citrus improvement programmes.

Documentation of present genetic resources status, traditional knowledge associated with these species and economic potential and threat perception for wild and semi-wild species of *Citrus* occurring in India especially in Northeastern and Northwestern parts is essential for designing the suitable strategies for their survey, exploration, sustainable utilization, conservation and preservation. It has been highlighted that erosion of genetic resources of *Citrus* due to various biotic and abiotic factors have resulted in loss of gene pools from nature and as well as from different centers of collections (Chadha, 1995). Farmers and local people do not prefer to grow the wild and semi-wild species in their field or home gardens due to low or negligible commercial value. All these factors are causing serious imbalance in the genetic resources representation of many *Citrus* species in this area of diversity, which has been classified as a hot spot with regard to threat to citrus biodiversity (Singh and Singh, 2003). Any species or cultivar lost from nature is a loss of unique genetic information contained in it, that had evolved over several generations. As per the International Union for Conservation of Nature and Natural Resources (IUCN) norms seven Indian C*itrus* species are endangered as indicated by threat perception analysis (Singh and Singh, 2003). These species are *C. indica*, *C. macroptera*, *C. latipes*, *C. assamensis*, *C. ichangensis*, *C. megaloxycarpa* and *C. rugulosa*.

Sustainable *in situ* and on-farm conservation is possible with active synergies with farmers, communities and national institutions. Role of farmers as active partners, conservator, promoter and custodian of local citrus diversity need to be recognised. Realising the role of *ex situ* conservation and analysing the advantages and disadvantages of all the current options available for Citrus Plant Genetic Resources (PGR), various attempts made so far need compilation. The present publication is a consolidation of information on various aspects of genetic resources management of Citrus and its wild species in India. Basic and applied studies especially for exploration, collection, characterization and conservation made by NBPGR and other centres involved in citrus research in India have been described in detail.

2. Genetic Resources Management

2.1 Genus *Citrus*

The genus *Citrus* L. belongs to the subtribe Citrinae, tribe Citreae, subfamily Aurantioideae of the family Rutaceae (Swingle and Reece, 1967). It is characterized by few diagnostic characters: shrubs or small to large trees; stem usually angular and spiny; leaves unifoliate usually with narrow to broadly winged petiole and pellucid dots (oil glands) on leaf surface; fruit a hesperidium (a type of berry with a leathery adherent pericarp, spongy or fibrous mesocarp and fleshy endocarp filled with pulp vesicles containing sour or sweet juice). *Citrus* species have diploid chromosome number (2n = 18), but some species show polyploidy (27 and 36 chromosomes) (Cameron and Frost, 1968; Guerra, 1984). *Citrus* is a diverse genus with species having vast phenotypic variations in tree and fruit characters. Some of the major citrus fruit types of the world are, Citron [*C. medica* L.], Lemon [*C. limon* (L.) Burm. *f.*], Lime [C. *aurantifolia* (Christm.) Swingle], Mandarin [*C. reticulata* Blanco], Sour orange [*C. aurantium* L.], Sweet orange [*C. sinensis* (L.) Osbeck], Pummelo [*C. maxima* (Burm.) Merr.], Grapefruit [*C. paradisi* Macf.] and Kumquats [*C. microcarpa* Bunge].

Hodgson (1965) provided detailed account on taxonomy and nomenclature of the citrus fruits in a book 'Advances in Agricultural Sciences and Their Applications'. He placed various citrus fruits into five groups based on their fruit characters:

(1) Acid members group: 7 species, i.e. *C. medica* L., *C. limon* (L.) Burm. f., *C. jambhiri* Lush., *C. limmetta* (Risso) Lush., *C. karna* Raf., *C. aurantifolia* (Christm.) Swingle, *C. latifolia* Tanaka and *C. limettioides* Tanaka.

(2) Orange group: 5 species, i.e. *C. aurantium* L., *C. myrtifolia* Raf., *C. bergamia* Risso, *C. natsudaidai* Hayata and *C. sinensis* (L.) Osbeck.

3) Pummelo-grapefruit group: 2 species, i.e. *C. maxima* (Burm.) Merr. and *C. paradisi* Macf.

(4) Mandarin group: 6 species, i.e. *C. reticulata* Blanco, *C. unshiu* Marcov., *C. deliciosa* Tenore, *C. tangerina* Hort. ex Tanaka, *C. reshni* Tanaka, and *C. nobilis* Lour.

(5) Other species group (according to Tanaka system): 11 species, i.e. *C. macroptera* Montr., *C. hystrix* DC., *C. latipes* (Swingle) Tanaka, *C. macrophylla* Wester, *C. limonia* Osbeck, *C. pennivesciculata* Tanaka, *C. maderaspatana* Tanaka, *C. junos* Seibold, *C. ichangensis* Swingle, *C. indica* Tanaka and *C. madurensis* Lour.

2.2 Centre(s) of Origin

Citrus is believed to have its primary centre of origin in South and South-East Asia, particularly in the region extending from Northeast India, eastward through the Malayan Archipelago to China and Japan, and southward to Australia and also to New Caledonia and New Guinea (Tanaka, 1954; Webber, 1967; Scora, 1975, 1988; Gmitter and Hu, 1990; Mabberley, 2004; Pfeil and Crisp, 2008; Bayer *et al*., 2009). The Citrus belt of the world extends approximately 35^{O} N and 35^{O}S latitude on either side of the equator. Citrus fruits are widely cultivated throughout the tropical and sub-tropical regions of the world, most of them located far away from their actual centers of origin (Webber, 1967).

Probable centers of origin of twenty important *Citrus* species based on various literature survey are summarized in Table 2.1.

Table 2.1. The principal *Citrus* species with probable centres of origin in Asia

S. No.	Species	Common name	Probable centre of origin
1.	*C. medica* L.	Citron	India
2.	*C. limon* (L.) Burm. f.	Lemon	Eastern Himalaya
3.	C. *aurantifolia* (Christm.) Swingle	Sour lime	India
4.	*C. limmetta* (Risso) Lush.	Sweet lime	None
5.	*C. jambhiri* Lush.	Rough lemon	Northeast India
6.	*C. karna* Raf.	Karna khatta	India
7.	*C. reticulata* Blanco	Mandarin	Cochin-China
8.	*C. tachibana* (Makino) Tanaka	Tachibana	Japan
9.	*C. indica* Tanaka	Indian wild orange	Northeast India
10.	*C. maxima* (Burm.) Merr.	Pummelo	Polynesia and Malay
11.	*C. megaloxycarpa* Lush.	Sour pummelo	Western India
12.	*C. aurantium* L.	Sour orange	India

13.	*C. sinensis* (L.) Osbeck	Sweet orange	Southern Indo-China
14.	*C. paradisi* Macf.	Grapefruit	West-Indies
15.	*C. latipes* (Swingle) Tanaka	Khasi papeda	Northeast India
16.	*C. macroptera* Montr.	Melanesian papeda	Southeast Asia
17.	*C. ichangensis* Swingle (= *C. cavaleriei* H. Leveille ex Cavalerie)	Ichang papeda	Southwest China
18.	*C. hystrix* DC.	Maurituis papeda	Southeast Asia
19.	*C. micrantha* Wester	Micrantha Papeda	Phillippines
20.	*C. assamensis* Dutta & Bhattacharya	Ada-jamir	Northeast India
21.	*C. pseudolimon* Tan.	Galgal	India

2.3 Production of Citrus Fruits

The global production of citrus fruits in the year 2010 was 123694474 tonnes in a total area of 86,45,339 hectares. China, Brazil, India, USA, Mexico, Spain and Iran are the leading citrus producing countries (Table 2.2) of the world (FAOSTAT, 2012). Production of top two countries China (19.35%) and Brazil (17.24%) accounted for more than 36% of the total global citrus fruits production, while India is at the third rank and has contributed only 8.40% of the total global production. In India area under the Citrus production is 987 (000HA) and production is 9638 (000MT) which amounts to the productivity of 9.8 MT/HA (Anonymous, 2010).

Andhra Pradesh state is the highest producer of Citrus fruits with 38837 (000MT) production and 13.8 MT/HA productivity while Maharashtra is the second largest producer state with 1725.1 MT production but very low productivity of 6.0 MT/HA. Other important states for Citrus production are Punjab, Madhya Pradesh, Gujarat, Rajasthan, West Bengal and all Northeast Indian states, with highest productivity recorded up to 21.3 MT/HA in Punjab.

The major citrus producing states and districts and commercial cultivars grown in different zones of india are as follows :

1. Northwestern Zone:

· Jammu & Kashmir (Jammu, Kathua, Udhampur and Rajauri)

Table 2.2. Global citrus fruits production (in tonnes)

Country	Pummelos and Grapefruits	Lemons and Limes	Oranges	Tangerines, etc.	Others	Total (%)
China	2868750	1058105	5003289	10121000	4886900	23938044 (19.35)
Brazil	72100	1020350	19112300	1122730	—	21327480 (17.24)
India	**260300**	**3098900**	**6268100**	**—**	**764300**	**10391600 (8.40)**
USA	1123090	800140	7478830	539770	43700 (8.07)	9985530
Mexico	400934	1891400	4051630	409442	103600 (5.54)	6857006
Spain	43200	578200	3120000	1708200	6800 (4.40)	5456400
Iran	46500	706800	1502820	276138	87000 (2.12)	2619258
World	**6957837**	**14244782**	**69416336**	**21311892**	**11763628**	**123694474**

Source: http://www.faostat.fao.org, visited on 27/06/2012.

- Himachal Pradesh (Kangra and Sirmaur)
- Punjab (Abohar, Fazilka, Faridkot, Batinda and Hoshiarpur)
- Haryana (Sirsa, Fatehabad, Hisar and Bhiwani)
- Rajasthan (Shriganganagar, Jhalawar, Bharatpur, Dholpur and Sawai Madhopur)

Commercial cultivars:

Mandarin- Kinnow;
Sweet oranges- Jaffa, Malta, Blood red, Valencia, Hamlin and Pineapple
Acid lime - Kagzi lime, Vikram, Kagzi Kalan
Lemon- Galgal, Eureka, Baramasi, Pant lemon 1, 2 and 3
Pummelo- Chakotra
Grapefruit- Duncan, Marsh seedless, Foster and Ruby red

2. Northeastern Zone:

- West Bengal (Darjeeling, Jalpaiguri, Midnapur and 24 Pargana (N),
- Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura

Commercial cultivars:

Mandarin - Khasi mandarin, Sikkim or Darjeeling mandarin
Sweet oranges - Malta, Tasi, Sohbitara, Soh-nariang, Mitha chakola, Ruby, Blood red, Valanecia
Acid lime - Kagzi lime, Vikram, Kagzi kalan
Lemon- Assam lemon, Pant lemon and Chinara
Pummelo- Kanapora, Batabi, Bhogote, Sah-myngor, Sagothra, Rabab, Jambura and Der-tawk
Grapefruit- Duncan, Marsh seedless and Ruby red
Others- Satkara

3. Central Zone:

- Madhya Pradesh (Mandsaur, Shajapur, Chhindwara, Khandwa and Hoshangabad)
- Maharashtra (Amravati, Nagpur, Akola, Aurangabad, Wardha and Yevatmal)
- Orissa (Ganjam), Uttar Pradesh and Bihar

Commercial cultivars:

Mandarin- Nagpur mandarin
Sweet oranges- Mosambi, Malta
Acid lime-Baramasi, Vikram, Jai devi, Pramalini, Sai Sarbati
Lemon- Bhadri lemon, Pant lemon
Pummelo- Chakotra, Mahatabi, Gagar
Grapefruit- Saharanpur special, Duncan, Marsh seedless Ruby red

4. Southern Zone:

- Andhra Pradesh (Nellore, Prakasam, West Godavari, Guntur, Kuddapa, Anantpur, Nalgonda and Karimnagar)
- Tamil Nadu (Dindgual Anna, Trichy, Tirunelveli and Kattabomman) Karnataka (Bijapur, Bagalkot, Chitradurga, Raichur, Bellari, Koppal, Korlagu, Chikmagalur and Hassan).

Commercial cultivars:

Mandarin- Coorg mandarin
Sweet oranges- Satgudi, Sonamitri
Acid Lime- Pramalini, Vikram, PKM-1
Lemon- Tirupati, Coorg Lime, Pant lemon, Sylhet lime, Gajanimma
Belladikithuli- Baduvapuli, Valadipudi, Khichli

In India all the four zones are important for commercial Citrus production where different citrus types and cultivars are grown and increase in area and production is noticed every year (Fig. 2.1). Maharashtra and Andhra Pradesh are important states for Citrus cultivation, much ahead of other Indian states (Fig. 2.2)

2.4. Indian Citrus wealth

India has a distinct position in the 'Citrus belt' of the world due to remarkable diversity in citrus genetic resources, both in cultivated and wild species. Apart from the most commonly cultivated species/hybrids, such as citrons, lemons, limes, mandarins, sour oranges, sweet oranges, pummelos and grapefruits, four species, viz. Indian wild orange, Khasi papeda, Ichang papeda, and Melanesian papeda were recorded to occur in wild or semi-wild state in Northeast India (Brandis, 1874; Bonavia, 1888-90; Lushington, 1910; Tanaka, 1937; Cheema and Bhatt, 1934; Bhattacharya and Dutta, 1956; Swingle and Reece, 1967; Singh, 1967; Singh and Nath, 1969; Nair and Nayar, 1997; Singh and Singh, 2001; Sharma *et al.,* 2004; Malik *et al*., 2006).

Natural diversity of Citrus in India has also contributed to the development of several distinct indigenous cultivars/land races/ natural hybrids known under *C. assamensis* Dutta & Bhattacharya (Ada- Jamir or Ginger lemon of Assam), *C. jambhiri* Lush. (rough lemon), *C. karna* Raf. (Karna Orange or Karna- khatta), *C. limetta* Risso (Sweet lime), *C. limettioides* Tanaka (Sweet lime), *C. megaloxycarpa* Lush. (Sour pummelo), *C. pseudolimon* Tanaka (Hill lemon), etc., which occur mostly in Northeast India and in the Northwestern Himalayas. Bhattacharya and Dutta (1956) recorded 17 species, 45 horticultural varieties and five hybrids of *Citrus* in Northeast India. These indigenous genetic resources have great utility in citrus improvement programmes. The diverse eco-geographical distribution and the occurrence of spontaneous mutations and natural hybridization have given rise to a wide range of variability in *Citrus* and related genera. Singh and Chadha (1993) listed 30 *Citrus* species and botanical varieties that are indigenous to India or have been domesticated here for a very

long time. It is interesting to note that out of 30 *Citrus* species available in India at least 9 species are available throughout India, whereas 15 species are confined to Northeastern India, 9 species to South India, 6 species to Northwestern India and 1 species to central India (Table 2.3).

Table 2.3. Important indigenous and exotic cultivars of *Citrus* cultivated in India

Citrus group	Cultivars		Areas of cultivation
	Indigenous	Exotic	
Mandarins (*C. reticulata*)	Nagpur mandarin, Khasi mandarin, Sikkim mandarin, Coorg mandarin, Laddu, Butwal, Hazara, Srinagar	Kinnow mandarin, Honey, Wilking, Fewtrell's Early, King, Willow leaf, Orlando, Temple, Fairchild, Fremont, Dancy, Ponkan, Kamla Australia, Fox mandarin, Thorny mandarin, Fortune, Afourer	Maharashtra, Madhya Pradesh, Northeastern states, Darjeeling, Sikkim, Coorg region of Karnataka, Punjab, Rajasthan, Haryana
Sweet orange (*C. sinensis*)	Mosambi, Satgudi, Sonamitri, Loyalpur S-1, Loyalpur S-2, Mitha chakola, Tasi, Chakola tenga	Jaffa, Hamlin, Malta, Valencia late, Pineapple, Blood red, Washington naval, Olinda Valencia late, Delta Valencia, Campbell Valencia, Vanale, Moro, Rhode Red Valencia, Parent naval, Declarbe sweet orange, Vaniglia sanguigno, Sweet orange, Teneriff, Tardiff, Seleta, Aspal orange, Joppa	Maharashtra, Andhra Pradesh, Punjab, Rajasthan, Northeastern states
Acid lime (*C. aurantifolia*)	Kagzi lime, PKM-1, Vikram, Pramalini, Sai Sarbati, Kagzi Kala, Tenali and Tirupati, Coorg	Tahiti lime	Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra

	Lime, Akola lime, Mungalipattu, Sylhet lime		
Lemon (*C. limon*)	Hill lemon, Assam lemon, Galgal, Baramasia, Pant lemon 1,2,3, Bhadri lemon, Chinara, Kagji kalan	Eureka lemon, Italian lemon, Lesban lemon, Seville, Harvey lemon no.252,No.302,Villa franca	Uttar Pradesh, Himachal Pradesh, Assam and North-eastern states, Karnataka, Uttar Pradesh
Pummelo (*C. maxima*)	Chakotra, Gagar, Red flesh, White flesh, Pink fleshed, Kanapora, Bhogote, Sah myngor, Sagothra, Rabab, Jambura, Ser tawk, Devanahalli-1. 2, Midnaapur sel-1, IKP-1, IKP-2	Sweet China, Royal, Triumph, Foxey	Northeastern states, Foothills of Northwestern Himalayas, parts of Bihar, Uttarakhand, Uttar Pradesh, Orissa
Grapefruit (*C. paradisi*)	Saharanpur special, Serbial, Champa umtambi	Duncan, Frost marsh, Marsh seedless, Ruby red, Foster pink, Red blush, Thompson seedless, Smooth flat	Northeastern Region, and parts of Uttarakhand, Himachal Pradesh, Punjab, Rajasthan
Citron (*C. medica*)	Bira jora, Pati jora, Jora tenga, Gandhraj, Pongam, Soh manong, Mitha jora, Tayum, Themachhi, Bemberia	Etrong citron	Northeastern states, foot hills of Northwestern and Central Himalayas, Punjab, and peninsular region of India
Citrus group	**Rootstocks**		**Areas of cultivation**
	Indigenous	**Exotic**	
Rough lemon (*C. jambhiri*)	Jatti-khatti, Jullandhari khatti, Jambhiri, Mithi, Renuka lemon,	EC-25833, Florida rough 8748, Rough lemon, South Africa,	Northeastern and foot hills of Northwestern and Central Himalayas,

	Wynad rough lemon, Gol nimbu, Kata jamir, Sinduri lemon, Naity jamir	Italian rough, Esteus rough	Punjab, and southern peninsular region
Karna khatta (*C. karna*)	Khatta, Duranj		Western Himalayan region
Small Mandarins (*C. reshni, C. maderaspatana*)	Billikichilli, Belladikithuli, Kodakithuli	Cleopatra mandarin, EC-18089	Field genebanks, gardens, backyards and orchards in Andhra Pradesh and other parts of India
Trifoliate orange (*Poncirus trifoliata*)	-	Flying dragon, Pomeroy, Rubidoux, Trifoliate Florida, EC-31974, Dweat tangor	Field genebanks, NRCC, Nagpur, PAU RS, Abohar and others
Sour orange (*C. aurantium*)	Karun Jamir, Sohmyndong, Mole kaipuli	Seville orange	Nagaland, Meghalaya, Assam
Rangpur Lime (*C. limonia*)	Rangpur lime L-19, Sharbati lime, Kusai lime, Kole jamir	EC-115795, Florida Rangpur- 8747, 8748	Northeastern India, Parts of Central and South India
C. macrophylla	-	Alemow	Field genebank of NRC Citrus, Nagpur
Other hybrids		Citranges cv. Troyer citrange (EC-22050), Carizo, Savage, Yama, Citremone, Citrumelos	Field genebanks of NRCC, Nagpur, PAU RS, Abohar and other field genebanks

2.5 Economic importance of Citrus

Citrus genetic diversity of India represented by several wild and cultivated species of *Citrus* have great potential for improvement of Citrus industry and also used for several nutritional and medicinal purposes. Citrus fruits are good sources of citric acid, flavonoids, phenolics, pectins, limonoids, ascorbic acid, etc. (Dugo and Digiacomo, 2002). The dietary, nutritional, medicinal and cosmetic properties of citrus fruits are well documented (Swingle and Reece, 1967; Dugo

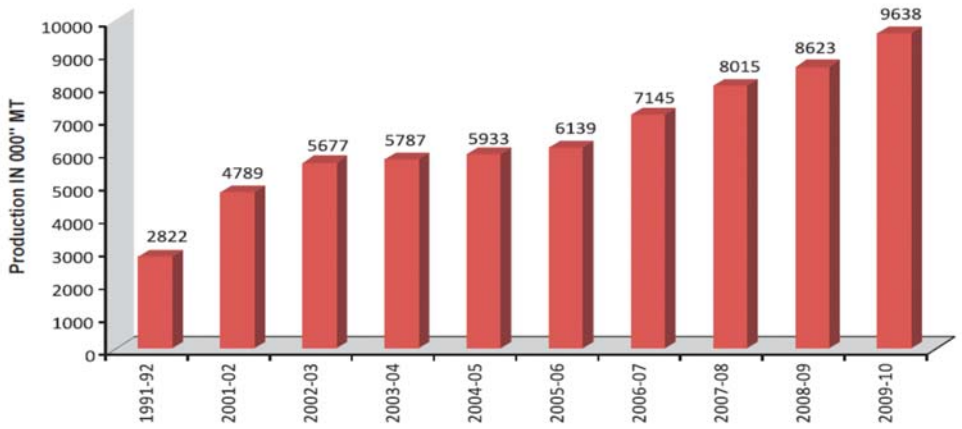

Fig. 2.1. Production trends of Citrus in India from 1991 to 2010. (Source: NHB database, Anonymous, 2010)

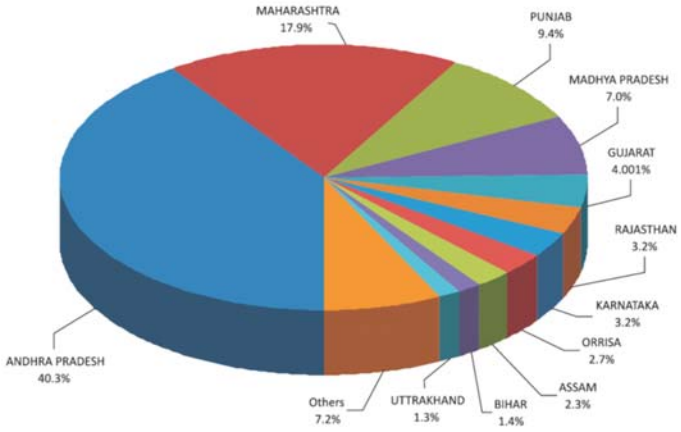

Fig. 2.2. Leading citrus producing states of India during 2009-10. (Source: NHB database, Anonymous, 2010)

and Digiacomo, 2002). Recent pharmacological studies support the traditional medical applications of citrus fruits in scurvy, obesity, cancer, HIV/AIDS, contraception, cough, and reducing blood pressure (Mabberley, 2004). Oranges are used for treatment of cold, fever, liver disorders, gall bladder problems, acne, and ringworm (Govindachari *et al.,* 2000; Inbesi and Pasquale, 2002; Bisignano and Saiya, 2002; Mabberley, 2004; Arias and Laca, 2005). Modern scientific studies confirm the utility of lemon fruit as antipyretic, and as a remedy for loss of appetite and haemorrhoids (Arteche Garcýa, 1998). The lemon and citron juice is used by traditional healers for treating snake bites in Northwestern Colombia. Citrus fruits are used for curing total tooth loss and prevalent cardiovascular disease in men and women (Lowe *et al.,* 2003). Citrus fruits contain many secondary metabolites, viz. ascorbic acid, flavanones, phenolics and pectin, which show antioxidant properties and are important to human nutrition. Anti-oxidant property has been reported in fruit extracts of *Citrus medica* (citron) and *C. sinensis* (blood orange) (Jayaprakasha and Patil, 2007). Limonoids are the secondary metabolites found in all citrus fruits, which showed anti-cancerous activities (Tian *et al.,* 2001). In a recent study, citrus components such as pectin, pulp, naringin and limonin showed anti-proliferative activity against colon cancer (Vanamala *et al.,* 2006). Further, several citrus flavonoids were examined for anti-cancerous activity against various stages of colon cancer, in which apigenin and naringenin were more efficient than the hesperidin and nobiletin (Leonardi *et al.,* 2004). Citrus flavonoids and limonoids, present in leaves and fruits, are also used for the fragrance. Besides several pharmaceutical and edible uses of Citrus fruits, various wild and semi-wild species and local cultivars have socio-economic and religious importance in specific tribes and community groups (Malik *et al*., 2006). Ethno-botanical studies revealed that local inhabitants and various tribes of Northeast India have been using different parts of these plants especially fruits for various economic purposes. Besides the commercially cultivated *Citrus* species, several important species like Memang narang, Melanesian papeda, Khasi papeda, Sour pummelo and Ada-jamir are found to grow in Northeast India in wild and semi-wild state (Singh and Singh, 2003; Sharma *et al.,* 2004; Malik *et al*., 2006). These wild and semi-wild species of Citrus have great socio-economic, cultural and religious importance and are important gene sources for agronomic traits like disease resistance, cold tolerance, etc.

Socio-economic importance of Citrus wild, semi-wild species and local cultivars is of great relevance especially for tribal population and marginal farmers in remote areas of Northeast and Northwest Himalayas. Several farm communities

and tribals farmers inhabited in the remote areas of Northeast and Northwestern India are earning their livelihood from these fruits and some of these rare species are of major livelihood support for them (Fig. 2.3 B-F). Due to the lack of infrastructure facilities, backend operations and processing facilities tribal farmers have to carry their fruits in specially designed baskets (Fig 2.3 A,B) from farm to local markets, some times 15-20 km away, on their backs in remote areas of Northeast India. There is an urgent need to develop marketing facilities and value chain for these fruits in such areas. There are some examples where at the initiative of the farmers communities, such operations have been successfully undertaken and processing of fruits at farm itself is providing good income and livelihood support to them. Citrus community garden of Kachai lemon (*Citrus jambhiri*) in Kachai village of Uhkrul district of Manipur in Northeast India is being successfully managed by village head and providing livelihood support to local inhabitants (Sthapit and Singh, 2012). Such models may be replicated for different local Citrus types having commercial importance in other parts of Northeast India to provide livelihood support and also serve the purpose of *in situ* on-farm conservation.

2.6 National and International PGR Status

2.6.1 National Status

In India Citrus genetic resources are being managed by multiple agencies such as research institutes of Indian Council of Agricultural Research (ICAR), State Agricultural Universities and also by the State Horticultural Farms, and Fruit Research Stations. Besides these several private nurseries, orchards, gardens, parks etc. which are owned by progressive farmers and public enterprises are also maintaining Citrus germplasm as field collections. Citrus research in India especially the genetic resource management and citrus improvement needs to be given more impetus at par with that existing in other countries like USA and China. India being the treasure house of indigenous germplasm of several species and home of important commercial citrus species still lags behind in production and productivity due to less emphasis on research, development and availability of quality planting material. Major drawback is the development of cultivars suitable for the indigenous cultivation which are adaptable to diverse edapho-climatic situations existing in India. Presently, rare Indian wild species germplasm has hardly been utilized for Citrus improvement programmes in india. Most of the commercial cultivars are introduced from the exotic sources and some of them have adapted fairly well to the Indian conditions e.g. Kinnow.

Fig. 2.3. Citrus marketing operations in Northeast India, A- Women carrying citrus fruits on their backs to market, B- Local Citrus fruit market in Sikkim. C- Roadside shops of Citrus fruits, D- Traditional healer selling *C. indica* fruits as medicine, E&F- Locally processed products of Citrus fruits being sold in roadside shops and in remote villages

Diverse suitable area having potential for Citrus cultivation especially Northeast India is unable to produce to its fullest capacity due to non-availability of quality planting material, poor agronomic pracitices and onset of diseases. Lack of technology, expertise and infrastructure with public and private nurseries is leading to poor services to farmers affecting productivity.

In India National Research Centre for Citrus (NRCC), of ICAR, located at Nagpur in Central India is the only dedicated institute for Citrus research, development and extension. This Centre has also been designated as National Active Germplasm Site (NAGS) for Citrus by NBPGR. Besides undertaking Citrus improvement programmes, production and protection, this centre takes up the germplasm collection, field maintenance, characterization, evaluation, supply and other genetic resources management activities. Other ICAR and CSIR national institutes such as Indian Institute of Horticultural Research (IIHR, Bangalore), National Bureau of Plant Genetic Resources (NBPGR, New Delhi) and National Botanical Research Institute (NBRI, Lucknow) are also undertaking research and management of Citrus genetic resources. State Horticulture Departments, State Agricultural Universities (SAUs) and some private nurseries and companies are also taking up germplasm maintenance and improvement in different parts of India. Some progressive farmers are taking up Citrus germplasm conservation and maintenance due to their passion and love for this wonder fruit. Diverse type of Citrus trees are being maintained in their orchards or farms not for any economical gains but for the sake of diversity conservation. One of the fascinating example is of Late Sardar Kartar Singh Narula, Udhyan Pandit promoter of Layalpur Farm/Nursery at Sri Ganganagar, Rajasthan who has been maintaining 50-60 different types of Citrus accessions since last several years and also taking up selection and improvement work. Similarly, in the Darjeeling district of West Bengal a Citrus garden with more than 50 different types of Citrus including indigenous and exotic collections is being maintained by a famous progressive farmer, Mr. Gambhir Das Gurung of Bara Mangwa Busty. These progressive farmers are providing germplasm to various stakeholders and also evaluating and improving it. All India Coordinated Research Project (AICRP) on Tropical Fruits (Citrus) of ICAR with its Network at nine centres (Table 2.4) at SAU's and ICAR institutes in various agro-ecological regions of India has been taking up work on genetic resources management, crop improvement, crop production and crop protection. Since last several decades crop specific responsibilities for multi-location evaluation and improvement work has been assigned to these centres.

2.6.2 International Status

Citrus being a diverse crop is cultivated in almost all the parts of World, however, with origin being in the Southeast Asia, maximum diversity and genetic resources are available in Asian and Australian countries. Countries with well organised National Plant Genetic Resources System like USA have build up an international collections in the field genebanks during early nineteenth century, while genetic resources rich countries in Asia depended more on the existing natural diversity with them. Consequently, germplasm resources assembled in the field genebanks have been amply utilized in developed countries for breeding work. Several selections and hybrid varieties have been released using these genetic resources. Some of these varieties of sweet oranges and mandarin have benefited the other countries in Asia, Europe and Australia. Introduction of varieties like Kinnow mandarin have largely benefited the countries in South Asia like India and Pakistan. Status of World citrus genetic resources have been compiled in the first report of 'The State of the World Plant Genetic Resources for Food and Agriculture' (http://apps3.fao.org/wiews/docs/swrfull.pdf) and presented to the Fourth International Technical Conference on Plant Genetic Resources held in Leipzig, Germany, in June 1996, and published in 1998 reporting only 6,174 accessions in the World. While the second report on World Status of PGR (http://www.fao.org/docrep/013/i1500e/i1500e.pdf) which was published recently in the year 2010 to update the information in the first report, indicated 29,690 accessions of Citrus in the World. Apparently there is a tremendous increase in the germplasm holdings of the nations approximately by five times during the past decade. This may be due to the limited information presented in the first report, probably lacked from some sources. The germplasm details provided in these reports only provided numbers for wild species, landraces, breeding lines, advance cultivars and most dominantly the mixture of all of these types of germplasm. This general information does not serve much useful purpose for any horticulturist or germplasm curator as Citrus being a diverse genus specific information is required for utilization of germplasm. For better management of World Citrus genetic resources for conservation and utilization, FAO in 1997, constituted the Global Citrus Germplasm Network (GCGN) to involve national institutions and existing regional and inter-regional citrus networks such as, the Inter-American Citrus Network (IACNET), MECINET, IACNET, CLAM and NeSCRA. The main objective of this network was to link germplasm related activities undertaken in the different parts of the World. However, the present status of existence of the GCGN could not be ascertained as the last proceedings of GCGN countires meeting available on

various Citrus related websites is of the year 2000. Even if this network exists there is need to have more proactive role by involving countries from all over the World to facilitate genetic resources exchange and utilization for Citrus improvement.

2.7 Exploration and Collection

Collection of *Citrus* genetic diversity from Northeastern parts of India was taken up intensively by Tanaka (1928; 1937) and Bhattacharya and Dutta (1956) during 3rd to 5th decade of last century. Most of the new *Citrus* species were identified, collected and documented from Northeastern parts of India during this period. Since then, no significant information has been added to our knowledge about the occurrence of any additional species of *Citrus* from this region. However, recent surveys and explorations enumerated loss of some species and local types from various pockets where these were earlier reported to occur (Singh and Singh, 2003; Malik *et al.*, 2006). Study on genetic resources of *Citrus* in Northeastern India indicated the presence of 23 species, one subspecies and 68 varieties, thus according this area a special status as a treasure house of *Citrus* germplasm (Sharma *et al.,* 2004). Some of the C*itrus* species still grow in a wild or semi-wild form in the forestlands. Natural populations of these species are shrinking drastically due to large-scale deforestation to meet the land requirement for cultivation in the Himalayan region (Ahuja, 1996). Therefore, there is an urgent need to collect this vast genetic diversity and document the ethno-botanical as well as indigenous technical knowledge about the *Citrus* species particularly from Northeastern India.

During last one and half decades, NRCC, Nagpur and NBPGR, New Delhi under the National Agricultural Technology Project (NATP) and also as

Table 2.4. Centres of AICRP on Tropical Fruits (Citrus) in India

Centre	University/institutes involved	Citrus crop group
Akola	Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra	Nagpur mandarin, Acid lime
Chethali	IIHR Regional station, Chethali, Karnataka	Coorg mandarin
Ludhiana	Punjab Agricultural University, Ludhiana, Punjab	Kinnow mandarin, Acid lime
Periyakulam	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	Acid lime

Pune	IARI Regional station, Pune, Maharashtra	Acid lime
Pusa	Rajendra Agricultural University, Samastipur, Bihar	Acid lime, Pummelo
Rahuri	Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra	Sweet orange, Acid lime
Tinsukhia	Assam Agricultural University, Jorhat, Assam	Khasi mandarin
Tirupati	Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh	Acid lime, Sweet orange

Source: http://www.iihr.ernet.in/aicrp/

institutional priority, undertook extensive explorations and survey programme of citrus in various parts of India. During these explorations vast diversity of various *Citrus* species representing important rootstocks species, mandarins, acid lime, pummelo, grapefruit and sweet oranges along with the indigenous wild species were collected (Singh and Singh, 2003; Malik *et al*., 2006; Malik *et al.*, 2012a). During these explorations major emphasis of NBPGR was on collecting diversity of wild, semi-wild and endangered *Citrus* species such as *C. indica*, *C. ichangensis*, *C. megaloxycarpa*, *C. macroptera* and *C. latipes* from entire Northeastern India and for which specific explorations were undertaken during 2003 to 2011 as a misson mode programme. Since last four decades germplasm representing sizable diversity of cultivated, wild and rootstocks species and several intermediate Citrus types have been collected during various explorations undertaken in India and national identity for more than 1400 accessions has been obtained from NBPGR (Table 2.5, Fig. 2.4). Accessions wise passport data of each species is provided in respective chapters dealing in that Citrus group.

2.8 Germplasm Introduction and Exchange

Introduction of citrus germplasm have been initiated since 1940s in India. Large number of exotic collections both scion and rootstocks were introduced at Indian Agricultural Research Institute, Pusa; Fruit Research Station, Abohar; Citrus Experiment Station, Chethali; Citrus Experiment Station, Shrirampur and Tirupati; Indian Institute of Horticultural Research and National Research Centre for Citrus, Nagpur. One of the successful and commercially important introductions of Citrus in India is "Kinnow Mandarin" introduced by Dr. J.C. Bakshi in 1954 at Abohar, Punjab from California (USA). This cultivar has been very well adapted now to the Northwestern parts of India especially Punjab, Haryana and Rajasthan and is providing very good income to farmers. This

Table 2.5. Number of collections of Citrus species made from various States during explorations by NBPGR and NAAS

S.No.	State	Total Collections
1	Andaman and Nicobar Islands	14
2	Andhra Pradesh	50
3	Arunachal Pradesh	86
4	Assam	84
5	Delhi	11
6	Gujarat	42
7	Himachal Pradesh	101
8	Jharkhand	4
10	Karnataka	16
11	Kerala	11
12	Madhya Pradesh	10
13	Maharashtra	85
14	Manipur	45
15	Meghalaya	273
16	Mizoram	119
17	Nagaland	23
18	Orissa	19
19	Punjab	91
20	Rajasthan	42
21	Sikkim	29
22	Tamil Nadu	10
23	Tripura	19
24	Uttar Pradesh	70
25	Uttarakhand	221
26	West Bengal	21

introduction has brought the "Golden Revolution" in the Citrus Industry of Northwestern India (Kaul and Aulakh, 2012). Other important introductions include several sweet orange, mandarin, lime and lemon varieties and hybrids from Europe, USA and Australia namely Valencia Late, Washington Navel, Jaffa, Malta Blood Red, Pineapple, Shamouti, Ruby Orange, Satsuma, Dancy tangerine, Clementine, Cleopatra, Wilking, Temple, Duncan, Marsh seedless, Lisbon lemon, Spora lime, Trifoliate orange, Ichange lemon, *C. hytrix* and *Microcitrus australis* (Dutta, 1958). Important rootstock Alemow (*Citrus macrophylla* Wester) native to the island of Cebu, Philippines introduced long back has proved to be the best rootstock for Nagpur mandarin and Acid lime and is gaining importance in India.

During 1956-2001, 268 exotic accessions were introduced at Indian Institute of Agricultural Research (IARI), however, presently only 23 accessions are existing in their field genebank (Pandey and Singh, 2004). Similarly at NRC Citrus, Nagpur which is an Active Germplasm Site for Citrus in India, 30 scions and 19 rootstocks mostly introduced from USA, France, Japan, Australia and Niger are existing (Singh *et al*., 2000). Regional Fruit Research Station, Punjab Agricultural University, Abohar is maintaining maximum 75 accessions of citrus germplasm introduced during 1956 to 1989 from USA. Vegetative and reproductive performance of these introductions has been evaluated and found satisfactory at these centers (Singh *et al*., 2000). Recently, in 2009-10 important germplasm of Citrus have been introduced from Brazil. These included Satsuma (*C. unshiu*), Clementine (*C. clementina*), Mandarin/Tangerin (*C. reticulata*), Sweet orange varieties (*C. sinensis*) (Singh *et al*., 2012). More than 262 accessions belonging to *C. limon, C. paradisi, C. reshni, C. limonia, C. grandis, C. jhambiri, C. obovoldea/ obovoidea, C. medica, C. clementina, C. sinensis, C. volkamariana, C. reticulata, C. unshiu, C. grandis, C. aurantium, C. jambhiri, C. shunkokan, C. wilsonii, C. unshiumarc, C. canaliculata, Citrus* hybrid, *Poncirus trifoliata* and *Fortunella* species have been introduced into India through NBPGR Exchange Unit since 1984 till to date from Egypt, USA, Brazil, Nigeria, New Zealand, Japan, Israel, France, Australia, Nepal and Peru. Private nurseries and some multinational companies in collaboration with State Horticulture Departments are also importing Citrus germplasm in India for research and commercial purposes. Citrus being an Annex-1 crop of Internationl Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) can be exchanged under the Standard Material Transfer Agreement (SMTA). Safe movement of Citrus germplasm and planting material from one country to another is ensured using various techniques available such as chemotherapy, thermotherapy, cryotherapy and various tissue culture based techniques namely ovule culture, nucellar culture and shoot tip grafting (Vijaya Kumari and Reddy, 2012).

Citrus germplasm and varieties have been amply exchanged even before 1947 within India where several new introductions were exchanged with existing and new orchards, state horticulture farms/ nurseries, Regional Fruit Research Stations and field genebanks and hence moved from one place to another. This exchange has amply benefited the farmers and commercial Citrus producers of various states from time to time.

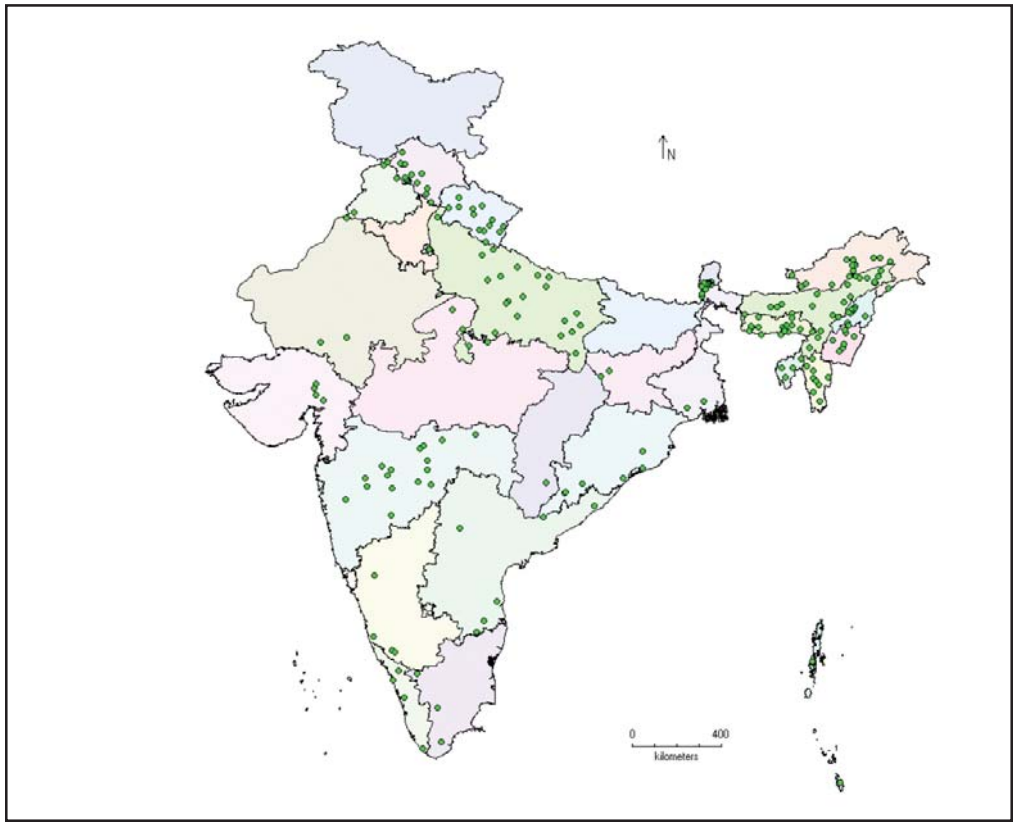

Fig. 2.4. Collection sites of Citrus germplasm from various states of India

2.9 Characterization and Evaluation

Characterization and evaluation of germplasm facilitates its utilization for crop improvement purposes. Indian Citrus germplasm especially of indigenous origin have not been sufficiently characterized and evaluated. Even if limited germplasm is characterized it has been for only phenotypic characters. Citrus is a very diverse fruit crop therefore, detailed evaluation and characterization data are needed to assess the genetic diversity present in individual species. In Citrus sizable variability is present with respect to tree structure/canopy development shape of canopy, features of fruits, diseases and insect resistance as well as their utility as rootstock. Apart from variation in fruit size, colour also varied from yellow green to red orange in lime and shape from oblate to pyriform. At maturity, fruits of some cultivars were observed to have high acidity while others had almost none. Tree size also varied considerably and hence offers breeders the possibility of breeding them for various desirable

characters. During the year 1999 to 2003 NRC Citrus, Nagpur collected 384 accessions of citrus from different parts of country and most of them were characterized based on physico-chemical characters of fruits (Singh and Singh, 2003). Indian Citrus germplasm has been characterised by several workers on the basis of herbarium observations and morphological descriptions (Singh and Chadha, 1993). Chemotaxonomic and numerical taxonomic studies have also aided in the characterization and classification of *Citrus* (Nath and Randhawa, 1969; Singh and Singh, 1983).

On the basis of multi-location evaluation, cultivars and rootstocks suitable for different agroclimatic situations have been identified (Singh and Chadha, 1993). Several species and clones have been evaluated for resistance to insect-pests and diseases and for processing qualities and suitability as rootstock. Germplasm collected from Northeastern region has been evaluated for physio-chemical characters of fruit (Singh and Govind, 2000). Some species like *C. indica* and *C. macroptera* when shifted to new environment showed poor performance with regard to plant growth. The variation in fruit size, thickness, seeds per fruit, juice content and acidity was found to be more pronounced. Based on the yield and physio-chemical parameters, certain lemon types having less seeds, thin rind and adequate juice content have been identified for commercial cultivation. Variability in vegetative growth and flowering in 30 accessions of citrus rootstocks, trifoliate orange and trifoliate hybrids collected from exotic and indigenous sources have been reported at Nagpur (Singh *et al*. 1999). Performance of different citrus rootstocks in citrus germplasm repository at NRCC, Nagpur showed large variability particularly in physico-chemical characteristicts of fruits (Singh and Singh, 2001). Singh and Sheo Govind (2002) evaluated nine citrus hybrids which were introduced in the year 1983 to assess their performance under mid hills situations of Umiam, Meghalaya. At NRC Citrus, Nagpur, evaluation of citrus rootstock strains for optimum growth and productivity of Nagpur mandarin and Acid lime has been undertaken. About 54 Nagpur mandarin clones have been evaluated for vegetative and reproductive characters and wide variation was observed in all the characters. Clonal selection among 54 Nagpur mandarin clones for early/late maturity, good fruit quality with high yield and less seed per fruit led to selection of 7 clones with promising characters at NRC Citrus (Singh *et al*., 2012). Besides this various sweet orange, acid lime, pummelo, citron, galgal and sweet lime clones have been characterized and evaluated at NRC Citrus. Overall 155 accessions of various Citrus types have been characterized and several superior plants belonging to different Citrus groups are identified for detailed evaluation. Eight exotic mandarin acessions

have been evaluated at ICAR Research Complex for NEH Region Gangtok, Sikkim and "Fortune" cultivars has been found to be more suitble for Sikkim (Kishore *et al.,* 2012).

Evaluation of citrus genetic resources has been undertaken at various centres in India under the AICRP Tropical Fruits (Citrus) and several promising genotypes have been identified in Nagpur mandarin, acid lime and pummelos (Table 2.6). Multi-location evaluation of various Acid lime selections at Rahuri and Tirupati namely Sai Sharbati, RHR-L-122, RHR-L-124, Tenali selection have been undertaken. Similarly Nagpur mandarin selections are evaluated at Akola and Coorg mandarin at Chethali. At Tinsukhia, Khasi mandarin germplasm is evaluated and selection CRS-4 recorded the highest yield. Sweet orange germplasm is evaluated at Rahuri and Tirupati, selections -2 and 4, Himakuntala selection-1, Kodur Sathgudi and Nucellar mosambi are evaluated for performance at various centres. Similarly production and protection trial including rootstocks performance have been undertaken at various centres for different agronomic traits and diseases (insects, pests and nematodes). At Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharasthra, 140 accessions of *Citrus* species and allied genera are being evaluated for horticultural performance and resistance to biotic and abiotic stresses (Pujari *et al*., 2000). They reported rough lemon strains to be more vigorous. Mandarin group, trifoliate orange and its hybrids showed delayed flowering. List of various superior selected clones under the AICRP Tropical Fruit (Citrus) - is given in Table 2.6.

At NBPGR, New Delhi various Citrus accessions collected during explorations from field genebanks, farmers' fields, orchards and natural habitats have been characterised for leaf, fruit and seed characters using IPGRI descriptors. 32 indigenous and exotic cultivars of sweet oranges, 51 accessions of mandarins including its hybrids have been characterized for morphological characters. Accessions wise characterization data of each species is provided in respective chapters dealing in that Citrus group.

2.10 Conservation: Strategy and Planning

Conservation of genetic resources of diverse genus like *Citrus* needs appropriate planning and complementarity of conservation approaches using both *in situ* and *ex situ* methods. Establishment of gene sanctuaries and on-farm conservation are the suitable approaches for *in situ* conservation while for *ex situ* conservation suitable methods are field genebank and cryogenebank. In the

Table 2.6. List of superior selected clones of Citrus from different AICRP Tropical Fruits (Citrus) Centres

S.No	Name of the center	Clone selected
1	NRC for Citrus, Nagpur, Maharashtra	N-4 clone of Nagpur mandarin; NRCC Pummelo-1,NRCC Pummelo-2, NRCC Pummelo-3, NRCC Pummelo-4, NRCC Pummelo-5
2	IIHR, Chethali, Karnataka	Clone 11 of Coorg mandarin
3	IIHR, Hessarghatta, Bangalore, Karnataka	Clone PTF-1, PTF-2, PTF-3, PTF-4 of Pummelo
4	Citrus Research Station, Assam Agricultural University, Tinsukia, Assam	CRS-4 clone of Khasi mandarin
5	Acharya N.G. Ranga Agricultural University, Hyderabad, Andhra Pradesh	Telani clone of acid lime
6	Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra	Mandarin 182

Source : http://www.iihr.ernet.in/aicrp/

present scenario most appropriate strategy for Citrus germplasm is to immediately adopt measures to ensure conservation of vulnerable species before they are lost from nature. *Ex situ* conservation in field genebanks with duplicate collections in cryogenebanks complemented with *in situ* conservation in Gene Sanctuary, National Parks and on-farm, especially for wild and semi-wild species of *Citrus* are the best options. *In situ* conservation facilitates dynamic conservation of species in its natural habitat where species evolve along with other ecosystem components. Till the appropriate steps and planning for *in situ* conservation are taken, the field genebank conservation and cryopreservation of seeds, embryo, embryonic axes of germplasm in the cryogenebank are needed to be immediately taken up. However, in view of differences in seed desiccation and freezing tolerances of many *Citrus* species, it necessitates the determination of seed storage behaviour and development of suitable protocols for seed/embryo cryopreservation. Therefore, the complementary conservation strategy is to be adopted for long-term comprehensive conservation of diverse genus like Citrus.

2.10.1 *In situ* Conservation

Wild species of Citrus in Northeast India have diverse social, economic and scientific importance. Sincere *in situ* conservation efforts are urgently required to safeguard existing genetic diversity for posterity and utilization in

Citrus improvement programmes. Policy interventions, implementation of Farmers' Rights and generating awareness among local tribal and farmer communities would support the task of dynamic conservation and preservation of associated indigenous knowledge. Bioprospecting for confirmation of medicinal and nutritional traits in these Citrus genotypes and use of modern biotechnological tools would further enhance the possibilities of utilizing rare genes to mitigate the challenges of climate change and biological stresses encountered by Citrus industry.

2.10.1.1 Gene Sanctuary

To protect the invaluable genetic resources of citrus, initiative was taken way back in 1981 by establishing the "Citrus Gene Sanctuary" in the Garo hills of Meghalaya by NBPGR (ICAR) covering an area of about 10, 266 hectares (Singh, 1981). The citrus gene sanctuary in the Garo hills of Meghalaya is a unique sanctuary, probably first of its kind in the World. It is endowed with highly specified microclimate with a combination of tropical and mild temperate seasons and experiencing very high humidity and rainfall. Gene sanctuary is a part of buffer zone of Nokrek Biosphere Reserve and spreads over the east, west and south Garo hills of Meghalaya. *Citrus* species growing inside the gene sanctuary are still safe, however, the slow rate of regeneration of these species and increasing human intervention around the gene sanctuary area are the causes of serious concern. This "Citrus Gene Sanctuary" (Fig. 2.5 A, B) deserves the status of 'Heritage Site' under the provisions existing in "Biological Diversity Act, 2002" of India (Anonymous, 2004).

Conservation of *Citrus* genetic resources needs urgent attention so as to protect the existing genetic diversity and to promote cultivation of rare and endangered species that are of great relevance in socio-economical structure of tribal populations of this area. Sharma *et al.* (2004) suggested the creation of more nature reserves, gene sanctuaries and gene parks, and inclusion of *Citrus* species in the social forestry system to safeguard the genetic resources and to allow their further evolution under the natural stresses. Species specific conservation strategy is to be adopted depending upon biological status, population size, diversity and endemism.

2.10.1.2 *In situ*-On-farm conservation

On-farm conservation is an important component of genetic resources conservation especially in marginal and diverse agro-ecosystems. Vast indigenous genetic diversity of Citrus in Southeast Asia is presently being maintained on-

farm especially in small orchards, backyards and farmers' fields. In Northeastern India and foot hills of Northwestern and central Himalayan tracts, specific species of *Citrus* are being maintained by local people for generations (Fig 2.5 C, D). The existing citrus diversity forms the important component of their socio-economic structure as the fruits of these species are being used for edible, medicinal and religious purposes. Important species of Northeastern India which are being conserved on-farm are *C. reticulata* (Khasi mandarin and Darjeeling mandarin), *C. sinensis* (Tasi and Soh-nairange), *C. medica, C. jambhiri, C. grandis, C. limon* (Assam lemon), *C. latipes*, *C. macroptera* and *C. assamensis*. Similarly diversity of *C. grandis, C. jambhiri*, *C. karna, C. rugulosa* and one hybrid of *C. grandis* locally known as Kimb is being maintained in foot hills of Northwestern Himalayas especially in parts of Uttaranchal, Himachal Pradesh, Uttar Pradesh and Punjab. Conservation of these species on-farm by local farmers is on their wish and discretion but due to the increasing population pressure and availability of commercial cultivars, several of these traditional citrus types are being removed by many farmers. Success of on-farm conservation of such arboreal species would require special measures such as commitment of some form of incentive to farming communities by local Government Departments, without which farmers would be unable to maintain these species of low or no commercial importance to them.

Species specific conservation strategy is to be adopted depending upon diversity and endemism and also population size. For example, *C. indica* and *C. latipes* are endemic to Northeast India and require to be grown in the specific microclimate. In contrast, *C. macroptera* var. *annamensis* and *C. indica* due to their increasing commercial, religious and cultural importance are now being preferred for cultivation by the farmers and tribal people in some parts of the Northeast india. *In situ* and *in situ* on-farm conservation strategies are proposed for wild and semi-wild species (*C. indica, C. macroptera, C. latipes, C. ichangensis*) and also for other indigenous domesticated species/varieties (*C. assamensis* and *C. megaloxycarpa*). *C. medica* which is growing as natural wild in various parts of Northeast India is still being conserved in National Parks. "Jora Tenga", a natural wild cultivar of *C. medica* is being conserved naturally in the Dibru-Saikhowa National Park which was earlier reported by Bhattacharya and Dutta (1956) in their monograph. While other natural wild strains of *C. medica* namely Tayum and Themachhi growing in natural wild conditions in Basar area of Arunachal Pradesh and Nokrek Biosphere Reserve (NBR), Garo Hills, respectively are threatened due to no conservation efforts. Similarly, *C. ichangensis* a natural wild species of Citrus is growing in disturbed forest land

of Naga hills of Khonama area of Nagaland and is being protected by local people inspite of no use of its fruits for edible or socio-economic purpose.

2.10.2 *Ex situ* Conservation

2.10.2.1 Field genebank

Presently most of the germplasm of *Citrus* species and allied genera in India is being maintained and conserved in field genebanks. Approximately 1,500 accessions of indigenous and exotic germplasm are being maintained in approximately 20 field genebanks throughout India (Table 2.7). Largest collection of 614 accessions of *Citrus* spp, *Poncirus trifoliata* and *Severinia* species including rootstocks from exotic and indigenous sources is being maintained (Fig 2.5 E) at National Research Centre (NRC) Citrus, Nagpur (Singh *et al*., 2012). Other centres where *Citrus* germplasm is being maintained include, Central Horticultural Experiment Station, Chethali, Karnataka; Indian Institute of Horticultural Research (IIHR), Bangalore, Karnataka; Regional Research Station, Punjab Agriculture University, Abohar, Punjab (Fig 2.5.F); Horticultural Experiment Station, Bhatinda, Punjab; Division of Fruits and Horticultural Technology, IARI, New Delhi; Department of Horticulture, Rahuri, Maharashtra, Citrus Improvement project, Tirupati, Andhra Pradesh; Citrus Experiment Station, Kalol, Maharashtra; Horticultural Experiment Station (HES), Periyakulam, Tamil Nadu and Citrus Experiment Station, Tinsukia, Assam and NBPGR Regional Station (RS), Bhowali and Shillong. Some of the important field genebanks such as at Burnihat, Assam and Dhaulakuan, Sirmour, Himachal Pradesh holding valuable *Citrus* germplasm have been completely declined (Singh and Singh, 2003). Other field genebanks which are older than 10-15 years, such as at Regional Research Station, Abohar, Regional Research Station, Chethali, ICAR Research Complex of NEH, Umiam, Meghalaya, ICAR Research Complex of NEH, Basar, Arunachal Pradesh are facing serious problems of virus diseases and die-back syndrome causing loss of many accessions.

Citrus growing countries of the World including India are also maintaining important *Citrus* germplasm in the field genebanks. These include USA (Citrus Research and Education Center, University of Florida, Florida; National Clonal Germplasm Repository at Riverside, California), Japan (Fruit Tree Research Stations, Okitsu and Kuchnotsu), China (National Citrus Germplasm Repository, Beibei Chongqing, Sichuan Province; Citrus Research Institute of the Chinese Academy of Agriculture Sciences, Beibei, Chongqing), Australia (Queensland Horticulture Institute, Queensland), Malaysia (MARDI, Cameron Highlands;

University of Malaya, UM; Botanical Gardens, Rimba Ilmu), Thailand (Nan Horticultural Research Station), Indonesia (National Plant Genetic Resources Laboratory, Institute of Plant Breeding, Los Banos, Laguna), Vietnam (National Institute of Agricultural Sciences and Technology), Israel and Korea.

In the field genebanks, trees are highly subjected to risks of losses caused by several biological and climatic factors like pests and pathogens attack, mineral deficiency, drought, weather damage, and human error (Withers and Engels, 1990). The routine maintenance of trees in the field genebank is most expensive when compared to other conservation methods (Engelmann, 2010). In addition, distribution and exchange from field genebanks is difficult because of the vegetative nature of the material and the greater risks of disease transfer from country to country (Engelmann, 1997). In case of Citrus specific agronomical and climate requirements and threat of die back and others diseases proved to be challenging task of field genebank maintenance.

2.10.2.2 *In vitro* conservation

In vitro conservation of woody species has been widely taken up for short to medium-term conservation. Feasibility of *in vitro* establishment, *in vitro* multiplication, regrowth pattern of sub-cultures, sub-culture period, rooting of cultures and hardening of plantlets in field are some of the crucial and essential steps for achieving successful *in vitro* conservation. In Citrus several explants like shoot tips, stem sections, root sections, leaf sections, stem internodes, epicotyl segments and transverse thin cell layer have been used for micropropagation followed by *in vitro* conservation and cryopreservation using various techniques in several laboratories of the World (Marin and Duran-Vila, 1991; Duran-Vila, 1997; De Carlo and Lambardi, 2005; Liu and Deng, 2007).

2.10.2.3 Cryopreservation

The cryobanking of plant germplasm offers safe storage for a substantial range of clonally propogated species, avoiding some of the challenges associated with field genebanks specifically in case of Citrus diversity. The *ex situ* stored citrus germplasm serves as a resource for citrus crop improvement programmes. In view of species to species variation in seed storage behavior in *Citrus* and to obtain genetically stable plants with high recovery percentage, cryopreservation of seeds and embryonic axes is the only suitable method for long-term conservation for citrus germplasm. However, seeds of many *Citrus* species show non-orthodox (recalcitrant or intermediate) seed storage behavior and therefore, can not be stored using conventional storage methods.

Table 2.7. Citrus germplasm being maintained at various Field genebanks in India (Modified from Singh and Singh, 2003)

S. No.	Location	Holdings (App. no. of acc.)
	Northeast India	
1.	Citrus Research Station, Assam Ag. Univ., Tinsukhia, Assam	36
2.	ICAR Res. Complex of NEH, Umiam, Meghalaya	92
3.	ICAR Res. Complex of NEH, Basar, Arunachal Pradesh	54
	Northwest India	
1.	RFRS, Punjab Agriculture University (PAU), Abohar, Punjab	132
2.	PAU, Ludhiana, Punjab	76
3.	Hort. Research Stn. (YSP Univ. of Hort. & Forestry), Sirmour, Dhaulakuan, Himachal Pradesh	11
4.	NBPGR, RS, Bhowali, Uttaranchal	35
5.	Reg. Res. Station (RAU), Sriganganagar, Rajasthan	45
6.	Indian Agricultural Research Institute, New Delhi	33
7.	HAU, Hisar, Haryana	50-60
8.	Layalpur Farm, Sriganganagar, Rajasthan	50-60
	Central India	
1.	NRC for Citrus, Nagpur, Maharashtra	614
2.	PDKV, Akola, Maharashtra	18
3.	RFRS (PDKV), Katol, Maharashtra	33
4.	Hort. Res. Sta. (Maha. Agr. Univ.), Parbhani, Maharahstra	68
5.	Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra	66
6.	FRS (MPKV), Srirampur, Rahuri, Maharashtra	34
	South India	
1.	Reg. Res. Sta. (IIHR), Chethali, Karnataka	126
2.	IIHR, Hessarghatta, Bangalore, Karnataka	76
3.	HES (TNAU), Periyakulam, Tamil Nadu	20
4.	S.V. College of Agr., Tirupati, Andhra Pradesh	115
5.	HRS (TNAU), Yercad, Tamil Nadu	41

Fig. 2.5. (A) View of Citrus Gene Sanctuary at Garo Hills, Meghalaya, (B) Entrance to the Nokrek National Park at Garo Hills, (C&D) Citrus plants maintained in back of farmers houses, (E) View of field genebank of NRC Citrus, Nagpur, (F) View of field genebank at Regional Research Station, PAU, Abohar

2.10.2.4 Cryopreservation using diverse explants

Cryopreservation techniques for long-term conservation of varied germplasm have been developed for more than 100 species of cultivated plants using various forms, including cell suspensions, callii, apices, somatic and zygotic embryos, embryonic axes, seeds, dormant buds and pollen (Englemann, 1997; 2010). These techniques have mainly been used for the long-term conservation of species which are vegetatively propagated or of species which produce seeds which are intermediate or recalcitrant in nature. Cryopreservation is the only current alternative for long-term conservation of species of *Citrus*, and this method has been extensively attempted using seeds and a wide range of other explants like zygotic embryos, embryonic axes, shoot apices, embryogenic callus, cell suspensions and somatic embryos (Engelmann 1991; 1994; Malik *et al.*, 2012b). Cryopreservation may be achieved through techniques namely air desiccation followed by fast freezing, vitrification, encapsulation–dehydration or encapsulation-vitrification. The design of suitable cryopreservation protocol requires a prior determination of the desiccation and freezing tolerance of the explant of targeted species.

A typical cryopreservation technique for *in vitro* materials involves pregrowth, cryoprotection, freezing, storage, thawing and recovery and for seeds and axes, air desiccation followed by freezing. New approaches like vitrification and encapsulation–dehydration have been introduced as simple and relatively inexpensive methods so as to use them routinely for plant germplasm conservation.

2.10.2.4.1 Air Desiccation Followed by Fast Freezing

Cryopreservation of seeds and embryonic axes has proved to be suitable method for long term conservation for citrus germplasm. Decoated seeds (embryo) are desiccated by silica gel drying to critical moisture content (CMC) level between 8.5 to 17.2% before fast freezing in liquid nitrogen (LN) at -196°C. The embryonic axes excised from the large seed is the preferred explant for cryostorage because of its organized small structure, independent identity and the presence of appreciable proportion of meristematic tissues. The aseptically excised embryonic axes are desiccated to around 11-16% moisture level using air drying (desiccation method) before exposing to temperatures of liquid nitrogen. The axes are later thawed rapidly in a water bath maintained at +38°C and cultured on a defined media to obtain complete plants. Effectiveness of these techniques for long-term conservation. has been proven in several *Citrus*

spp with high recovery growth of intact seeds of *C. limon, C. sinensis, C. grandis, C. aurantium, C. deliciosa, C. aurantifolia, C. australasica, C. inodora* and *C. garrawayi* and of embryonic axes of *C. aurantifolia*, *C. halimii, C. madurensis*, *C. macroptera*, *C. latipes*, *C. aurantifolia, C. jambhiri*, *C. reticulata, C. grandis, C. mitis* and *Poncirus* (Table 2.8, Fig. 2.8)

2.10.2.4.2 Vitrification

Vitrification technique using Plant Vitrification Solution (PVS) have been first time successfully attempted on nucellar cells of Naval orange (Sakai, 1990) and somatic embryos of Sweet orange "Washington Navel" for cryopreservation (Marin and Duran-Vila, 1988). Vitrification involves treatment (loading) of sample with cryoprotective substances followed by dehydration with highly concentrated vitrifying solution, rapid freezing and thawing, removal of cryoprotectant (unloading) and recovery. Various cryoprotectants like dimethylsulphoxide, glycerol, sorbitol, mannitol, sucrose or polyethylene glycol, are used either alone or in binary or tertiary mixtures. Mixtures of cryoprotectants have generally proved to be more effective than using single cryoprotectant. Vitrification procedures have been developed for more than 10 different species of Citrus using embryonic axes and cell suspensions (Table 2.8, Fig. 2.6B).

2.10.2.4.3 Encapsulation-dehydration

This technique is based on the technology developed for the production of synthetic seeds. Encapsulation technique has been applied mostly to shoot apices, axillary buds and somatic embryos. Specimens are encapsulated in calcium alginate beads. These are then pre-grown in liquid medium with high sucrose concentration. After removal from liquid medium beads are partially dehydrated and rapidly frozen in liquid nitrogen. Recovered beads are cultured *in-vitro* for regeneration and recovery of whole plantlet (Table 2.8, Fig. 2.6C). Successful cryo recovery has been achieved in *C. aurantifolia, C. madurensis, P. trifoliata* using axes and apices.

2.10.2.5 National status of cryopreservation

At NBPGR, New Delhi emphasis has been given to study the sensitivity of embryo and embryonic axes to desiccation and freezing in several Indian *Citrus* species. Successful cryopreservation has been achieved using all three techniques namely desiccation followed by fast freezing for embryo and EA, vitrification and encapsulation-dehydration of EA with varying recovery percentages (Table 2.8). Cryopreservation of decoated seeds of 28 *Citrus* species

and one related genus *Poncirus trifoliata* was attempted after desiccating them to a range of moisture content between 7.23 to 17.8 % as shown in Table 2.8 and Fig. 2.6. Desiccated seeds of *Citrus* species survived liquid nitrogen exposure well with original germinability percentages; 85-90% recovery in 10 species and 52-84% in 19 species. *C. indica*, wild endemic and endangered species could be successfully cryostored (Fig. 2.7).

Embryonic axes of 11 *Citrus* species (*C. reticulata, C. sinensis, C. aurantifolia, C. medica, C. grandis, C. paradisi, C. jambhiri, C. karna, C. latipes, C. macroptera,* and *C. indica*) and *Poncirus trifoliata* hybrids (Fig. 2.8 A-F) were successfully cryopreserved using desiccation and followed by fast freezing method (Table 2.8). Embryonic axes of all the species were desiccated in the range of moisture content between 10.11-16.38% in sterile condition followed by direct plunging into liquid nitrogen for fast freezing. On desiccation of embryonic axes in laminar flow, a critical moisture content level between 10.11 to 16.38 % was achieved within 3 to 5 hrs. There was variation between the species in duration for achieving the required desiccation level. Embryonic axes of *C. jambhiri*, *C. karna, C. grandis, C. latipes* and *Poncirus* could be desiccated upto 16% moisture level within 5 hrs, whereas, it took 4 hrs in *C. medica* and *C. reticulata.* These desiccation levels, however, did not have adverse affect on germinability of axes in *C. jambhiri, C. grandis, C. limon, C. aurantifolia* and *C. reticulata*. Fast freezing of axes of different species at moisture contents between 10-16% was successfully achieved. The growth of cryopreserved axes *in vitro* was similar to that of desiccated controls (Fig. 2.8). Recovery of cryopreserved axes of *C. sinensis, C. jambhiri, C. grandis* and *C. indica* was more than 90% (Table 2.8). Growth of all plantlets whether from fresh, desiccated or cryopreserved axes was normal with no intervening callus. However, in species like *C. jambhiri* some abnormal and stunted growth of embryonic axes after desiccation and cryopreservation was observed during *in vitro* regeneration. *In vitro* regenerated plantlets could be successfully transferred to the field in all the species. Using developed protocols diverse accessions of 29 species collected from various parts of India from naturally growing plants and from field genebank collections have been successfully cryostored. Cryostored germplasm of various species has been monitored for viability for different periods and it has been found to retain the original viability levels (Malik *et al*., 2012b).

Successful cryopreservation of these many species and diverse genotypes/ cultivars using embryos and embryonic axes with species to species variation in recovery growth further confirms the variable seed storage behavior among *Citrus*

Table 2.8 Seed storage behaviour and successful cryopreservation of Citrus species undertaken at Cryogenebank at NBPGR, New Delhi, India using embryos and EA

S. No.	Species	Seed storage behaviour	Explant stored	Method of cryostorage	Recovery (%) accessions
1.	*C. reticulata*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	93.3,75,80,70
2.	*C. sinensis*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	70,90,80,90
3.	*C. aurantifolia*	Intermediate	Embryo,EA	SDFF,DFF, VT	55,57,67
4.	*C. limon*	Intermediate	Embryo	SDFF	88
5.	*C. medica*	Intermediate	Embryo,EA	SDFF,DFF, VT	80,85,77
6.	*C. grandis*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	85,95,100,90
7.	*C. paradisi*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	88,75,100
8.	*C. jambhiri*	Recalcitrant	Embryo,EA	SDFF,DFF, ED, VT	68.7,96,100,90
9.	*C. karna*	Recalcitrant	Embryo,EA	SDFF,DFF, ED, VT	60.5,73,70,70
10.	*C. latipes*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	60,64, 45,77
11.	*C. macroptera*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	70,87,62,92
12.	*C. indica*	Intermediate	Embryo,EA	SDFF,DFF, ED, VT	86,90,87,90
13.	*C. aurantium*	Intermediate	Embryo	SDFF	90
14.	*C. limetta*	Intermediate	Embryo	SDFF	80
15	*C. limettioides*	Intermediate	Embryo	SDFF	80
16.	*C. limonia*	Intermediate	Embryo	SDFF	85.6
17.	*C. pseudolimon*	Intermediate	Embryo	SDFF	74
18.	*C. amblycarpa*	Intermediate	Embryo	SDFF	90
19.	*C.maderaspatana*	Intermediate	Embryo	SDFF	50
20.	*C. madurensis*	Intermediate	Embryo	SDFF	52
21.	*C. myritifolia*	Intermediate	Embryo	SDFF	60
22.	*C. pectinifera*	Intermediate	Embryo	SDFF	56.6
23.	*C. reshni*	Intermediate	Embryo	SDFF	87.5
24.	*C. regulosa*	Intermediate	Embryo	SDFF	71
25.	*C. samperflorens*	Intermediate	Embryo	SDFF	70
26.	*C. taiwanica*	Intermediate	Embryo	SDFF	90
27.	*C. tangerina*	Intermediate	Embryo	SDFF	90
28.	*Citrus* spp.	Intermediate	Embryo	SDFF	74.8
29.	*P. trifoliata*	Intermediate	Embryo,EA	SDFF,DFF	88.3,70

EA- Embryonic axes; SDFF- Silica drying of embryos/decoated seeds followed by fast freezing; DFF- Desiccation of EA in sterile conditions followed by fast freezing; ED-Encapsulation-Dehydration; VT-Vitrification

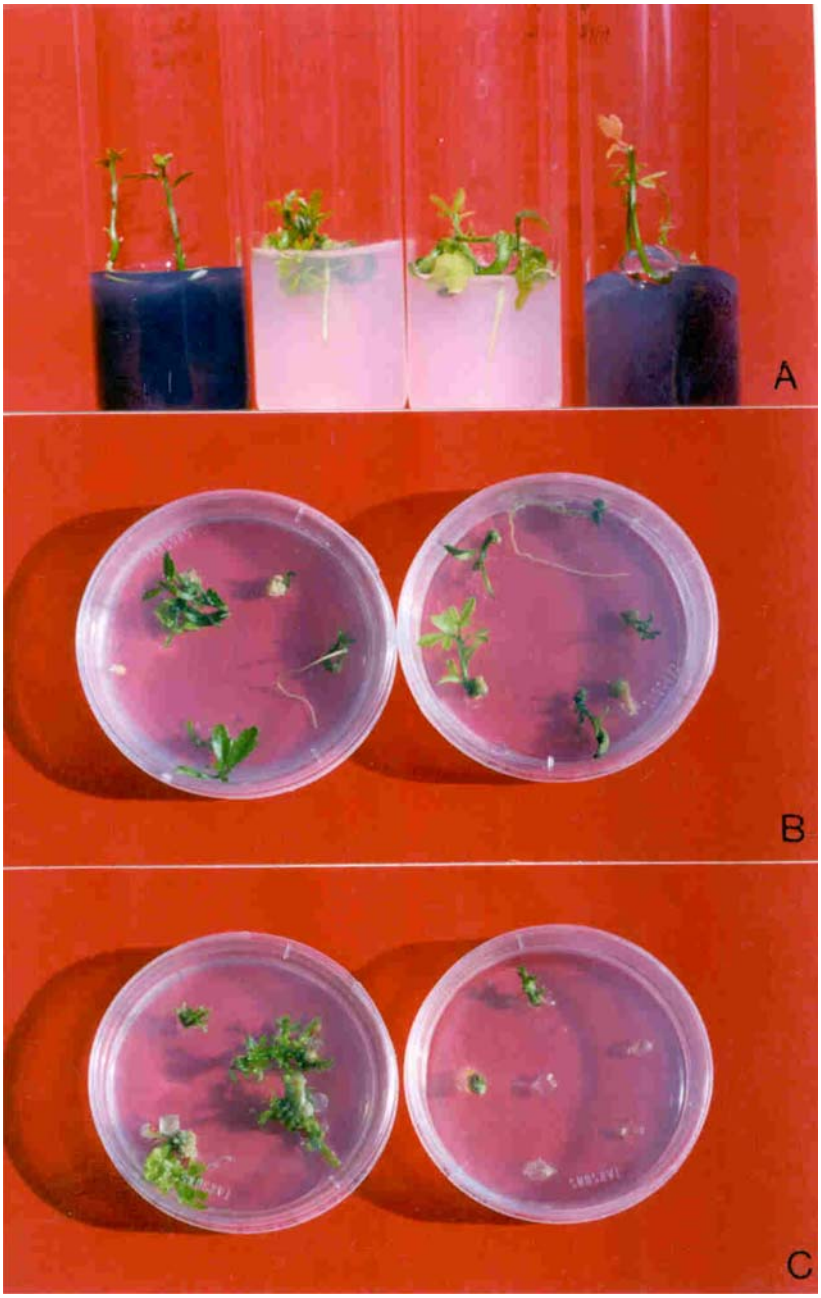

Fig. 2.6. Successful cryopreservation of *Poncirus trifoliata* EA using (A) desiccation-freezing, (B) Vitrification and (C) encapsulation-dehydration techniques

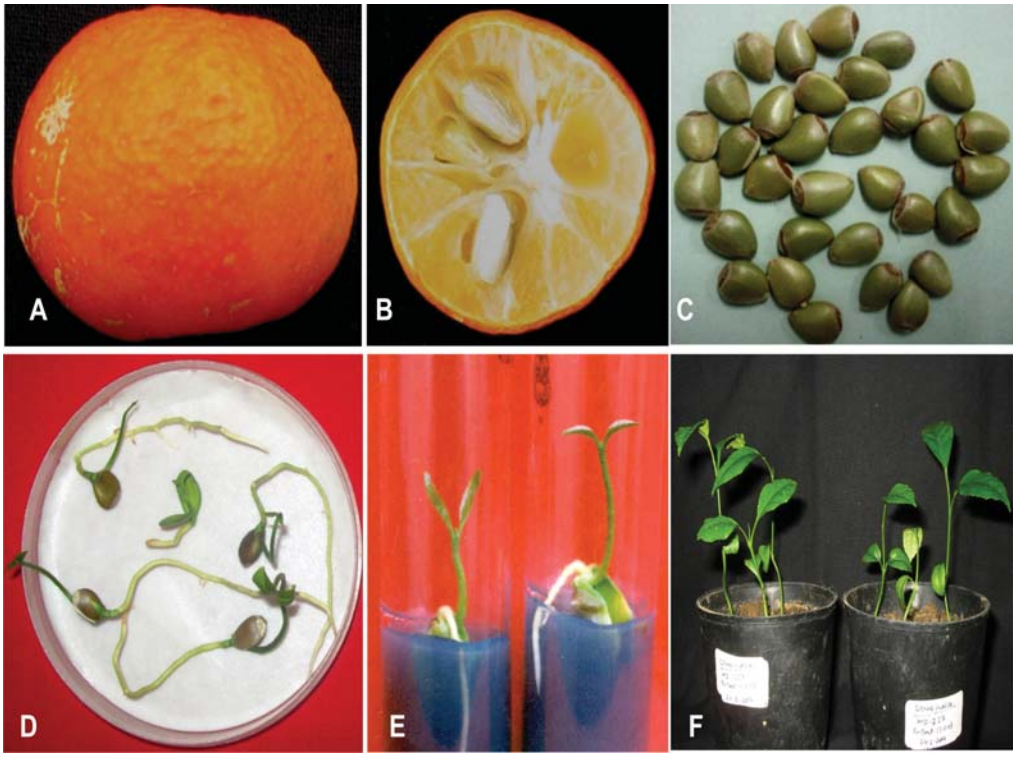

Fig. 2.7. Successful cryopreservation of embryos of *C. indica*, a wild endemic and endangered species (A, B) Fruit and cut halve showing seeds, (C) Extracted bold seeds, (D) Seedlings raised from cryopreserved embryo in petriplates (E) Healthy plantlets raised from cryopreserved embryos, (F) Healthy seedling plants transferred in the pots

species. Successful crypreservation with high percentage viability in many species of *Citrus* using very simple protocol suggests the effectiveness of this technique for long-term conservation. Development of reliable methods for long-term conservation of Citrus germplasm, high recovery rate of genetically stable plantlets with normal growth has prompted the initiation of efforts for establishment of base collection of several indigenous and exotic *Citrus* species in National cryogenebank at NBPGR (Malik *et al.,* 2012a) (Table 2.9).

In conclusion, there are certain key parameters which should be considered when planning complementary conservation strategy. The extent of genepool

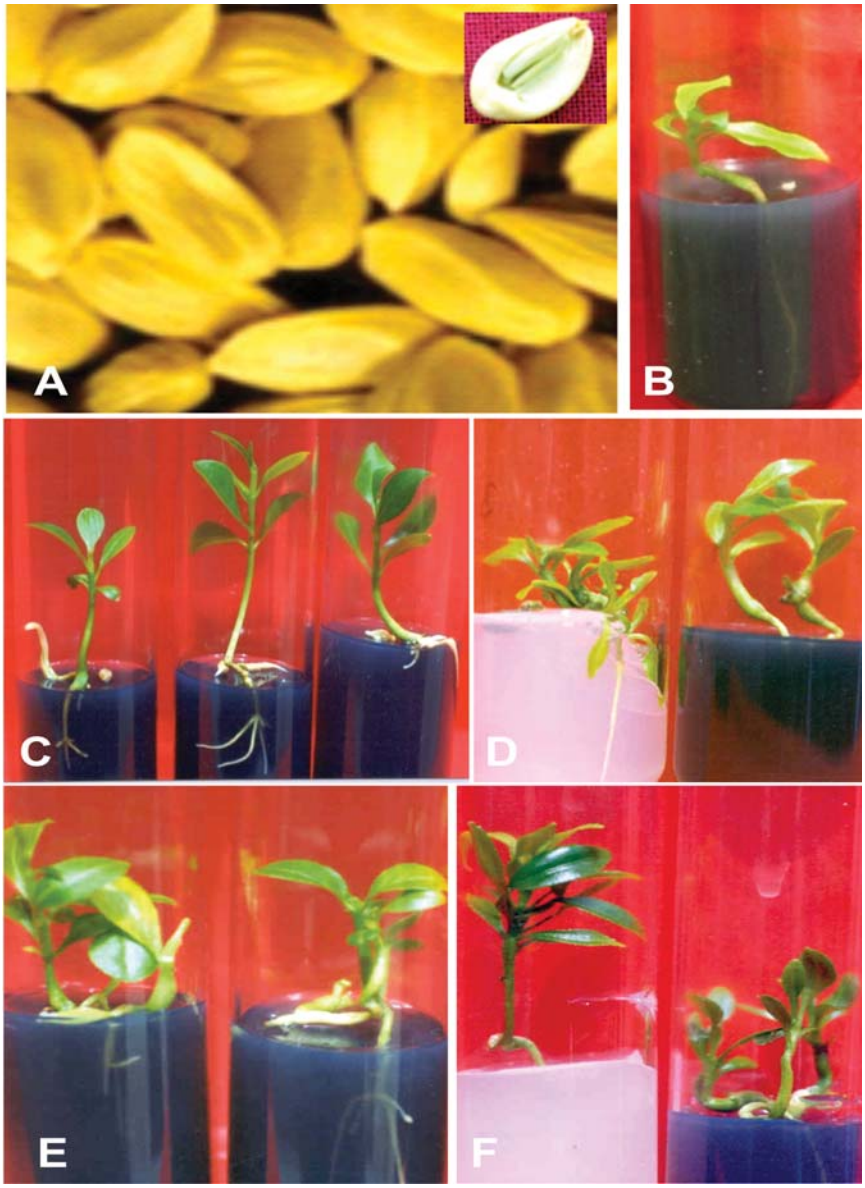

Fig. 2.8. Successful cryopreservation of embryonic axes using DFF method in *Citrus* species, (A) Whole seeds- inset: embryo and embryonic axes, (B-F) Normal plantlets raised from embryonic axes in different *Citrus* species after cryopreservation

Table 2.9. Present status of cryostored accessions of Citrus species in liquid nitrogen vapour phase at NBPGR Cryogenebank

Species	No. of acc. cryostored	Indigenous and exotic cultivars	Explant	Embryony Status
C. reticulata, *C. nobilis, C. reshni, C. amblycarpa, C. madurensis, C. tangerina, C. taiwanica, C. pectinifera,* Tangors, Tangelos	84	Nagpur orange, Local orange, Khasi Mandarin, Lahore Local, Laddu, Orange East India, Narangi, Hazara, Butwal, Cleopatra Mandarin, Billi Kitchli, King, Wilking, Kinnow, Sikkim Mandarin, Dweet Tangor, Ponkan, Temple, SZ-In-COM, Feutrell's early, Kamla, Ser thlum, Ser thumb, Fox mandarin, Santara, Calamondin, Janeru-tenga, Nandshodai, Japanese orange, Pearl tangelo, Minneola Tangelo, Orlando tangelo, Darjeeling mandarin, Soh-niamtra, Sampson Tangelo, Thornton tangelo, Dweet tangor, Shekwasha, Nasnaran, Calamondin, Summer orange	Embryos	Polyembryonic
C. sinensis	69	Declarbe sweet orange, Olinda Valencia late, Teneriffe, Tardiff, Mosambi, Morro, Vanale, Med. Sweet orange, Blood Red, Satgudi, Seleta, Malta, Jaffa, Sonamitri, Hamlin, Vaniglia sanguigno, Mitha chakola, New Hall (Naval), Temple, Joppa, Zingthuang, Sernam, Tahii (Tasi), Loyalpur S-1, Loyalpur S-2, Campbell velencia	Embryos	Polyembryonic
C. aurantium, C. myrtifolia	32	Karun jamir, Smooth flat Seville, Sour orange, Chinnota	Embryos	Polyembryonic
C. medica	29	Etrog Citron, Madkakkar, Tayum, The-ma-chhi, Pati-Jora, Bira- Jora, Gandhraj, Pongam, Holong Tenga, Soh-mondong, and Jora Tenga, Chonchunu, Bor-tenga, Bemberia	Embryos	Monoembroyonic
C. limon	37	Bhadri lemon, Eureka lemon, Nimbu, Baramasi lemon, Villa franca, Sopai, Sher thur, Dhori, Sher phang, Assam lemon	Embryos	Polyembryonic

C. pseudolimon	09	Hill lemon, Galgal, Chinara	Embryos	Polyembryonic
C. limettioides	10	Sweet lime, Kagzi-wak-ma	Embryos	Polyembryonic
C. limonia	22	Rangpur lime, Kole jamir, Tenga	Embryos	Polyembryonic
C. aurantifolia	58	Kagzi lime, Assam lime, Sylhet lime, Coorg lime, Kagazi nimbu, Nimbu, Atol nimbu, Pant-l lime, Seedless lime, Coorg lime,	Embryos	Polyembryonic
C. jambhiri	95	Jatti-khatti, Jamir, Naity Jamir, Gambhiri, Jullundhri-khatti, Florida Rough, Italian Rough, Mithi, Soh-myng-dong, Soh bitter, Hathi nimbu, Soh-Julia, Gole nimbu, Nimbu Tenga, Sinduri lemon, Hasu, Ganpen, Esteus rough, Atol, Rough lemon, Sher-phang, Mithi, Chawangbawla	Embryonic axes and Embryos	Polyembryonic
C. karna	61	Karna khatta, Duranj, Sher-pharkar	Embryos	Polyembryonic
C. pennivasiculata	02	Gajanimma	Embryos	Polyembryonic
C. volkameriana	04	Volkomer lemon	Embryos	Polyembryonic
C. semperflorens	03	Sadaphal	Embryos	Polyembryonic
C. maxima	70	Pummelo, Chakotra, White Flesh, Red Flesh, Triumph, Jambura	Embryos	Monoembroyonic
C. megaloxycarpa	07	Sour pummelo, Sisuphal	Embryos	Monoembroyonic
C. paradisi	17	Marsh seedless, Grapefruit red flesh, Thompson seedless, Soh-khayllah, Smooth flat, Foster pink, Duncan	Embryos	Polyembryonic
C. indica	09	Memang Narang, Memang athur	Embryos	Monoembroyonic
C. latipes	12	Khasi Papeda, Soh-kymphor	Embryos	Monoembroyonic
C. macroptera	09	Melanesian papeda, Satkara, Hatkara	Embryos	Monoembroyonic
C. ichangensis	02	Ketsa chupfu	Embryos	Monoembroyonic
C. hybrid	24	—	Embryos	Polyembryonic
C. spp.	46	—	Embryos	Polyembryonic

Fortunella japonica	2	Kumquat	Embryos	Polyembryonic
Poncirus trifoliata & its hybrids	9	Pomeroy, Rubidoux, Troyer Citrange, Seaton citrumelo, carizo Citrange, Citrumelo, Citremone	Embryos	Polyembryonic
	722			

coverage and the distribution of genetic diversity should be assessed, both within the genepool and geographically. The reproductive biology of a species is critically important to decide the methodology. The extent of genetic erosion and other threats need to be taken into consideration. The nature of the plant materials to be stored, together with the importance of a continued evaluation for the germplasm would be deciding factors. Combinations of different methods would depend on availability of human and financial resources, of conservation facilities and mandate of the institute and Nation.

3. Mandarins

3.1 Genetic resources

***Citrus reticulata* Blanco**

Common name: Mandarin

Vernacular name: Santara, Soh-niamtra

Description

Plant medium to tall, upto 20 ft height, erect habit, branches erect in young trees, relatively less spiny. Leaves broadly or narrowly lanceolate; margin crenate, apex attenuated and almost acute, emarginated, medium coriaceous, dark green, lighter beneath; veins slightly prominent on upper surface, articulated; flowers arising singly or in small clusters in the axils of the leaves, white, perfect; fruits depressed globose or sub-globose, with thin, loose peel easily separating from the segments, bright orange or scarlet-orange when fully ripe hollow axis, segment 10-14, orange pulp, very juicy and sweet; seeds small, pointed at one end, chalazal spot brown, cotyledon green, polyembryonic.

***Citrus reshni* Hort. ex Tan.**

Common name: Cleopatra mandarin

Discription

The tree is round-topped, densely branched symmetrical, and thornless, with small, dark-green leaves. The fruit is orange-red, small, oblate, and highly depressed at the apex, with thin, slightly rough rind. The flesh texture is soft and juicy and the flavor is somewhat acidic highly aromatic. Seeds are small, polyembryonic, and have green cotyledons. This species is grown as ornamental plant in home gardens throughout India and also used as rootstock for mandarin.

***Citrus madurensis* Lou.**

Common name: Calamondin

Description

Calamondin is a shrub or small onamental tree growing upto 15 ft. height. Leaves broadly oval, dark green above; petiole narrowly winged, articulated;

flower white, small, solitary or in pair, stamens 20; The fruits small, 2.5 to 3 cm wide, sub-globose or oblate to spherical, bright orange or reddish orange in colour with depressed apex, segments 7-10, juicy and taste very sour even at maturity. Seed usually 2-5, small, green colyledon, polyembryonic.

***Citrus nobilis* Lour.**

Common name: King orange

Description

King mandarin is medium size tree, branching upright, thorny; leaves small, dark green; petiole narrowly winged, obovate shape; flower similar to sweet orange; fruit large and mandarin like with rough and bumpy surface, colour deep orange yellow; base rounded, segments easily separable, juice sac spindle shape, abundant juice, acidity and sweetness well blended; seeds large similar to sweet orange, 18-20 in number; cotyledon white, chalazal spot reddish, polyembryonic.

Tangelos [*Citrus reticulata* x *C. paradisi*]

Tangelos are hybrid between mandarin (*C. reticulata*) and grapefruit (*C. paradisi*). Generally, these hybrids are morphologically very close to mandarin in fruit characters. The first tangelo was made by Swingle using safeguarded cross-pollination technique. Similar hybrids have originated in China, Indo-China, Japan, and other Far Eastern countries by insect cross-pollination of mandarin oranges and grapefruit growing in dooryard groves of mixed varieties of citrus fruit trees. Some of these tangelos are Pearl, Minneola, Orlando, Sampson, Thornton, etc.

Tangors [*Citrus reticulata* x *C. sinensis*]

Tangors are hybrid of mandarin (*C. reticulata*) and sweet orange (*C. sinensis*). These hybrids have been made by safeguarded cross-pollination of these two species mandarin and sweet orange. The Temple orange which is one of the important tangor, was developed through cross pollination in Florida. The King mandrain of Indo-China is a natural tangor which is growing for very long in the United States.

3.2 Exploration and Collection

C. reticulata (mandarin) is one of the most important commercially cultivated fruit crops of India. Several cultivars of this species are found, which are adapted to different agro-climatic regions of India. Among them, Khasi

mandarin, Sikkim/Darjeeling mandarin, Kinnow and Nagpur mandarin are most successful region-specific cultivars. These cultivars are commercially cultivated as cash crop. A total of 45 accessions of mandarin representing several indigenous and exotic cultivars, viz. Kinnow, Honey, Laddu, Kamla, Local orange, King, Orange east India, Ser-thlum, Khasi mandarin, Sikkim mandarin, Nagpur mandarin, Dancy etc. were collected from Himachal Pradesh, Punjab, Rajasthan, Sikkim, West Bengal and other Northeastern states. *C. reshni* (Cleopatra mandarin) sour type of mandarin is grown in the home garden and farmer's field for ornamental as well as rootstock purpose. Eight accessions of this species have been collected from Punjab, Rajasthan, Sikkim, West Bengal, Assam, Arunachal Pradesh and Nagaland. Germplasm of other related mandarin species like *C. madurensis, C. nobilis, C. pectinifera, C. deliciosa*, *C. taiwanica* and tangelos and tangors were also collected from field genebanks, farmers fields and orchards in Assam, Sikkim, Himachal Pradesh, Rajasthan and Punjab. Passport details of all the collected accessions of mandarin group are given in Table 3.1 and collection sites are shown in Fig. 3.1.

3.3 Characterization

Citrus reticulata

A large variability have been recorded in all of the fruit characters of this species. Fruits were obloid, pyriform and spheroid and rarely ellipsoid in shape with depressed, rounded or truncate apex. Fruits were greenish yellow to drak orange in colour with smooth surface rarely pitted. Seed shape also showed a large variation. Seeds were clavate, ovoid, semi-deltoid or spheroid in shape. Seed cotyledon green, cream and white in colour with purple, reddish, brown chalazal spot. Fruit weight varied from 28.33 gm (IC593855) to 205.35 gm (IC470343), which exhibited a large variability. TSS value ranged from 2.00 to 12.00°B. Seed weight also showed a large variation. Heaviest ten seed weight (3.08 gm) was recorded in IC586983 and lowest seed weight (0.36 gm) was observed in IC591448. Detailed characterization data of qualitative and quantitative traits is given in Table 3.2 and 3.3. Representative photographs of phenotypic variability in mandarin cultivars are given in Fig. 3.2 and 3.3.

Citrus reshni

Fruits varied from spheroid to obloid in shape with truncate apex. Fruits were yellow and orange in colour with smooth to pitted surface texture. Most of cultivar showed pitted surface texture. Seeds were clavate, ovoid and spheroid in shape with green, yellow and creamish cotyledons and brown chalazal spot.

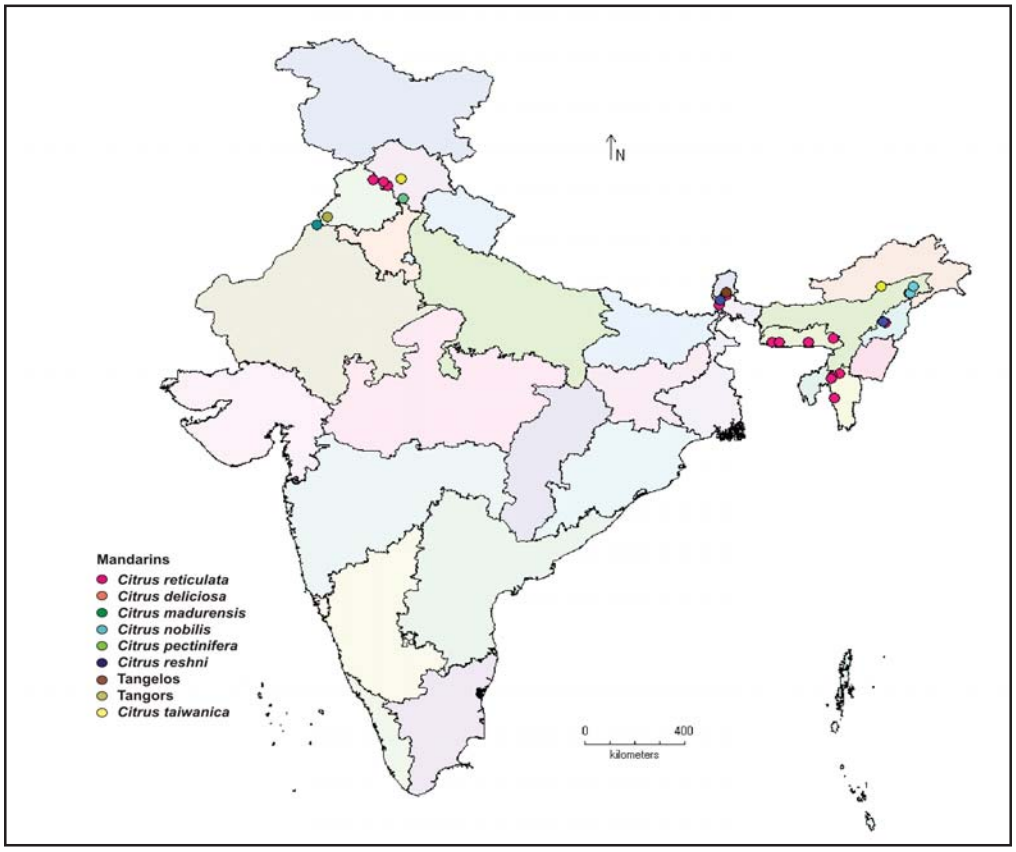

Fig. 3.1. Map of India showing collection sites of mandarin cultivars

Fruit weight varied from 28.33 gm (IC591411) to 58.00 gm (IC395379). TSS value ranged from 6.00 to 12.67°B. Heaviest seed weight was 1.35 gm in IC587012 and lowest seed weight was 0.51 gm in IC591453. The accession with highest fruit weight and high TSS value was IC395379. Detailed characterization data of qualitative and quantitative traits is given in Table 3.2 and 3.3. Representative photographs of phenotypic variability in cleopatra mandarin cultivars are given in Fig. 3.5 A, D.

Other Mandarains

Two accession each of *C. nobilis* and *C. taiwanaca* and one accession each of *C. madurensis*, *C. pectinifera* and tangor and five accessions of tangelos were characterized for fruit and seed characters and data is shown in Table 3.2 and 3.3. Representative photographs of phenotypic variability in mandarin cultivars are given in Fig. 3.4 A-F and 3.5 E, F.

Table 3.1. Passport data of mandarins group (*C. reticulata*, *C. reshni*, *C. deliciosa*, *C. nobilis*, *C. pectinifera*, *C. taiwanica*, etc.) collected from different parts of India

S. No.	Collector Number	IC No.	Botanical Name	Common/Vern. /Cult. Name	Biological status	District	State	Lati-tude	Longi-tude
1	DMRK-43	278045	*Citrus reticulata*	Santara	Cultivated	Kolasib	Mizoram	24.23	92.67
2	MDY-2	395337	*Citrus reticulata*	Kinnow	Cultivated	Sirmour	Himachal Pradesh	30.91	76.96
3	MDY-8	395343	*Citrus reticulata*	Nagpuri Orange	Cultivated	Hoshiarpur	Punjab	31.65	75.89
4	MDY-49	395380	*Citrus reticulata*	Honey	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
5	MDY-85	395413	*Citrus reticulata*	Laddu	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
6	MD-159	417227	*Citrus reticulata*	Kamla	Cultivated	West Garo Hills	Meghalaya	25.30	90.20
7	MD-426	470341	*Citrus reticulata*	Wilking	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
8	MD-427	470342	*Citrus reticulata*	Feutrel early	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
9	MD-442	470357	*Citrus reticulata*	Local orange	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
10	MD-443	470358	*Citrus reticulata*	Honey	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
11	MD-456	470367	*Citrus reticulata*	Kinnow	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
12	MD-464	470369	*Citrus reticulata*	King	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
13	MD-469	470373	*Citrus reticulata*	Fremont	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
14	MD-470	470374	*Citrus reticulata*	Ponkan	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
15	MD-501	470395	*Citrus reticulata*	mandarin King	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
16	MD-502	470396	*Citrus reticulata*	Orange East India	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
17	MD-503	470397	*Citrus reticulata*	Feutrel early	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
18	MD/07/143	558167	*Citrus reticulata*	Kambla	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
19	MD/08/206	568598	*Citrus reticulata*	Ser-thlum	Cultivated	Kolasib	Mizoram	24.11	92.41

20	MD/08/221	568613	*Citrus reticulata*	Ser-thlum	Cultivated	Kolasib	Mizoram	24.03	92.40
21	MD/08/238	568630	*Citrus reticulata*	Ser-thlum	Cultivated	Serchhip	Mizoram	23.28	92.51
22	MD/08/230	568622	*Citrus reticulata*	Sherta	Cultivated	Aizawl	Mizoram	23.48	92.39
23	MD-09-15	583258	*Citrus reticulata*	King Theppi	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
24	MD-09-17	583260	*Citrus reticulata*	Sikkim orange	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
25	MD-09-18	583261	*Citrus reticulata*	Hill orange	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
26	MD-09-19	583262	*Citrus reticulata*	Kamla Australia	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
27	MD-09-21	583264	*Citrus reticulata*	Khasi mandarin	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
28	KARHMD-10/33	586981	*Citrus reticulata*	Dancy	Cultivated	East Sikkim	Sikkim	27.34	88.62
29	KARHMD-10/34	586982	*Citrus reticulata*	King mandarin	Cultivated	East Sikkim	Sikkim	27.34	88.62
30	KARHMD-10/35	586983	*Citrus reticulata*	Thorny mandarin	Cultivated	East Sikkim	Sikkim	27.34	88.62
31	KARHMD-10/36	586984	*Citrus reticulata*	Fox mandarin	Cultivated	East Sikkim	Sikkim	27.34	88.62
32	KARHMD-10/37	586985	*Citrus reticulata*	Fortune	Cultivated	East Sikkim	Sikkim	27.34	88.62
33	KARHMD-10/38	586986	*Citrus reticulata*	Afourer	Cultivated	East Sikkim	Sikkim	27.34	88.62
34	MD-10/45	586993	*Citrus reticulata*	Santara	Cultivated	East Sikkim	Sikkim	27.22	88.58
35	MD-10/46	586994	*Citrus reticulata*	Santara	Cultivated	East Sikkim	Sikkim	27.21	88.62
36	MD-10/60	587008	*Citrus reticulata*	Darjeeling mandarin	Cultivated	Darjeeling	West Bengal	27.04	88.39

37	MD-10/66	587014	*Citrus reticulata*	Santara	Cultivated	Darjeeling	West Bengal	26.86	88.22
38	MS-07	587025	*Citrus reticulata*	Soh-niamtra	Cultivated	Ri-Bhoi	Meghalaya	25.41	91.55
39	MD-11/78	591437	*Citrus reticulata*	Khasi mandarin	Cultivated	Tinsukia	Assam	27.31	95.23
40	MD-11/89	591448	*Citrus reticulata*	Kinnow mandarin	Cultivated	Mokokchung	Nagaland	26.18	94.34
41	MD-11/90	591449	*Citrus reticulata*	Khasi mandarin	Cultivated	Mokokchung	Nagaland	26.18	94.34
42	MD-457	470368	*Citrus reticulata*	Dancy	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
43	MSA-10	593855	*Citrus reticulata*	Kinnow mandarin	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.40
44	MSA-11	593856	*Citrus reticulata*	Mandarin	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.40
45	MSA-21	593864	*Citrus reticulata*	Kinnow mandarin	Cultivated	Hamirpur	Himachal Pradesh	31.55	76.27
46	MDY-48	395379	*Citrus reshni*	Cleoptra mandarin	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
47	MDY-84	395412	*Citrus reshni*	Billi-kitchli	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
48	MD-429	470344	*Citrus reshni*	Cleopatra mandarin	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
49	MD-09-08	583251	*Citrus reshni*	Cleopatra mandarin	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
50	KARHMD-10/39	586987	*Citrus reshni*	Cleopatra mandarin	Cultivated	East Sikkim	Sikkim	27.34	88.62
51	MD-10/64	587012	*Citrus reshni*	Cleopatra mandarin	Cultivated	Darjeeling	West Bengal	27.04	88.39
52	MD-11/53	591411	*Citrus reshni*	Cleopatra mandarin	Cultivated	Tinsukia	Assam	27.31	95.21
53	MD-11/94	591453	*Citrus reshni*	Cleopatra mandarin	Cultivated	Mokokchung	Nagaland	26.22	94.27
54	MD-428	470343	*Citrus reticulata*	Kinnow mandarin	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
55	MDY-53	395384	*Citrus madurensis*	Calamondin	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
56	MD-430	470345	*Citrus madurensis*	Calamondin	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
57	MD-11/77	591436	*Citrus nobilis*	Janaru tenga	Cultivated	Tinsukia	Assam	27.31	95.23
58	MD-11/82	591441	*Citrus nobilis*	Janaru tenga	Cultivated	Tinsukia	Assam	27.57	95.36

59	MDY-3	395338	*Citrus pectinifera*	Shekwasha	Cultivated	Sirmour	Himachal Pradesh	30.91	76.96
60	MDY-52	395383	*Citrus pectinifera*	Shekwasha	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
61	MD-437	470352	*Citrus pectinifera*	Shekwasha	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
62	MDY-35	395368	*Citrus taiwanica*	Summer orange	Cultivated	Mandi	Himachal Pradesh	31.67	76.91
63	MDY-57	395388	*Citrus taiwanica*	Nanshodai dai	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
64	MD-09-24	583267	*Citrus taiwanica*	Japanese orange	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
65	MD-444	470359	*Citrus reticulata*	Dancy	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
66	MDY-50	395381	*Citrus reticulata x C. paradisi*	Pearl tangelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
67	MD-453	395389	*Citrus reticulata x C. paradisi*	Minneola tangelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
68	MD-468	470372	*Citrus reticulata x C. paradisi*	Orlando tangelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
69	MD-474	470375	*Citrus reticulata x C. paradisi*	Sampson tangelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
70	KARHMD-10/43	586991	*Citrus reticulata x C. paradisi*	Thornton tangelo	Cultivated	East Sikkim	Sikkim	27.34	88.62
71	MDY-86	395414	*Citrus reticulata x C. sinensis*	Dweet tangor	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
72	MD-513	470406	*Citrus reticulata x C. sinensis*	Dweet tangor	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22

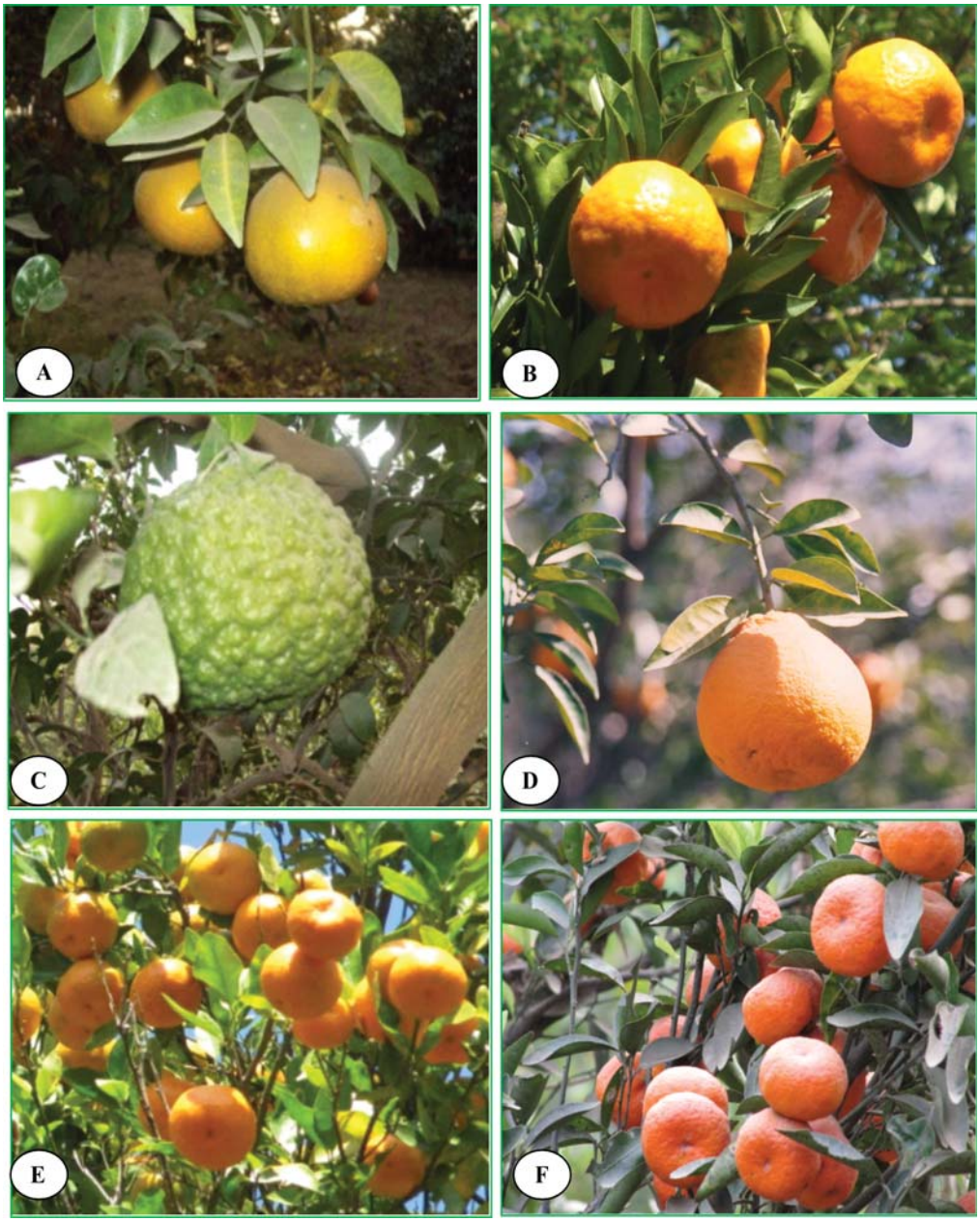

Fig. 3.2. Phenotypic variability in indigenous and exotic cultivars of mandarin collected from different parts of India, (A,) Kinnow mandarin from Punjab; (B) Khasi mandarin from Meghalaya; (C) King mandarin (*C. nobilis*) from Punjab; (C) Nanshodaidai (*C. taiwanica)* from Arunachal Pradesh; (D) Sikkim mandarin from Sikkim; (E) Shekwasha (*C. pectinifera*) from Himachal Pradesh

Fig. 3.3. Phenotypic variability in indigenous and exotic cultivars of *C. reticulata* (mandarin) collected from different parts of India, (A) MSA-11, from H.P.; (B) MSA-21, Kinnow mandarin from H.P; (C) MD-456, Kinnow mandarin from Punjab; (D) MD-11/78, Khasi mandarin from Assam; (E) MD-09/17, Sikkim mandarin from Sikkim; (F) MD-10/60, Darjeeling mandarin from West Bengal

Fig. 3.4. Phenotypic variability in indigenous and exotic cultivars of mandarin collected from different parts of India, (A) MDY-35, Nanshodaidai from H.P; (B) MD-457, Dancy from Punjab; (C) MD-513, Dweet Tangor from Punjab; (D) MD-469, Fremont from Punjab; (E) MD-464, King mandarin from Punjab; (F) MD-427, Feutrell's early from Rajasthan

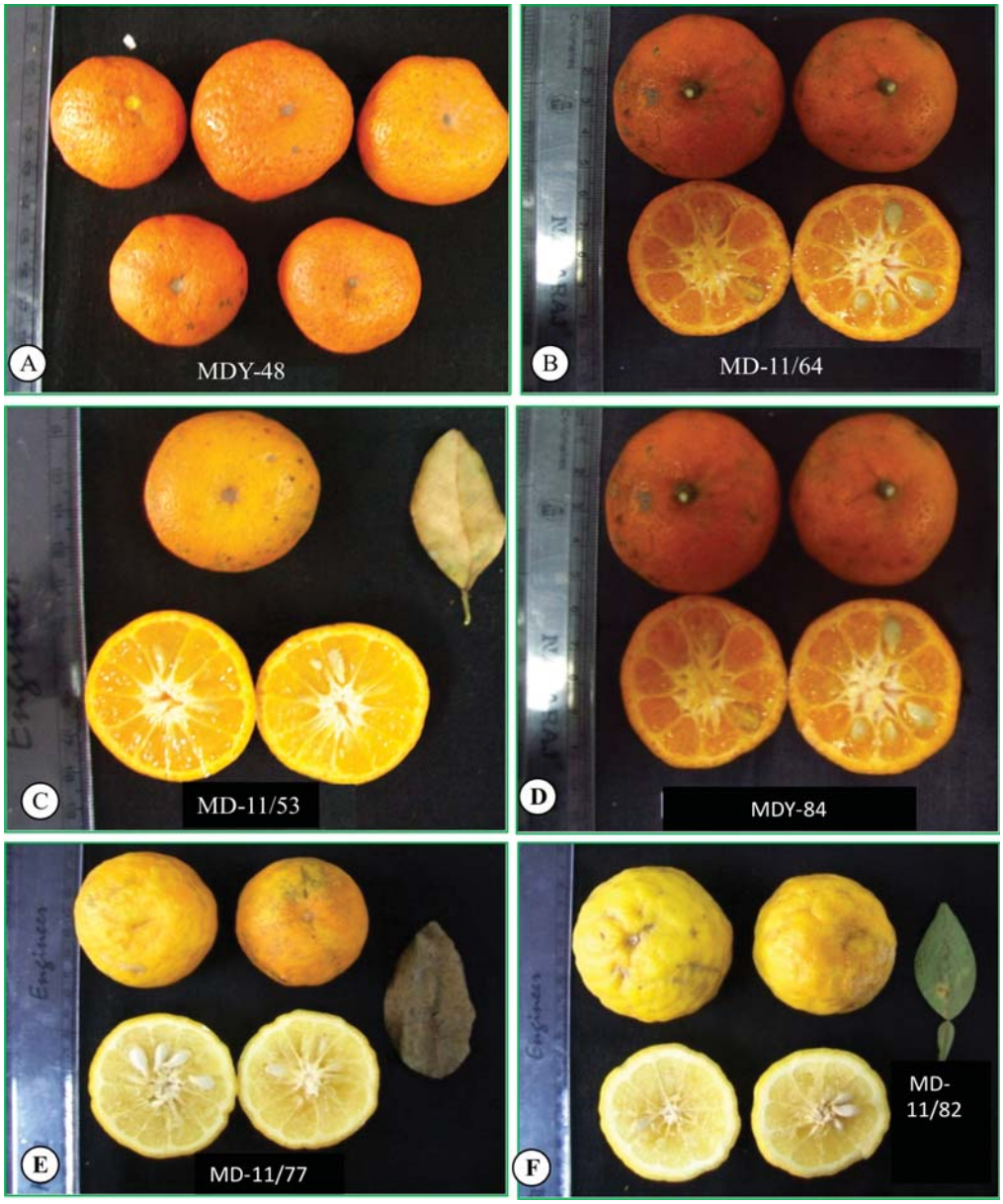

Fig. 3.5. Phenotypic variability in indigenous and exotic cultivars of mandarin collected from different parts of India, (A) MDY-48, Cleopatra mandarin from Punjab; (B) MD-11/64, Cleopatra mandarin from West Bengal; (C) MD-11/53, Cleopatra mandarin from Assam; (D) MDY-84, Billi Kitchli from Punjab; (E) MD-11/77, Janeru tenga from Assam; (F) MD-11/82, Janeru tenga from Assam

Table 3.2. Qualitative data of Mandarins group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit shape	Shape of fruit apex	Fruit colour	Fruit surface texture	Adherence of albedo to pulp	Seed shape	Colour of coty-ledons	Chalazal spot colour
MDY-2	395337	*C. reticulata*	Kinnow	Spheroid	Truncate	Orange	Smooth	Weak	Spheroid	Light green	Purple
MDY-8	395343	*C. reticulata*	Nagpur orange	Obloid	Depressed	Orange	Smooth	Weak	Ovoid	Light green	Brown
MDY-49	395380	*C. reticulata*	Honey	Spheroid	Truncate	Green yellow	Smooth	Medium	Clavate	Light yellow cream	Yellow
MDY-85	395413	*C. reticulata*	Laddu	Obliod	Depressed	red orange	Smooth	Weak	Spheroid	Dark green	Brown
MD-426	470341	*C. reticulata*	Wilking	Obloid	Rounded	Green yellow	Smooth	Medium	Semi spheroid	Light green	Cream
MD-427	470342	*C. reticulata*	Feutrell early	Obloid	Depressed	Orange	Smooth	Medium	Spheroid	Light yellow cream	Brown
MD-442	470357	*C. reticulata*	Local orange	Pyriform	Depressed	Green yellow	Smooth	Weak	Clavate	Light green	Brown
MD-443	470358	*C. reticulata*	Honey	Spheroid	Truncate	Orange	Smooth	Medium	Clavate	Light green	Brown
MD-444	470359	*C. reticulata*	Dancy	Pyriform	Rounded	Orange	Pitted	Strong	Clavate	Light green	Brown
MD-456	470367	*C. reticulata*	Kinnow	Obloid	Truncate	Orange	Smooth	Medium	Clavate	Green	Purple
MD-457	470368	*C. reticulata*	Dancy	Obloid	Truncate	Orange	Smooth	Weak	Clavate	Green	Brown
MD-464	470369	*C. reticulata*	King	Spheroid	Truncate	Dark yellow	Rough	Strong	Ovoid	Light green	Reddish
MD-469	470373	*C. reticulata*	Fremont	Spheroid	Truncate	Green yellow	Smooth	Strong	Clavate	Cream	Indian Red
MD-470	470374	*C. reticulata*	Ponkan	Spheroid	Truncate	Yellow green	Smooth	Low	Clavate	Light green	Light purple
MD-501	470395	*C. reticulata*	Mandarin King	Obloid	Depressed	Orange	Smooth	Medium	Ovoid	Light green	Brown
MD-502	470396	*C. reticulata*	Orange East India	Pyriform	Depressed	Orange	Smooth	Weak	Clavate	Light yellow cream	Brown
MD-503	470397	*C. reticulata*	Feutrell early	Obloid	Truncate	Dark orange	Smooth	Medium	Spheroid	Light green	Reddish
MD/07/143	558167	*C. reticulata*	Kambla	Obloid	Depressed	Orange	Smooth	Weak	Ovoid	Green	Brown

KARHMD-10/33	586981	*C. reticulata*	Dancy	Spheroid	Truncate	Yellow orange	Rough	Medium	Clavate	Light green	Light purple
KARHMD-10/34	586982	*C. reticulata*	Mandarin King	Ellipsoid	Truncate	Green Yellow	Pitted	Medium	Ovoid	Green	Cream
KARHMD-10/37	586985	*C. reticulata*	Fortune	Spheroid	Truncate	Orange	Pitted	Weak	Spheroid	Cream	Purple
KARHMD-10/38	586986	*C. reticulata*	Afourer	Spheroid	Truncate	Orange	Pitted	Weak	Semi-deltiod	Cream	Light brown
MD-10/45	586993	*C. reticulata*	Santara	Obloid	Truncate	Orange	Rough	Weak	Clavate	Light green	Light brown
MD-10/46	586994	*C. reticulata*	Santara	Spheroid	Truncate	Orange	Pitted	Weak	Spheroid	Light green	Light brown
MD-10/60	587008	*C. reticulata*	Darjeeling mandarin	Obloid	Truncate	Orange	Smooth	Strong	Clavate	Light green	Dark brown
MS-07	587025	*C. reticulata*	Soh-niamtra	Spheroid	Truncate	Yellow	Smooth	Weak	Spheroid	Light green	Light brown
MD-11/78	591437	*C. reticulata*	Khasi mandarin	Spheroid	Truncate	Orange	Smooth	Strong	Spheroid	Cream	Brown
MD-11/89	591448	*C. reticulata*	Kinnow mandarin	Obloid	Truncate	Orange	Smooth	Weak	Clavate	White	Brown
MD-11/90	591449	*C. reticulata*	Khasi mandarin	Spheroid	Truncate	Orange	Smooth	Weak	Clavate	White	Brown
MSA-10	593855	*C. reticulata*	Kinnow mandarin	Spheroid	Rounded	Orange	Smooth	Intermediate	Clavate	White	Red
MSA-11	593856	*C. reticulata*	Mandarin	Obloid	Truncate	Red Orange	Smooth	Weak	Ovoid	White	Brown
MSA-21	593864	*C. reticulata*	Kinnow mandarin	Spheroid	Truncate	Dark Yellow	Smooth	Weak	Ovoid	White	Brown
MD-511	—	*C. reticulata*	Butwal	Pyriform	Depressed	Dark yellow	Smooth	Medium	Clavate	Green	Brown
MDY-48	395379	*C. reshni*	Cleoptra mandarin	Spheroid	Truncate	Yellow	Pitted	Medium	Clavate	Light yellow	Light brown
KARHMD-10/39	586987	*C. reshni*	Cleopatra mandarin	Obloid	Truncate	Dark orange	Pitted	Weak	Spheroid	Light green	Brown
MD-10/64	587012	*C. reshni*	Cleopatra mandarin	Obloid	Truncate	Orange	Pitted	Weak	Spheroid	Light green	Light brown

MD-11/53	591411	*C. reshni*	Cleopatra mandarin	Obloid	Truncate	Orange	Smooth	Weak	Clavate	Cream	Brown
MD-11/94	591453	*C. reshni*	Cleopatra mandarin	Obloid	Truncate	Orange	Pitted	Weak	Ovoid	Green	Brown
MD-11/77	591436	*C. nobilis*	Janeru tenga	Spheroid	Rounded	Green yellow	Warty	Medium	Fusiform	Cream	Brown
MD-11/82	591441	*C. nobilis*	Janeru tenga	Obloid	Truncate	Green yellow	Warty	Strong	Cuneate	Light green	Brown
MD-428	470343	*C. reticulata*	Kinnow mandarin	Obloid	Truncate	Green yellow	Smooth	Medium	Ovoid	Light green	Reddish
MDY-35	395368	*C. taiwanica*	Summer orange	Pyriform	Truncate	Orange	Smooth	Medium	Ovoid	Light green	Brown
MDY-57	395388	*C. taiwanica*	Nanshodaidai	Obloid	Truncate	Green	Pitted	Medium	Clavate	Cream	Light brown
MDY-53	395384	*C. madurensis*	Calamondin	Spheroid	Truncate	Light orange	Smooth	Weak	Ovoid	Dark green	Light brown
MDY-52	395383	*C. pectinifera*	Shekwasha	Spheroid	Depressed	Light orange	Smooth	Medium	Spheroid	Dark green	Brown
MDY-50	395381	*C. reticulata* x *C. paradisi*	Pearl tangelo	Spheroid	Rounded	Green	Smooth/ pitted	Strong	Semi-deltoid	Light green	Reddish
MDY-58	395389	*C. reticulata* x *C. paradisi*	Minneola tangelo	Pyriform	Rounded	Orange	Smooth	Medium	Semi-deltoid	Light green	Reddish
MDY-86	395414	*C. reticulata* x *C. sinensis*	Dweet tangor	Spheroid	Rounded	Golden Yellow	Smooth	Strong	Clavate	Light yellow	Brown cream
MD-468	470372	*C. reticulata* x *C. paradisi*	Orlando tangelo	Spheroid	Truncate	Green	Rough	Medium	Clavate	Cream	Purple
MD-474	470375	*C. reticulata* x *C. paradisi*	Sampson tangelo	Spheroid	Truncate	Yellow	Smooth	Strong	Clavate	Light green	Brown
KARHMD-10/43	586991	*C. reticulata* x *C. paradisi*	Thornton tangelo	Spheroid	Truncate	Yellow green	Pitted	Medium	Clavate	Cream	Purple

Table 3.3. Quantitative parameters of Mandarins group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit weight (gm)	Fruit diameter (mm)	Fruit length (mm)	Width of epicarp at equatorial area (mm)	Fruit rind thick-ness (mm)	No. of segments per fruit	TSS(^{0}B)	No. of seed/ fruit	10 Seed wt. (gm)
MDY-2	395337	*C. reticulata*	Kinnow	191.33 ±6.98	73.25 ±1.64	59.41 ±1.03	1.70 ±0.03	3.20 ±0.00	11.00 ±0.00	9.00 ±0.00	15.00 ±0.45	1.62 ±0.45
MDY-8	395343	*C. reticulata*	Nagpur Orange	153.25 ±5.50	55.00 ±0.46	49.80 ±0.40	1.20 ±0.13	2.27 ±0.13	10.00 ±0.00	2.00 ±0.58	13.00 ±6.43	1.31 ±0.03
MDY-49	395380	*C. reticulata*	Honey	90.73 ±6.50	56.28 ±5.88	53.74 ±6.15	2.23 ±0.24	2.55 ±0.25	10.00 ±0.58	8.07 ±0.07	13.67 ±1.67	0.69 ±0.07
MDY-85	395413	*C. reticulata*	Laddu	135.25 ±5.50	56.83 ±0.20	55.77 ±0.23	1.20 ±0.13	2.04 ±0.34	9.33 ±0.33	2.00 ±0.47	11.33 ±3.67	1.31 ±0.03
MD-426	470341	*C. reticulata*	Wilking	78.32 ±9.97	48.97 ±6.22	53.23 ±3.12	1.35 ±0.11	1.16 ±0.04	11.33 ±0.33	7.07 ±0.07	2.33 ±0.67	0.57 ±0.50
MD-427	470342	*C. reticulata*	Feutrell's early	161.20 ±6.50	64.38 ±3.97	56.44 ±2.50	1.20 ±0.13	2.27 ±0.13	11.33 ±0.67	7.33 ±0.18	11.33 ±3.67	1.31 ±0.03
MD-442	470357	*C. reticulata*	Local orange	118.49 ±5.50	63.42 ±3.24	65.17 ±2.19	2.35 ±0.21	1.10 ±0.14	11.00 ±0.58	7.33 ±0.18	3.33 ±1.86	0.74 ±0.03
MD-443	470358	*C. reticulata*	Honey	191.33 ±6.98	73.25 ±1.64	59.41 ±1.03	1.70 ±0.63	3.20 ±0.45	11.00 ±0.12	9.00 ±0.56	15.00 ±0.00	1.07 ±0.02
MD-444	470359	*C. reticulata*	Dancy	108.69 ±5.50	59.72 ±2.90	62.43 ±0.80	2.16 ±0.18	1.83 ±0.40	9.33 ±0.67	8.67 ±0.33	16.33 ±2.33	0.70 ±0.04
MD-456	470367	*C. reticulata*	Kinnow	150.96 ±6.50	69.77 ±5.31	57.75 ±2.91	1.60 ±0.45	1.93 ±0.15	10.67 ±0.33	8.53 ±0.07	7.33 ±1.76	1.15 ±0.03
MD-457	470368	*C. reticulata*	Dancy	91.04 ±4.34	64.33 ±2.33	51.00 ±1.00	1.00 ±0.05	1.00 ±0.12	3.00 ±0.26	7.53 ±0.07	15.33 ±1.45	0.54 ±0.04
MD-464	470369	*C. reticulata*	King	174.54 ±5.50	71.73 ±1.17	65.29 ±1.08	2.46 ±0.15	3.64 ±0.78	10.33 ±0.33	5.07 ±0.07	11.33 ±0.88	1.16 ±0.03

MD-469	470373	*C. reticulata*	Fremont	60.00 ±10.00	47.29 ±3.87	45.70 ±3.50	1.77 ±0.15	2.77 ±0.09	10.67 ±0.33	6.07 ±0.07	11.67 ±0.33	2.15 ±2.77
MD-470	470374	*C. reticulata*	Ponkan	55.00 ±5.77	16.00 ±0.57	4.16 ±0.44	1.00 ±0.00	1.83 ±0.16	10.66 ±0.88	8.00 ±0.00	14.66 ±1.76	1.05 ±0.13
MD-501	470395	*C. reticulata*	Mandarin King	203.68 ±5.50	56.67 ±0.35	55.27 ±0.64	1.23 ±0.03	3.30 ±0.00	11.33 ±0.33	9.13 ±0.07	7.00 ±2.52	1.50 ±0.20
MD-502	470396	*C. reticulata*	Orange East India	137.83 ±5.50	56.59 ±0.18	56.00 ±0.47	1.67 ±0.03	3.00 ±0.06	11.00 ±0.58	9.13 ±0.07	8.33 ±2.19	1.83 ±0.05
MD-503	470397	*C. reticulata*	Feutrell's early	110.16 ±1.36	63.00 ±1.53	54.00 ±1.00	2.00 ±0.00	2.00 ±0.00	2.67 ±0.33	8.53 ±0.07	11.00 ±0.58	1.07 ±0.02
MD/07/143	558167	*C. reticulata*	Kambla	146.15 ±5.75	51.00 ±0.46	56.80 ±0.40	1.20 ±0.13	2.37 ±0.03	10.00 ±0.00	2.00 ±0.47	8.33 ±2.40	0.85 ±0.01
KARHMD-10/33	586981	*C. reticulata*	Dancy	62.67 ±4.84	51.52 ±1.44	41.40 ±1.07	1.56 ±0.09	3.68 ±0.03	10.00 ±0.58	9.50 ±0.29	3.33 ±1.67	1.12 ±0.12
KHRHMD-10/34	586982	*C. reticulata*	Mandarin King	166.67 ±6.50	51.17 ±1.01	56.90 ±0.56	1.23 ±0.03	3.20 ±0.07	11.33 ±1.45	8.83 ±0.17	8.67 ±0.88	1.42 ±0.10
KARHMD-10/37	586985	*C. reticulata*	Fortune	65.67 ±8.69	51.47 ±2.82	42.92 ±1.91	1.90 ±0.29	3.98 ±0.50	8.50 ±0.41	12.00 ±1.15	14.33 ±0.67	0.90 ±0.12
KARHMD-10/38	586986	*C. reticulata*	Afourer	38.33 ±6.49	44.10 ±1.88	34.93 ±2.26	0.71 ±0.17	3.94 ±0.89	8.33 ±0.88	11.17 ±0.73	5.00 ±0.42	0.71 ±0.25
MD-10/45	586993	*C. reticulata*	Santara	133.00 ±4.36	69.53 ±1.08	53.07 ±1.38	1.83 ±0.04	4.84 ±0.02	10.00 ±0.05	12.00 ±0.05	9.67 ±0.33	1.07 ±0.01
MD-10/46	586994	*C. reticulata*	Santara	61.00 ±7.02	50.69 ±0.93	41.89 ±3.98	1.21 ±0.23	2.32 ±0.18	10.33 ±0.67	12.00 ±1.15	10.00 ±1.15	0.98 ±0.12
MD-10/60	587008	*C. reticulata*	Darjeeling mandarin	94.00 ±5.57	60.59 ±2.20	48.79 ±0.60	1.35 ±0.02	2.86 ±0.01	10.00 ±0.45	10.67 ±0.33	12.00 ±1.00	1.02 ±0.40
MS-07	587025	*C. reticulata*	Soh-niamtra	76.67 ±0.33	54.65 ±0.06	47.68 ±0.38	2.00 ±0.12	3.40 ±0.36	10.00 ±0.12	9.20 ±0.56	12.00 ±0.12	1.16 ±0.23
MD-11/78	591437	*C. reticulata*	Khasi mandarin	100.00 ±5.77	58.92 ±0.33	48.04 ±1.85	1.33 ±0.04	3.04 ±0.41	10.00 ±0.00	8.67 ±0.33	12.32 ±0.00	0.67 ±0.07
MD-11/89	591448	*C. reticulata*	Kinnow mandarin	80.00 ±5.00	56.31 ±1.90	46.12 ±1.35	1.46 ±0.14	4.85 ±0.18	11.00 ±0.00	14.33 ±0.33	23.00 ±7.00	0.36 ±0.07
MD-11/90	591449	*C. reticulata*	Khasi mandarin	75.00 ±7.64	50.78 ±2.99	48.03 ±2.19	1.18 ±0.06	3.72 ±0.54	10.00 ±0.58	10.00 ±0.00	15.33 ±2.91	1.05 ±0.03

MSA-10	593855	*C. reticulata*	Kinnow mandarin	28.33 ±3.33	42.51 ±0.97	36.41 ±0.73	0.55 ±0.02	1.61 ±0.02	9.00 ±0.00	12.00 ±0.63	25.00 ±3.51	1.54 ±0.04
MSA-11	593856	*C. reticulata*	Mandarin	128.33 ±4.41	60.61 ±2.22	52.10 ±2.87	2.01 ±0.05	3.65 ±0.05	12.00 ±0.42	10.00 ±0.56	18.67 ±5.84	2.12 ±0.01
MSA-21	593864	*C. reticulata*	Kinnow mandarin	78.33 ±3.33	55.05 ±0.58	54.64 ±2.49	1.40 ±0.06	3.75 ±0.07	10.00 ±0.09	10.33 ±0.33	16.34 ±0.06	0.60 ±0.60
MD-511	—	*C. reticulata*	Butwal	98.08 ±8.50	41.39 ±2.46	45.48 ±1.73	2.33 ±0.26	3.00 ±0.05	10.67 ±0.33	8.13 ±0.07	13.00 ±6.43	1.17 ±0.05
MDY-48	395379	*C. reshni*	Cleopatra mandarin	58.00 ±1.15	52.29 ±0.58	31.55 ±0.62	1.23 ±0.29	4.14 ±0.22	13.33 ±0.67	12.67 ±0.67	6.00 ±0.58	0.96 ±0.06
KARHMD-10/39	586987	*C. reshni*	Cleopatra mandarin	52.00 ±1.15	51.29 ±0.58	33.55 ±0.62	1.64 ±0.29	4.54 ±0.22	11.33 ±0.67	11.67 ±0.67	4.00 ±0.58	0.86 ±0.00
MD-10/64	587012	*C. reshni*	Cleopatra mandarin	35.67 ±3.48	46.59 ±0.96	33.38 ±0.64	1.68 ±0.02	3.66 ±0.11	7.00 ±3.00	11.00 ±0.05	12.00 ±1.15	1.35 ±0.08
MD-11/53	591411	*C. reshni*	Cleopatra mandarin	28.33 ±3.33	39.40 ±1.37	31.93 ±0.54	1.88 ±0.06	3.18 ±0.02	11.00 ±0.05	6.00 ±0.08	30.67 ±5.50	0.93 ±0.03
MD-11/94	591453	*C. reshni*	Cleopatra mandarin	33.33 ±1.67	44.35 ±0.36	31.33 ±0.74	1.31 ±0.07	2.06 ±0.04	10.67 ±0.33	12.33 ±0.67	17.00 ±2.52	0.51 ±0.12
MD-11/77	591436	*C. nobilis*	King mandarin	85.00 ±6.50	56.59 ±5.45	48.99 ±4.95	1.91 ±0.11	5.57 ±0.24	11.00 ±0.89	10.67 ±0.44	17.33 ±2.60	1.38 ±0.09
MD-11/82	591441	*C. nobilis*	Janaru tenga	140.00 ±6.50	71.68 ±3.87	52.86 ±4.02	2.19 ±0.26	7.95 ±0.23	10.33 ±0.33	10.67 ±0.33	9.33 ±1.33	4.05 ±0.24
MD-428	470343	*C. reticulata*	Kinnow mandarin	205.35 ±6.60	81.67 ±1.67	71.67 ±3.33	2.67 ±0.33	2.67 ±0.33	3.00 ±0.45	3.33 ±2.33	21.33 ±4.37	1.07 ±0.02
MDY-35	395368	*C. taiwanica*	Summer orange	49.99 ±1.37	39.77 ±0.43	38.93 ±0.43	1.00 ±0.09	1.83 ±0.40	11.00 ±0.58	3.00 ±0.03	16.33 ±2.33	0.73 ±0.02
MDY-57	395388	*C. taiwanica*	Nanshodaidai	134.00 ±6.50	66.52 ±3.41	54.22 ±2.56	2.63 ±0.15	8.75 ±0.13	11.67 ±0.33	10.00 ±0.00	20.00 ±0.00	3.08 ±0.43
MDY-53	395384	*C. madurensis*	Calamondin	43.99 ±1.37	32.07 ±0.07	31.70 ±0.15	1.00 ±0.08	1.53 ±0.03	7.67 ±0.33	5.00 ±0.56	15.33 ±1.45	0.73 ±0.02
MDY-52	395383	*C. pectinifera*	Shekwasha	23.72 ±3.21	35.54 ±1.36	29.09 ±1.47	0.62 ±0.12	0.50 ±0.08	7.67 ±0.33	6.07 ±0.07	6.00 ±2.08	1.32 ±0.02
MDY-50	395381	*C. reticulata* x *C.paradisi*	Pearl tangelo	49.36 ±1.57	35.67 ±0.12	35.33 ±0.18	1.02 ±0.08	1.60 ±0.28	10.66 ±0.66	3.00 ±0.07	10.00 ±1.10	0.475 ±0.04

MDY-58	395389	*C. reticulata* x *C.paradisi*	Minneola tangelo	99.56 ±6.63	53.00 ±0.15	56.00 ±0.10	1.76 ±0.08	2.17 ±0.23	11.33 ±0.33	3.00 ±0.12	11.00 ±2.20	1.72 ±0.09
MDY-86	395414	*C. reticulata* x *C. sinensis*	Dweet tangor	238.33 ±5.50	56.00 ±0.30	65.20 ±0.05	2.33 ±0.33	3.00 ±1.23	10.33 ±0.33	3.00 ±0.12	10.00 ±2.50	1.45 ±0.05
MD-468	470372	*C. reticulata* x *C.paradisi*	Orlando tangelo	117.86 ±6.50	59.84 ±5.08	60.29 ±4.52	1.02 ±0.08	1.60 ±0.28	12.00 ±0.04	8.267 ±0.24	7.66 ±5.66	0.691 ±0.02
MD-474	470375	*C. reticulata* x *C.paradisi*	Sampson tangelo	171.77 ±6.50	70.49 ±1.78	73.17 ±4.63	1.76 ±0.08	1.17 ±0.23	10.00 ±0.05	8.26 ±0.24	11.00 ±2.00	0.94 ±0.07
KARHMD-10/43	586991	*C. reticulata* x *C.paradisi*	Thornton tangelo	73.33 ±5.50	53.44 ±4.23	51.27 ±2.31	1.81 ±0.09	5.26 ±0.44	9.66 ±0.33	10.33 ±0.33	9.90 ±2.00	0.55 ±0.05

4. Oranges

4.1 Genetic resources

***Citrus sinensis* (L.) Osbeck**

Common name: Sweet orange

Vernacular name: Mosambi, Sonamitri, Ser-nam, Sohning-raing, Tasi, Mitha chakola, Chakola tenga

Description

The tree is medium sized upto 12ft in height, profusely branched, dense canopy and spiny. Leaves have elliptic to ovate lamina with acute or slightly acuminate apex, lamina margin almost entire to slightly crenate, narrowly winged petiole with obovate in shape. Flowers in small racemes or singly in the axils of the leaves, medium-sized; calyx with 5 lobes; petals 5; stamens 20-25; ovary sub-globose with 10-13 locules; style slender, clearly delimited. Fruits sub-globose, oval or spheroid, peel thin, tight, not bitter, central axis (pith) solid, pulp yellowish; seeds cuneate-ovoid with rough-margined plane surfaces, white inside, cotyledon creamish, chalazal cap brown seeds highly polyembryonic.

***Citrus aurantium* L.**

Common name: Bitter or Sour orange

Vernacular name: Karun jamir, Serenga, Bamsim, Kampil

Description

A medium-sized tree, 10-20 ft in height, with a rounded top; twigs angled when young, with single, slender spines, often short, or stout spines up to 5-8 cm long on rapidly growing shoots; leaves medium-sized, ovate, bluntly pointed at tip, broadly rounded to cuneate at base; petioles 2-3 cm long, broadly winged, often 1.2-1.8 cm wide at top, but sometimes narrower, 1 cm or less, narrowing rapidly towards wingless base; flowers large, white, very fragrant; 5-12 per cent male (staminate only); fruits sub-globose, usually slightly depressed at both base and apex, peel thick, with a rather rough surface, becoming brilliant orange with

a reddish or scarlet red at maturity; segments 10-12, hollow axis filled with juicy pulp, acidic, bitter in taste. Seeds numerous, medium size, ovoid in shape, cream colour cotyledon, dark brown chalazal cap, polyembryonic.

4.2 Exploration and Collection

Germplasm of *C. sinensis* (Sweet orange) was collected through various surveys and exploration missions conducted to diversity rich areas in different parts of India. *C. sinensis* is found in cultivation at large scale in India for production of juice and processed products. A total of 56 accessions of sweet oranges indigenous as well as exotic cultivars/types *viz*. Mosambi, Sohoj, Sonamitri, Ser-nam, Sohning-raing, Tasi, Mitha Chakola, Jaffa, Joppa, Satgudi, Blood oranges, Naval oranges, Valencia, etc. were collected from Punjab, Rajasthan, Himachal Pradesh, Meghalaya, Assam, Nagaland, Mizoram, Arunachal Pradesh and West Bengal. However, large collection representing indigenous and exotic cultivars were made from the Field genebank of Punajb Agricultural University, Regional Station, Abohar, Punjab. Important local cultivars Tasi which is vanishing rapidly from the natural habitat, farmers fields due to less demand was collected from the Basar area of Arunachal Pradesh. Mitha chakola and Chakola tenga, cultivars of sweet oranges were collected from Tinsukhia area of Upper Assam, which are found as semi-domesticated in these locations. These local cultivars are also under the threat due to the farmers liking for more remunerative commercial crops.

A total of 17 accessions of *C. aurantium* (Sour orange) representing cultivars/types *viz.* Karun jamir, Smooth flat Seville, Chinotto, Serenga, Kampil and Bamsim were collected from Punjab, Rajasthan, Sikkim and Meghalaya. One accession of *C. myrtifolia* was collected from Abohar, Punjab.

Passport details of sweet and sour oranges collected through various explorations by NBPGR and partners are provided in Table 4.1 and collection sites are shown in Fig. 4.1.

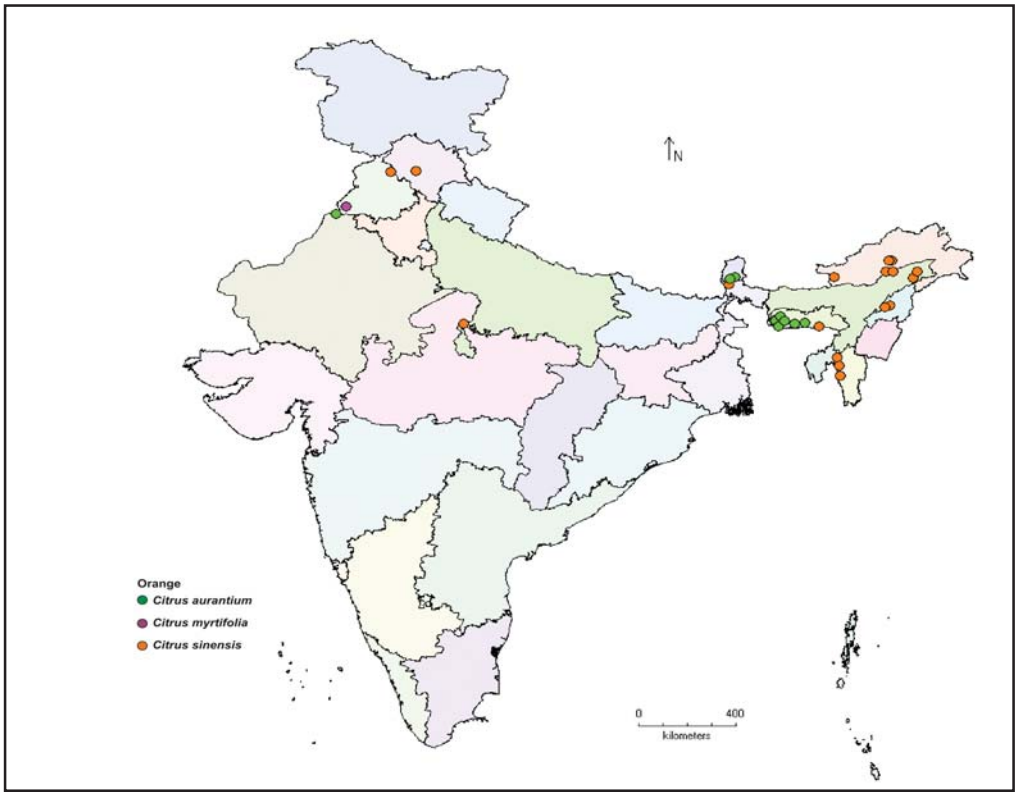

Fig. 4.1. Map of India showing collection sites of sweet and sour oranges

4.3 Characterization

Citrus sinensis

Fruits were spheroid, ellipsoid, ovoid and oblique in shape. Fruit apex varied from rounded to truncate. Fruits were greenish yellow to orange in colour with pitted surface texture in most of the cultivar and rarely smooth texture in some cultivars. Seeds were clavate, ovoid and semi-deltoid in shape with creamish to white cotyledons and reddish chalazal spot. A large variability was recorded in almost all of the fruit characters. Large variation was found in fruit weight, ranged from 71.84 gm to 382.33 gm. A very large variation was found in TSS value of the fruit. Highest TSS was 31.33^0B and lowest TSS was recorded as 2.00^0B. Seeds also showed a large variability in shape, size and colour. Ten seed weight varied from 0.20 to 8.20 gm. The accession having heaviest seed and high value of TSS was IC395346. Detailed characterization data of qualitative and quantitative traits is given in table 4.2 and 4.3. Phenotypic variability in fruits of various sweet orange cultivars are shown in Fig. 4.2, 4.3 and 4.4.

Table 4.1. Passport data of oranges group (*C. sinensis* and *C. aurantium*) collected from different parts of India

S. No.	Collector Number	IC No.	Botanical Name	Common/Vern. /Cult. Name	Biological status	District	State	Lati-tude	Longi-tude
1	DMRK-10	278012	*Citrus sinensis*	Sojoh	Cultivated	East Khashi Hills	Meghalaya	25.30	91.70
2	MDY-12	395346	*Citrus sinensis*	Jaffa	Cultivated	Hoshiarpur	Punjab	31.65	75.89
3	MDY-13	395347	*Citrus sinensis*	Sonamitri	Cultivated	Hoshiarpur	Punjab	31.65	75.89
4	MDY-33	395366	*Citrus sinensis*	Sweet orange	Cultivated	Mandi	Himachal Pradesh	31.67	76.80
5	MDY-94	395421	*Citrus sinensis*	Loyalpur S- 1	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
6	MDY-95	395422	*Citrus sinensis*	Loyalpur S- 2	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
7	MD-199	417265	*Citrus sinensis*	Sweet orange	Cultivated	West Kameng	Arunachal Pradesh	27.35	92.28
8	MD-431	470346	*Citrus sinensis*	Blood red	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
9	MD-439	470354	*Citrus sinensis*	Mosambi	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
10	MD-440	470355	*Citrus sinensis*	Jaffa	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
11	MD-441	470356	*Citrus sinensis*	Hamlin	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
12	MD-445	470360	*Citrus sinensis*	Blood red	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
13	MD-452	470365	*Citrus sinensis*	Campbell Valencia	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
14	MD-465	470370	*Citrus sinensis*	Campbell Valencia	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
15	MD-485	470383	*Citrus sinensis*	Aspal orange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
16	MD-486	470384	*Citrus sinensis*	Sweet orange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
17	MD-488	470386	*Citrus sinensis*	Vanale	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
18	MD-494	470390	*Citrus sinensis*	Sweet orange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
19	MD-499	470394	*Citrus sinensis*	Satgudi	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
20	MD-507	470401	*Citrus sinensis*	Mosambi	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
21	MD-508	470402	*Citrus sinensis*	Declarbe sweet orange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
22	MD-509	470403	*Citrus sinensis*	New Hall (Naval)	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
23	MD-510	470404	*Citrus sinensis*	Mediterranian sweet orange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22

24	MD-512	470405	*Citrus sinensis*	Teneriffe	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
25	MD-514	470407	*Citrus sinensis*	Tardiff	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
26	MD-515	470408	*Citrus sinensis*	Temple	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
27	MD-516	470409	*Citrus sinensis*	Vaniglia sanguigno	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
28	MD-517	470410	*Citrus sinensis*	Joppa	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
29	MD/07/140	558164	*Citrus sinensis*	Mausambi	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
30	MD/08/225	568617	*Citrus sinensis*	Zingthuang	Cultivated	Kolasib	Mizoram	24.03	92.40
31	MD/08/242	568634	*Citrus sinensis*	Ser nam	Cultivated	Serchhip	Mizoram	23.28	92.51
32	MD/08/260	568652	*Citrus sinensis*	Ser nam	Cultivated	Mamit	Mizoram	23.53	92.29
33	MD/08/271	568663	*Citrus sinensis*	Ser nam	Cultivated	Mamit	Mizoram	23.49	92.29
34	MD-09-06	583249	*Citrus sinensis*	Exelyer malta	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
35	MD-09-07	583250	*Citrus sinensis*	Daccus malta	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
36	MD-09-09	583252	*Citrus sinensis*	Sohning raing	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
37	MD-09-10	583253	Citrus sinensis	Valenacia newton	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
38	MD-09-14	583257	*Citrus sinensis*	Sweet orange	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
39	MD-09-30	583273	*Citrus sinensis*	Mosambi	Cultivated	West Siang	Arunachal Pradesh	28.02	94.40
40	MD-09-32	583275	*Citrus sinensis*	Tahii (Tasi)	Cultivated	West Siang	Arunachal Pradesh	28.02	94.30
41	MD-09-33	583276	*Citrus sinensis*	Tahii (Tasi)	Cultivated	West Siang	Arunachal Pradesh	27.56	94.46
42	MD-10/59	587007	*Citrus sinensis*	Malta	Cultivated	Darjeeling	West Bengal	27.04	88.39
43	MD-10/61	587009	*Citrus sinensis*	Naval Washington	Cultivated	Darjeeling	West Bengal	27.04	88.39
44	MD-11/71	591430	*Citrus sinensis*	Mitha chakola	Cultivated	Tinsukia	Assam	27.31	95.21
45	MD-11/79	591438	*Citrus sinensis*	Chakola tenga	Cultivated	Tinsukia	Assam	27.57	95.36
46	MD-11/88	591447	*Citrus sinensis*	Mosambi	Cultivated	Mokokchung	Nagaland	26.18	94.34
47	MD-11/98	591457	*Citrus sinensis*	Malta	Cultivated	Wokha	Nagaland	26.08	94.13
48	IPSKM-262	322089	*Citrus sinensis*	Mosambi	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
49	IPSKM-270	322097	*Citrus sinensis*	Mosambi	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
50	IPSKM-281	322108	*Citrus sinensis*	Mosambi	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57

51	MSD-01	—	*Citrus sinensis*	Seleta	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
52	MSD-02	—	*Citrus sinensis*	Parent naval	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
53	MSD-03	—	*Citrus sinensis*	Rhode red valencia	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
54	MSD-04	—	*Citrus sinensis*	Olinda valencia late	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
55	MSD-05	—	*Citrus sinensis*	Morro	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
56	MSD-06	—	*Citrus sinensis*	Delta valencia	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
57	MDY-78	395406	*Citrus aurantium*	Karun jamir	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
58	MDY-87	395415	*Citrus aurantium*	Karun jamir	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
59	MD-170	417237	*Citrus aurantium*	Serenga	Cultivated	South Garo Hills	Meghalaya	25.21	90.93
60	MD-178	417245	*Citrus aurantium*	Kampil	Cultivated	South Garo Hills	Meghalaya	25.44	90.82
61	MD-185	417251	*Citrus aurantium*	Sarenga	Cultivated	West Garo Hills	Meghalaya	25.58	90.06
62	MD-186	417252	*Citrus aurantium*	Bamsin	Cultivated	West Garo Hills	Meghalaya	25.54	90.12
63	MD-432	470347	*Citrus aurantium*	Sour orange	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
64	MD-498	470393	*Citrus aurantium*	Karun jamir	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
65	MD/07/127	558151	*Citrus aurantium*	Serenga	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
66	MD/07/129	558153	*Citrus aurantium*	Serenga	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
67	MD/07/132	558156	*Citrus aurantium*	Bamsim	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
68	MD/07/148	558172	*Citrus aurantium*	Bamsim	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
69	MD/07/151	558175	*Citrus aurantium*	Bamsim	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
70	MD/07/157	558181	*Citrus aurantium*	Kampil	Cultivated	South Garo Hills	Meghalaya	25.16	90.39
71	KARHMD-10/42	586990	*Citrus aurantium*	Smooth flat seville	Cultivated	East Sikkim	Sikkim	27.34	88.62
72	MD-10/52	587000	*Citrus aurantium*	Sour orange	Cultivated	East Sikkim	Sikkim	27.26	88.43
73	MDY-72	395401	*Citrus myrtifolia*	Chinotto	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22

Citrus aurantium

Fruit shape varied from pyriform, spheroid to ellipsoid with rounded or truncate apex. Fruits were greenish yellow to orange in colour with pitted, rough or smooth surface texture. Seeds were fusiform, cunieform, ovoid, spheroid and semi-deltoid in shape with creamish to whitish cotyledons and dark brown to reddish chalazal spot. A large variation was found in fruit and seed characters. Fruit weight ranged from 72.92 gm to 280.00 gm. TSS value of the fruits varied from 5.07 to 22.67°B. Seed weight also showed large variation. Lowest weight (0.41 gm) was recorded in IC470347 and highest weight (3.04 gm) was found in IC558172 for ten seeds. The accessions having light seed weight and lowest value of TSS is IC470347. Detailed characterization data of qualitative and quantitative traits is given in Table 4.2 and 4.3. Phenotypic variability in fruits of various sour orange cultivars is shown in Fig. 4.5.

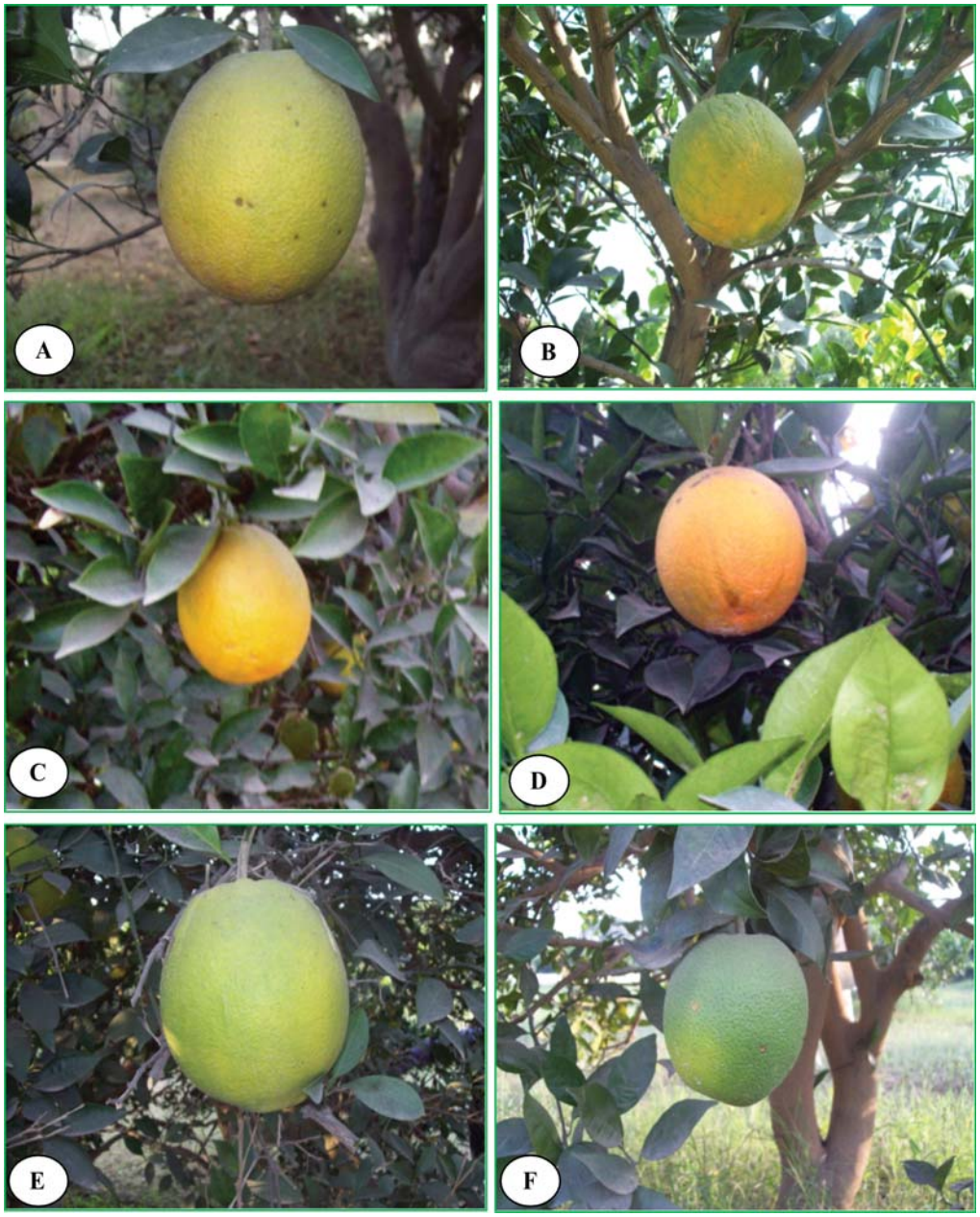

Fig. 4.2. Phenotypic variability in indigenous and exotic cultivars of *Citrus sinensis* (Sweet orange) collected from Punjab, (A) Satgudi; (B) Mosambi; (C) Jaffa; (D) Blood red; (E) Olinda Valencia late; (F) Campbell Valencia

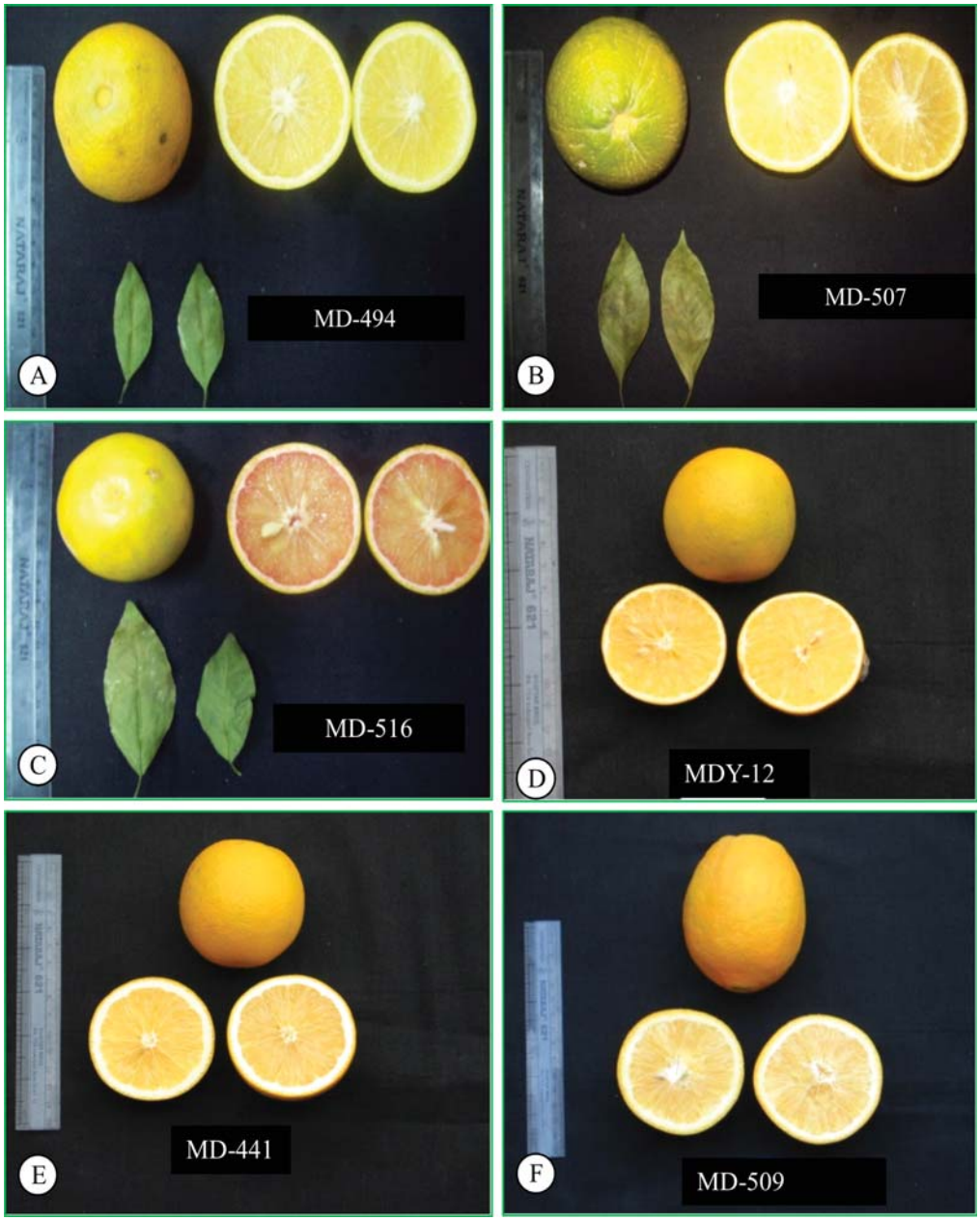

Fig. 4.3. Phenotypic variability in indigenous and exotic cultivars of *Citrus sinensis* (Sweet orange) collected from different part of India, (A) MD-494, Sweet orange from Punjab; (B) MD-507, Mosambi from Punjab; (C) MD-516, Vaniglia sanguigno from Punjab; (D) MDY-12, Jaffa from Punjab; (E) MD-441, Hamlin from Rajasthan; (F) MD-509, New Hall (Naval) from Punjab

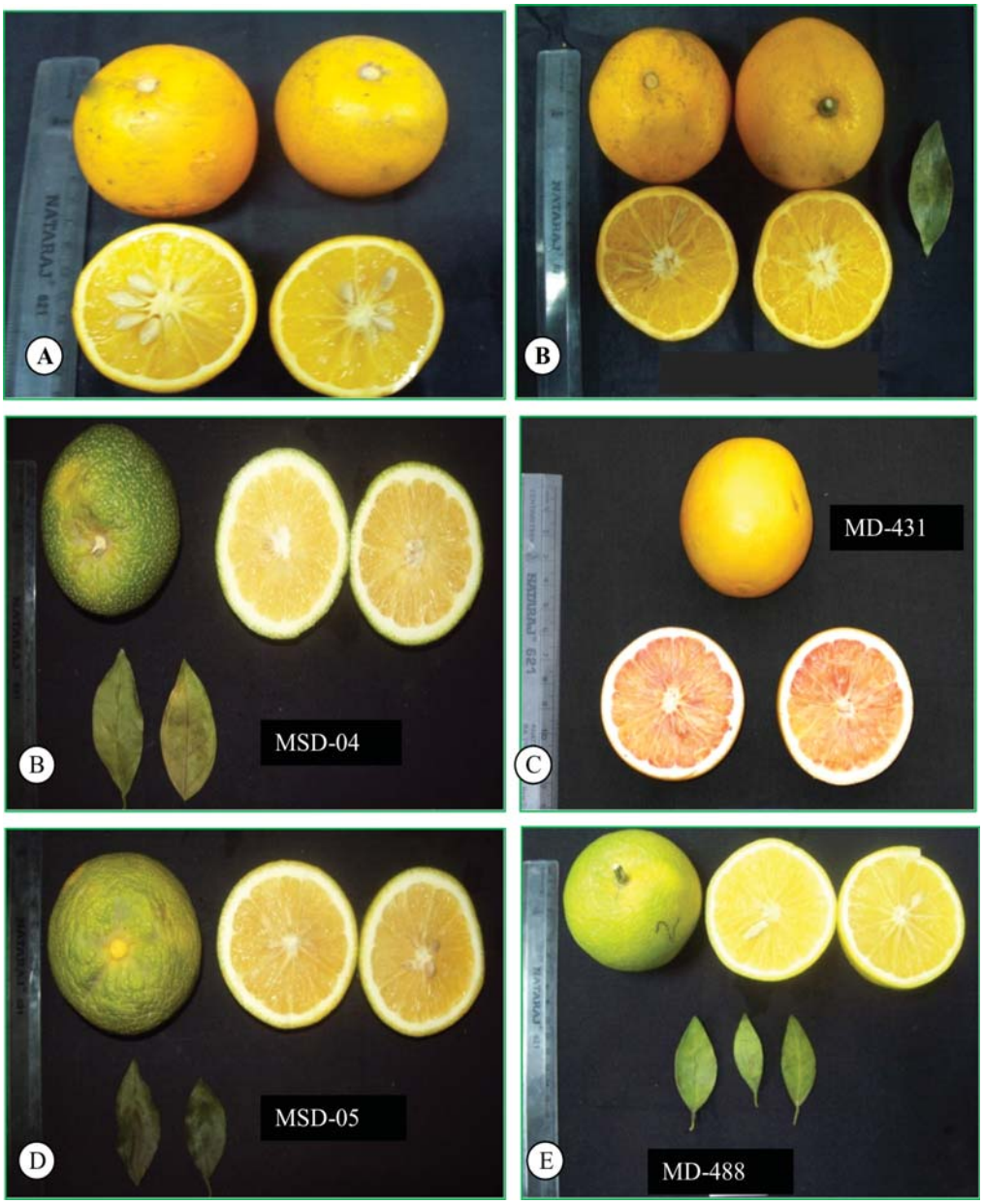

Fig. 4.4. Phenotypic variability in indigenous and exotic cultivars of *Citrus sinensis* (Sweet orange) collected from different parts of India, (A) MD-09/30, Mosambi from A.P; (B) MD-10/59, Malta from W.B; (C) MSD-04, Olinda Valencia Late from Punjab; (D) MD-431, Blood red from Rajasthan; (E) MSD-05, Morro from Punjab; (F) MD-488, Vanale from Punjab

Fig. 4.5. Phenotypic variability in indigenous and exotic cultivars of *C. aurantium* (sour orange) collected from different parts of India, (A) KARHMD-10/42, Smooth flat seville from Sikkim; (B) MD-498, Karun jamir from Abohar; (C) MD-10/52, from Sikkim; (D) MD-432, from Rajasthan

Table 4.2. Qualitative data of Oranges group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit shape	Shape of fruit apex	Fruit colour	Fruit surface texture	Adherence of albedo to pulp	Seed shape	Colour of coty-ledons	Chalazal spot colour
MDY-12	395346	*C. sinensis*	Jaffa	Spheroid	Truncate	Green yellow	Pitted	Strong	Clavate	White	Indian Red
MDY-13	395347	*C. sinensis*	Sonamitri	Spheroid	Rounded	Dark yellow	Pitted	Strong	Clavate	White	Indian Red
MDY-33	395366	*C. sinensis*	Sweet orange	Spheroid	Truncate	Orange	Pitted	Strong	Ovoid	White	Indian Red
MDY-94	395421	*C. sinensis*	Loyalpur S- 1	Spheroid	Truncate	red orange	Pitted	Strong	Ovoid	Cream	Indian Red
MDY-95	395422	*C. sinensis*	Loyalpur S- 2	Spheroid	Rounded	Dark yellow	Smooth	Strong	Clavate	White	Indian Red
MD-445	470360	*C. sinensis*	Blood red	Spheroid	Rounded	Green yellow	Pitted	Strong	Clavate	White	Indian Red
MD-465	470370	*C. sinensis*	Valencia	Spheroid	Truncate	Green yellow	Pitted	Strong	Ovoid	Cream	Indian Red
MD-485	470383	*C. sinensis*	Aspal orange	Ovoid	Truncate	Green yellow	Smooth	Strong	Semi-deltoid	White	Light brown
MD-488	470386	*C. sinensis*	Vanale	Spheroid	Truncate	Green yellow	Pitted	Strong	Ovoid	Cream	Indian Red
MD-499	470394	*C. sinensis*	Satgudi	Ellipsoid	Truncate	Orange	Pitted	Strong	Clavate	Cream	Indian Red
MD-507	470401	*C. sinensis*	Mosambi	Spheroid	Truncate	Orange	Pitted	Strong	Semi deltoid	Cream	Indian Red
MD-508	470402	*C. sinensis*	Declarbe sweet orange	Spheroid	Truncate	Yellow	Pitted	Strong	Clavate	White	Indian Red
MD-509	470403	*C. sinensis*	New Hall (Naval)	Ellipsoid	Rounded	Light orange	Pitted	Strong	Fusiform	Cream	Indian Red
MD-510	470404	*C. sinensis*	Mediterranean sweet orange	Spheroid	Truncate	Yelloiw	Pitted	Strong	Clavate	Cream	Indian Red

MD-512	470405	*C. sinensis*	Teneriffe	Spheroid	Truncate	Green-Yellow	Pitted	Strong	Clavate	Cream	Indian Red
MD-514	470407	*C. sinensis*	Tardiff	Spheroid	Rounded	Green-Yellow	Pitted	Strong	Clavate	Cream	Indian Red
MD-515	470408	*C. sinensis*	Temple	Spheroid	Truncate	Orange	Pitted	Strong	Ovoid	Cream	Indian Red
MD-516	470409	*C. sinensis*	Vaniglia sanguigno	Spheroid	Rounded	Green yellow	Pitted	Strong	Ovoid	Cream	Indian Red
MD-517	470410	*C. sinensis*	Joppa	Ellipsoid	Truncate	Orange	Pitted	Strong	Ovoid	Cream	Indian Red
MD/07/140	558164	*C. sinensis*	Mausambi	Ellipsoid	Rounded	Green-Yellow	Pitted	Strong	Clavate	Cream	Indian Red
MD-10/59	587007	*C. sinensis*	Malta	Spheroid	Truncate	Orange	Pitted	Strong	Clavate	White	Indian Red
MD-10/61	587009	*C. sinensis*	Naval Washington	Spheroid	Truncate	Orange	Pitted	Strong	Ovoid	White	Indian Red
MD-11/71	591430	*C. sinensis*	Mitha chakola	Spheroid	Truncate	Green yellow	Pitted	Strong	Ovoid	White	Indian Red
MD-11/79	591438	*C. sinensis*	Chakola tenga	Spheroid	Truncate	Green yellow	Pitted	Strong	Semideltoid	White	Indian Red
MD-11/88	591447	*C. sinensis*	Mosambi	Spheroid	Truncate	Green yellow	Pitted	Strong	Spheroid	White	Indian Red
MD-11/98	591457	*C. sinensis*	Malta	Spheroid	Truncate	Green yellow	Pitted	Strong	Spheroid	White	Indian Red
MSD-01	—	*C. sinensis*	Seleta	Oblique	Truncate	Yellow	Pitted	Strong	Semi-deltoid	Cream	Indian Red
MSD-02	—	*C. sinensis*	Parent naval	Spheroid	Truncate	Yellow green	Pitted	Strong	Semi-deltoid	Cream	Indian Red
MSD-03	—	*C. sinensis*	Rhode red valencia	Spheroid	Truncate	Green yellow	Pitted	Strong	Semi-deltoid	Cream	Indian Red
MSD-04	—	*C. sinensis*	Olinda valencia late	Oblique	Truncate	Green	Pitted	Strong	Semi deltoid	Cream	Indian Red
MSD-05	—	*C. sinensis*	Morro	Oblique	Rounded	Green yellow	Pitted	Strong	Ovoid	Cream	Indian Red

MSD-06	—	*C. sinensis*	Delta valencia	Spheroid	Rounded	Green	Pitted	Strong	Clavate	White	Indian Red
MDY-78	395406	*C. aurantium*	Karun jamir	Spheroid	Rounded	Green yellow	Smooth	Strong	Fusiform	Cream	Dark brown
MD-432	470347	*C. aurantium*	Sour orange	Spheroid	Truncate	Green yellow	Rough	Strong	Cuneiform	Cream	Dark brown
MD-498	470393	*C. aurantium*	Karun jamir	Spheroid	Rounded	Green yellow	Pitted	Strong	Ovoid	Cream	Brown
MD/07/127	558151	*C. aurantium*	Serenga	Ovoid	Rounded	Green yellow	Pitted	Strong	Spheroid	Cream	Indian Red
MD/07/129	558153	*C. aurantium*	Serenga	Ellipsoid	Rounded	Yellow	Pitted	Strong	Ovoid	Cream	Indian Red
MD/07/148	558172	*C. aurantium*	Bamsim	Pyriform	Truncate	Yellow	Smooth	Strong	Ovoid	Cream	Indian Red
MD/07/151	558175	*C. aurantium*	Bamsim	Spheroid	Rounded	Yellow	Rough	Strong	Ovoid	Cream	Indian Red
MD/07/157	558181	*C. aurantium*	Kampil	Pyriform	Truncate	Orange	Pitted	Strong	Semi-deltoid	White	Indian Red
KARHMD-10/42	586990	*C. aurantium*	Smooth flat seville	Spheroid	Truncate	Yellow	Smooth	Strong	Wrinkle	White	Indian Red

Table: 4.3. Quantitative data of Oranges group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit weight (gm)	Fruit diameter (mm)	Fruit length (mm)	Width of epicarp at equatorial area (mm)	Fruit rind thick-ness (mm)	No. of segments per fruit	TSS (°B)	No. of seed/ fruit	10 Seed wt. (gm)
MDY-12	395346	*C. sinensis*	Jaffa	170.67 ±0.33	56.23 ±0.03	62.43 ±0.03	2.33 ±0.33	4.80 ±0.12	9.00 ±0.40	31.33 ±1.67	1.50 ±0.01	8.20 ±0.34
MDY-13	395347	*C. sinensis*	Sonamitri	272.53 ±7.33	66.17 ±0.17	76.73 ±0.23	1.92 ±0.32	5.02 ±0.37	11.33 ±0.67	2.00 ±0.43	10.00 ±2.08	0.40 ±0.18
MDY-33	395366	*C. sinensis*	Sweet orange	208.33 ±6.23	72.40 ±2.95	70.23 ±1.35	2.60 ±0.31	6.60 ±0.87	11.67 ±0.33	8.33 ±0.67	5.00 ±0.58	2.45 ±0.89
MDY-94	395421	*C. sinensis*	Loyalpur S- 1	172.53 ±7.33	57.57 ±0.30	67.10 ±0.31	1.92 ±0.32	5.02 ±0.37	11.00 ±0.58	2.00 ±0.89	3.33 ±0.88	0.40 ±0.99
MDY-95	395422	*C. sinensis*	Loyalpur S- 2	231.67 ±5.50	56.10 ±0.38	65.13 ±0.07	3.14 ±0.10	6.25 ±0.22	11.00 ±1.00	2.00 ±0.72	1.00 ±0.00	0.40 ±0.58
MD-445	470360	*C. sinensis*	Blood red	231.67 ±6.50	75.23 ±2.66	78.29 ±1.92	2.03 ±0.03	6.25 ±0.22	11.67 ±0.33	8.00 ±1.00	4.33 ±0.88	2.45 ±1.82
MD-465	470370	*C. sinensis*	Valencia	296.67 ±6.50	85.02 ±1.81	85.64 ±1.96	2.70 ±0.12	6.13 ±0.18	11.00 ±0.58	7.33 ±0.33	2.33 ±0.33	1.45 ±0.59
MD-488	470386	*C. sinensis*	Vanale	261.67 ±5.50	80.57 ±3.53	75.27 ±2.08	3.03 ±0.38	5.60 ±0.35	11.00 ±0.45	8.40 ±0.31	9.00 ±0.58	1.82 ±0.78
MD-499	470394	*C. sinensis*	Satgudi	200.00 ±6.50	71.16 ±4.41	75.68 ±4.40	1.90 ±0.38	5.27 ±1.52	10.67 ±0.33	7.00 ±0.58	3.33 ±0.88	1.42 ±0.54
MD-507	470401	*C. sinensis*	Mosambi	275.00 ±9.50	76.97 ±1.62	71.84 ±0.75	2.22 ±0.42	5.02 ±0.37	10.00 ±1.00	8.67 ±0.67	2.67 ±0.33	1.82 ±0.45
MD-508	470402	*C. sinensis*	Declabre sweet orange	246.67 ±6.12	77.59 ±2.58	73.12 ±2.19	4.25 ±0.12	5.35 ±0.43	12.00 ±0.58	8.20 ±0.57	10.67 ±1.76	2.66 ±1.23
MD-509	470403	*C. sinensis*	New Hall (Naval)	342.67 ±6.45	79.68 ±3.91	100.91 ±2.82	3.14 ±0.10	6.79 ±0.58	9.33 ±0.33	7.73 ±0.07	2.00 ±1.00	0.40 ±0.78

MD-510	470404	*C. sinensis*	Mediterranean sweet orange	260.00 ±6.50	78.48 ±3.67	83.97 ±5.56	2.99 ±0.23	5.78 ±0.50	10.33 ±0.33	8.00 ±0.00	3.00 ±0.58	1.20 ±0.15
MD-512	470405	*C. sinensis*	Teneriffe	241.67 ±7.50	83.48 ±3.26	88.74 ±1.68	2.75 ±0.30	5.17 ±0.91	10.00 ±0.58	8.33 ±0.88	6.00 ±0.58	2.30 ±2.45
MD-514	470407	*C. sinensis*	Tardiff	170.00 ±5.50	66.68 ±1.00	67.10 ±2.78	1.53 ±0.20	3.70 ±0.32	11.33 ±0.33	7.83 ±0.17	1.33 ±0.33	3.15 ±3.15
MD-515	470408	*C. sinensis*	Temple	326.67 ±5.50	84.17 ±2.08	74.75 ±2.46	2.10 ±0.06	3.53 ±0.24	13.33 ±0.88	9.00 ±0.00	18.67 ±0.67	3.49 ±0.58
MD-516	470409	*C. sinensis*	Vaniglia sanguigno	175.00 ±9.50	67.51 ±7.34	67.51 ±7.34	1.17 ±0.09	3.80 ±0.12	11.33 ±0.33	8.17 ±0.17	3.00 ±1.15	1.45 ±0.56
MD-517	470410	*C. sinensis*	Joppa	129.48 ±5.50	64.02 ±2.66	61.37 ±4.76	1.92 ±0.32	3.20 ±0.27	9.33 ±0.33	7.87 ±0.07	3.33 ±0.33	1.33 ±0.14
MD-07/140	558164	*C. sinensis*	Mosambi	226.67 ±7.50	73.67 ±2.16	77.90 ±1.19	2.17 ±0.09	5.07 ±0.07	11.33 ±0.33	8.40 ±0.60	3.00 ±0.05	2.00 ±0.56
MD-10/59	587007	*C. sinensis*	Malta	163.01 ±1.90	52.17 ±0.03	64.59 ±0.28	1.67 ±0.33	3.10 ±0.78	10.00 ±0.56	15.67 ±2.33	1.82 ±0.12	2.07 ±0.03
MD-10/61	587009	*C. sinensis*	Naval Washington	71.84 ±0.75	42.22 ±0.42	55.02 ±0.37	1.00 ±1.00	3.02 ±0.37	9.00 ±0.58	2.67 ±0.33	2.03 ±0.48	3.04 ±0.08
MD-11/71	591430	*C. sinensis*	Mitha chakola	161.92 ±3.90	52.62 ±3.84	61.39 ±0.09	3.58 ±0.46	4.33 ±0.33	10.67 ±0.33	10.83 ±0.17	12.33 ±1.76	2.53 ±0.21
MD-11/79	591438	*C. sinensis*	Chakola tenga	157.16 ±1.01	50.02 ±0.29	60.77 ±0.09	3.29 ±0.32	5.33 ±0.88	11.00 ±0.58	12.33 ±0.88	20.00 ±9.45	1.87 ±0.16
MD-11/88	591447	*C. sinensis*	Mosambi	266.14 ±0.33	61.85 ±1.92	61.36 ±0.07	2.55 ±0.25	4.00 ±0.18	11.33 ±0.33	10.90 ±0.42	9.33 ±3.71	1.41 ±0.11
MD-11/98	591457	*C. sinensis*	Malta	197.95 ±1.51	52.70 ±0.67	61.65 ±0.13	2.85 ±0.09	4.00 ±0.78	11.00 ±0.58	12.17 ±0.17	11.67 ±2.40	2.06 ±0.03
MSD-01	—	*C. sinensis*	Seleta	326.67 ±6.50	87.79 ±2.03	79.34 ±1.48	3.30 ±0.26	5.78 ±0.11	12.33 ±0.33	9.00 ±0.45	3.33 ±0.33	2.02 ±0.26
MSD-02	—	*C. sinensis*	Parent naval	382.33 ±6.74	94.02 ±3.44	101.13 ±3.02	1.60 ±0.06	6.00 ±0.12	14.67 ±0.33	7.67 ±0.33	3.33 ±0.33	2.02 ±0.89

MSD-03	—	*C. sinensis*	Rhode red valencia	142.33 ±4.33	62.89 ±0.69	62.74 ±0.79	2.20 ±0.21	3.20 ±0.06	11.00 ±0.58	6.43 ±0.12	1.00 ±0.45	0.20 ±0.10
MSD-04	—	*C. sinensis*	Olinda valencia late	323.33 ±3.33	83.99 ±1.10	94.94 ±2.69	2.33 ±0.09	8.40 ±0.31	11.00 ±0.58	6.00 ±0.00	0.33 ±0.33	2.15 ±0.15
MSD-05	—	*C. sinensis*	Morro	233.33 ±5.50	77.52 ±2.77	77.44 ±5.31	3.00 ±0.12	7.80 ±0.12	11.00 ±0.00	6.67 ±0.33	4.00 ±2.08	2.07 ±0.78
MSD-06	—	*C. sinensis*	Delta valencia	142.33 ±4.33	62.89 ±0.69	62.74 ±0.79	2.20 ±0.21	3.20 ±0.06	11.00 ±0.58	6.43 ±0.12	1.00 ±0.58	0.20 ±1.45
MDY-78	395406	*C. aurantium*	Karun jamir	72.92 ±4.43	43.37 ±0.19	46.67 ±0.44	1.67 ±0.33	2.10 ±0.78	9.77 ±0.38	12.33 ±1.45	2.13 ±0.45	2.11 ±0.80
MD-432	470347	*C. aurantium*	Sour orange	219.84 ±9.50	81.77 ±1.62	78.57 ±1.75	2.11 ±0.09	5.18 ±0.59	10.67 ±0.33	5.07 ±0.07	18.00 ±1.53	0.41 ±0.14
MD-498	470393	*C. aurantium*	Karun jamir	221.86 ±8.75	85.08 ±6.49	82.01 ±3.75	3.02 ±0.32	7.68 ±1.43	9.67 ±0.33	9.20 ±0.25	21.00 ±3.79	1.02 ±0.10
MD/07/127	558151	*C. aurantium*	Serenga	88.33 ±1.67	39.17 ±3.44	43.60 ±0.06	2.10 ±0.47	3.10 ±0.12	9.00 ±0.58	5.67 ±0.88	11.00 ±4.36	0.75 ±0.10
MD/07/129	558153	*C. aurantium*	Serenga	86.67 ±4.41	34.77 ±0.39	44.10 ±0.06	2.30 ±0.00	3.10 ±0.45	7.33 ±0.33	7.53 ±0.15	18.67 ±9.17	2.11 ±0.80
MD/07/148	558172	*C. aurantium*	Bamsim	166.67 ±7.50	42.67 ±0.33	51.67 ±0.33	2.27 ±0.03	3.63 ±0.07	10.33 ±0.33	7.33 ±0.07	18.33 ±4.67	3.04 ±0.08
MD/07/151	558175	*C. aurantium*	Bamsim	280.00 ±6.12	50.67 ±2.67	53.23 ±0.63	2.27 ±0.03	3.77 ±0.07	11.00 ±0.00	7.33 ±0.07	94.00 ±0.10	2.07 ±0.03
MD/07/157	558181	*C. aurantium*	Kampil	140.00 ±7.12	40.63 ±1.93	45.67 ±0.17	2.10 ±0.15	3.13 ±0.03	13.33 ±0.88	6.33 ±0.33	39.00 ±5.50	1.81 ±0.34
KARHMD-10/42	586990	*C. aurantium*	Smooth flat seville	75.95± 1.73	42.64 ±0.22	46.05 ±0.27	1.67 ±0.67	2.63 ±0.07	10.00 ±0.00	22.67 ±3.71	1.86 ±0.00	2.07 ±0.03

5. Acid members group

5.1 Genetic resources

***Citrus medica* L.**

Common name: Citron

Vernacular name: Bira-jora, Bemberia, Pati-jora, Soh-mondong, Tayum, Themachhi

Description

A bushy small shrub or tree of irregular habit of growth upto 10 ft height; twigs angled and purplish when young, cylindrical at maturity, glabrous, with spine stout, short, single spines in the axils of the leaves; leaves glabrous, obovate or elliptic-ovate or ovate-lanceolate, bluntly pointed or rounded at the tips, cuneate or rounded at the base, margins serrate; petioles short, wingless or narrowly margined, not clearly articulated with the leaf blade or sometimes articulation absent; inflorescences short, few-flowered racemes, flower buds large, purplish, flowers perfect, petals 5, pinkish on the outside; stamens numerous, 30-40 or even 60, ovary large, with 10-13 locules, tapering into the thick style; fruit large, oblong or oval, surface smooth or more often rough and bumpy, mammilated apex, yellowish when ripe, rind very thick, segments small, filled with pale greenish pulp-vesicles with acid or sweetish pulp; seeds numerous, small, pointed at the base, smooth, cotyledon white, chalazal cap red, monoembryonic.

***Citrus limon* (L.) Burm. f.**

Common name: Lemon

Vernacular name: Nimbu, Assam lemon, Kagji kalan, Baramasi lemon

Description

The tree is 10 to 20 ft in height and usually with sharp thorns on the twigs. Leaves are oblong, elliptic or long-ovate in shape, serrated margin, slightly winged or margined petiole. Flowers are solitary or 2 or more clustered in the

leaf axils. Flower buds are purplish tinged; the opened flowers have 4 or 5 petals, white on the upper surface (inside), purplish beneath (outside) and stamens 20-40. The fruit is oval or oblong with a mammilated apex, surface smooth or rough, pale green colour, rind thick, albedo white, segments 8-10, pulp light yellow, juice sour in taste. Seeds are ovoid or cuneate in shape, creamish cotyledon, chalazal cap reddish, polyembryonic.

***Citrus pseudolimon* Tanaka**

Common name: Hill lemon

Vernacular name: Galgal, Chukh, Chinara

Description

Galgal is a medium size tree 5.0-6.5 m tall, profusely branched, spiny, stout spines, upto 2-3 cm long; leaflets broadly elliptic-ovate to oblong, 9.5-15.5 cm, crenate margin, base cuneate-rounded, obtuse-acute to blunt or pointed at apex; petioles 1-2 cm long and 0.3-0.4 cm wide, marginally winged, distinctly articulated; flowers in clusters of 4-9, solitary, terminal or axillary, mildly fragrant. Fruits ovate-oblong, yellow, 10-11.5 cm in diameter, apex slightly mammilated, smooth to slightly rough surface, rind 0.6-0.8 cm thick, strongly adhering, segments 8-10, pulp light yellow, coarse, vesicles cylindrical, fusiform, loosely packed, seeds 28-59/fruit, light yellow, conical ovate with prominent ridges and smooth surface, creamish cotyledon, purple colour chalazal cap, polyembryonic.

***Citrus jambhiri* Lush.**

Common name: Rough lemon

Vernacular name: Jambhiri, Jatti khatti, Gol nimbu, Gambhir, Jamir, Naity jamir

Description

Tree is 10 to 20 ft height and usually has sharp thorns on the twigs. The alternate leaves, reddish when young, become dark-green above, light-green below; leaf lamina are oblong, elliptic or long-ovate, finely serrated, with slender wings on the petioles, distinctly articulated. Flower buds purplish tinged, flowers solitary or in clusters with 4 or 5 petals. Fruit is spherical with collared mammilated apex, peel is rough and yellow, aromatic, dotted with oil glands. The pulp is pale-yellow, in 8 to 10 segments, hollow axis, pulp melting, very

juicy and acidic. Seeds are ovoid in shape, cotyledon light green, chalazal cap purplish, highly polyembryonic.

***Citrus karna* Raf.**

Common name: Karna khatta

Vernacular name: Duranj, Karna Nimbu, Khatta Nimbu

Description

Tree is upto 20 ft in height. Leaves are elliptic or broadly lanceolate with narrowly winged petiole. Fruit is medium to medium large, of variable form but in general round to oval, usually with broad and prominent nipple, sometimes depressed or lacking, rind moderately thick, firm, surface smooth, warty or ribbed, tightly adherent, colour golden yellow to deep orange, segments 10-12, axis medium-large and semi-hollow to solid, flesh colour dull orange, coarse-textured, only moderately juicy, flavor acid with faint aroma suggestive of sour orange. Seeds are numerous, clavate in shape, creamish cotyledon, chalazal cap reddish and polyembryonic.

***Citrus aurantifolia* (Christm.) Swingle**

Common name: Sour lime

Vernacular name: Nimbu, Kagzi lime, Atol nimbu, Arunachal lime

Description

It is a shrubby tree, upto 4 m tall, with spiny branches. The leaves are ovate or elliptic with narrowly winged petiole. The flowers are yellowish white with a light purple tinge on the margins, in clusters of 3-5 flowers in the axil of leaves. Fruits are rounded, smooth surface, greenish yellow or yellowish at maturity, thin rind, strong adherence with endocarp, pulp light greenish, juicy, segments 6-10, solid axis and juice very sour. Seeds are ovoid in shape, creamish cotyledons, brown chalazal cap and polyembryonic.

***Citrus limettioides* Tan.**

Common name: Sweet lime

Vernacular name: Mitha nimbu, Kagji-wak-ma

Description

The tree is upto 15 ft height. Leaves are elliptic or elliptic-oblong, margin serrated and petioles nearly wingless or margined. The flowers are solitary in the leaf axils or in terminal clusters of 2 to 6 flowers. Fruits solitary or in bunches of 2 to 5, round in shape with rounded apex, smooth surface, yellow colour after maturity, segments 8-12, strong adherence of rind with endocarp, very juicy, juice sweet with light sour in taste. Seeds are ovoid or spheroid in shape, cream cotyledon, chalazal cap brown and polyembryonic.

***Citrus limonia* Osbeck**

Common name: Rangpur lime

Vernacular name: Kole jamir, Tenga

Description

Tree is upto 20 ft tall, densely foliaged and profusely branched. The fruits are spheroid or round in shape with truncate or round base and apex, orange to reddish orange colour surface with minutely pitted smooth texturey moderately loose skin, lime like aroma. Fruit is highly acidic and very juicy, 8 to 10 segments with numerous seeds, slightly hollow in the center. Seeds are clavate or semi-deltoid in shape, light green cotyledon, reddish chalazal cap and polyembryonic.

5.2 Exploration and Collection

Survey and exploration missions were carried out to diversity rich regions of India especially Northeast India to study the area of occurrence, distribution, natural population and biological status of these Citrus species. *C. medica* (Citron) is cultivated throughout India, although natural wild populations of this species are also found to grow in Northeast India. A total of 30 accessions of citron represented by various cultivars and natural types of citron, *viz.* Bira-jora, Bora-tenga, Bemberia, Themachhi, Tayum, Pati-jora, Jora-tenga, Soh-mondong, Gandhraj, Pongam, Chonchunu, etc. were collected from various states of India (Northeastern states, Sikkim, West Bengal, Punjab, Himachal Pradesh), however most of the accessions were collected from Northeast India (Table 5.1). During the survey natural wild population of citron was observed in Debru Saikhowa National Park, Tinsukhia, Assam. 'Tayum', a natural wild type of citron, is found to grow in wild and semi-wild state throughout the Arunachal Pradesh (Fig. 5.2 C). 'Themachhi' is another natural wild type of this species, naturally growing

in the Nokrek Biosphere Reserve, Garo Hills, Meghalaya (Fig. 5.2A). It is also grown by the tribal people in their backyard and homestead garden for their medicinal and nutritional value. Passport details of all the collected accessions are given in Table 5.1 and collection sites are shown in Fig. 5.1.

Citrus limon (Lemon) is distributed throughout India and showed high level of variability (Fig 5.3). A total of 46 accessions of indigenous and exotic types lemon representing several cultivars/types, *viz.* Assam lemon, Khasi lemon, Harvey lemon, Nimbu, Baramasi lemon, Bhadri lemon, Villa franca, Eureka lemon, Kagzi kalan and Sher-phang were collected from different Indian states of Assam, Arunachal Pradesh, Meghalaya, Mizoram, Himachal Pradesh, Punjab and Uttarakhand. *C. peudolimon* (Hill lemon) is commercially cultivated throughout the Western Himalayan regions especially in Himachal Pradesh and Uttarakhand and locally known as Galgal. It is also cultivated in Northeast India and known as 'Chinara' by the local people. Thirty six variable accessions of *C. peudolimon* were collected from Himachal Pradesh, Uttarakhand, Rajasthan, Meghalaya, Assam and Mizoram (Fig. 5.1 and Table 5.1).

Citrus jambhiri (Rough lemon) is an important Indian species and referred in old Indian literature as Jambir. High level of phenotypic variability has existed within the *C. jambhiri* throughout India, but maximum diversity was observed in Western Himalayan region (Uttarakhand and Himachal Pradesh) and Northeast India. Rough lemon is commercially cultivated in Uttarakhand and Himachal Pradesh for production of lemon juice and for making pickles. A total of 56 diverse accessions of rough lemon, *viz.* Jambhiri, Jalandhari khatti, Jatti khatti, Esteus rough, Gambhir, Naity jamir, Gol nimbu, Hathi nimbu, Sinduri lemon, Hasu, Ganpan, etc. were collected from Himachal Pradesh, Uttarakhand, Punjab, Sikkim, West Bengal and Northeastern states (Fig 5.1 and Table 5.1).

Citrus karna is cultivated throughout the Uttarakhand and Himachal Pradesh and locally known as Karna khatta or Duranj. Distribution of this species is not restricted to Western Himalayan region but also distributed and cultivated in other states of India like Uttar Pradesh, Punjab and Northeastern states. A total of 38 accessions of Karna khatta were collected from different part of India, especially Western Himalayas and Northeast India. Two accessions of *C. volkameriana* (Volkomer lemon) were collected from Assam and Arunachal Pradesh, while one accession of *C. pennivesiculata* (Gajanimma) was collected from Field genebank of Punjab Agricultural University, Regional Station, Abohar,

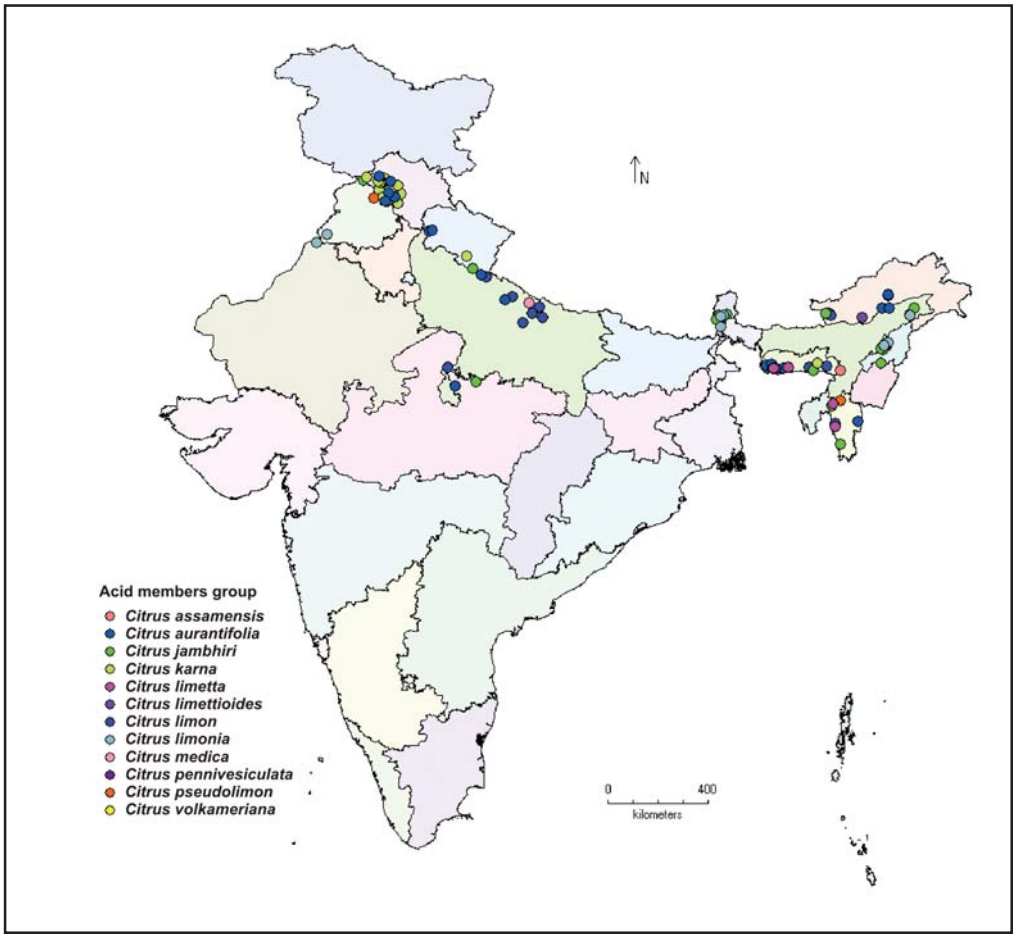

Fig. 5.1. Map of India showing collection sites of acid members group

Punjab. *C. pennivesiculata* is generally found to grow in South India (Table 5.1, Fig. 5.1).

Citrus aurantifolia (Sour lime) is widely distributed and most cultivated species throughout India and locally known as Nimbu, Atol nimbu, Kagzi nimbu and lime. A total of 33 accessions of this species were collected from Himachal Pradesh, Punjab, Uttarakhand, Uttar Pradesh, Rajasthan and Northeast India. *C. limettioides* (Sweet lime) is occasionally distributed in different parts of India, but frequency of this species is very low. Twelve accessions of this species representing cultivars/types viz. Sweet lime, Kagzi-wak-ma were collected from Uttar Pradesh, Meghalaya, Mizoram and Arunachal Pradesh. A total of 10 accessions of *C. limonia* (Rangpur lime) were collected from different states of

Table 5.1. Passport data of Acid members group (*C. medica, C. limon*, *C. pseudolimon*, *C. aurantifolia, C. limettioides, C. limonia, C. jambhiri, C. karna*, etc.) collected from different part of India

S. No.	Collector Number	IC No.	Botanical Name	Common/Vern. /Cult. Name	Biological status	District	State	Lati-tude	Longi-tude
1	DMRK-44	278046	*Citrus medica*	Citron	Cultivated	Kolasib	Mizoram	24.23	92.67
2	DMRK-116	278118	*Citrus medica*	Citron	Cultivated	Champhai	Mizoram	23.47	93.33
3	MDY-71	395400	*Citrus medica*	Citron	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
4	MD-154	417222	*Citrus medica*	Themachhi	Wild	East Garo Hills	Meghalaya	25.30	90.20
5	MD-176	417243	*Citrus medica*	Themachhi	Wild	South Garo Hills	Meghalaya	25.44	90.82
6	MD-475	470376	*Citrus medica*	Citron	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
7	RS/OPD-54	548593	*Citrus medica*	Citron	Cultivated	Bahraich	Uttar Pradesh	27.75	81.48
8	MD/07/115	558139	*Citrus medica*	Themachhi	Wild	East Garo Hills	Meghalaya	25.29	90.19
9	MD/07/116	558140	*Citrus medica*	Themachhi	Wild	East Garo Hills	Meghalaya	25.29	90.19
10	MD/07/123	558147	*Citrus medica*	Themachhi	Wild	East Garo Hills	Meghalaya	25.30	90.20
11	MD/08/211	568603	*Citrus medica*	Ser	Wild	Kolasib	Mizoram	24.11	92.41
12	MD/08/252	568644	*Citrus medica*	Ser	Wild	Lunglei	Mizoram	22.51	92.48
13	MD-09-16	583259	*Citrus medica*	Tayum	Wild	Upper Subansiri	Arunachal Pradesh	27.56	94.20
14	MD-09-27	583270	*Citrus medica*	Tayam	Wild	West Siang	Arunachal Pradesh	28.05	94.42
15	MD-10/49	586997	*Citrus medica*	Bemberia	Wild	East Sikkim	Sikkim	27.29	88.53
16	MD-10/54	587002	*Citrus medica*	Bemberia	Wild	South Sikkim	Sikkim	27.27	88.40
17	MD-10/62	587010	*Citrus medica*	Bemberia	Wild	Darjeeling	West Bengal	27.04	88.39
18	MS-41	587029	*Citrus medica*	Themachhi	Wild	East Garo Hills	Meghalaya	25.35	90.16
19	MD-11/48	591406	*Citrus medica*	Pati-jora	Cultivated	Tinsukia	Assam	27.31	95.21
20	MD-11/49	591407	*Citrus medica*	Bira-jora	Cultivated	Tinsukia	Assam	27.31	95.21
21	MD-11/52	591410	*Citrus medica*	Soh-mondong	Cultivated	Tinsukia	Assam	27.31	95.21
22	MD-11/63	591421	*Citrus medica*	Citron	Cultivated	Tinsukia	Assam	27.31	95.21

23	MD-11/64	591422	*Citrus medica*	Gandharaj	Cultivated	Tinsukia	Assam	27.31	95.21
24	MD-11/65A	591424	*Citrus medica*	Pongam	Cultivated	Tinsukia	Assam	27.31	95.21
25	MD-11/66	591425	*Citrus medica*	Holong tenga	Cultivated	Tinsukia	Assam	27.31	95.21
26	MD-11/74	591433	*Citrus medica*	Citron	Cultivated	Tinsukia	Assam	27.31	95.21
27	MD-11/83	591442	*Citrus medica*	Bore tenga	Cultivated	Tinsukia	Assam	27.57	95.36
28	MD-11/84	591443	*Citrus medica*	Jora tenga	Wild	Tinsukia	Assam	27.35	95.21
29	MD-11/85	591444	*Citrus medica*	Citron	Wild	Tinsukia	Assam	27.35	95.21
30	MD-11/99	591458	*Citrus medica*	Chonchuno	Wild	Kohima	Nagaland	25.58	94.13
31	DMRK-11	278013	*Citrus limon*	Assam lemon	Cultivated	Ri-Bhoi	Meghalaya	25.41	91.55
32	DMRK-16	278018	*Citrus limon*	Adhalatio	Cultivated	Jaintia Hills	Meghalaya	25.45	92.20
33	DMRK-68	278070	*Citrus limon*	Nimbu	Cultivated	Kolasib	Mizoram	24.23	92.67
34	DMRK-86	278088	*Citrus limon*	Khasi lemon	Cultivated	Kolasib	Mizoram	24.23	92.67
35	MDY-21	395354	*Citrus limon*	Baramasi lemon	Cultivated	Hamirpur	Himachal Pradesh	31.56	76.65
36	MDY-81	395409	*Citrus limon*	Harvey lemon	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
37	MD-191	417257	*Citrus limon*	Nimbu	Cultivated	West Garo Hills	Meghalaya	25.50	90.10
38	MD-202	417268	*Citrus limon*	Num	Cultivated	West Kameng	Arunachal Pradesh	27.36	92.29
39	MD-206	417272	*Citrus limon*	Dhori	Cultivated	West Kameng	Arunachal Pradesh	27.36	92.29
40	MD-413	470328	*Citrus limon*	Baramasi lemon	Cultivated	Dehradun	Uttarakhand	30.34	77.91
41	MD-483	470382	*Citrus limon*	Lemon	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
42	MD-487	470385	*Citrus limon*	Bhadri lemon	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
43	MD-489	470387	*Citrus limon*	Lemon	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
44	MD-497	470392	*Citrus limon*	Lemon	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
45	MD-504	470398	*Citrus limon*	Villa Franca	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
46	MD-604	537669	*Citrus limon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.73	76.45
47	RS/OPD-10	548549	*Citrus limon*	Nimbu	Cultivated	Pilibhit	Uttar Pradesh	28.75	79.77
48	RS/OPD-23	548562	*Citrus limon*	Nimbu	Cultivated	Pilibhit	Uttar Pradesh	28.68	79.97
49	RS/OPD-44	548583	*Citrus limon*	Galgal	Cultivated	Lakhimpur	Uttar Pradesh	27.97	80.88

50	RS/OPD-50	548589	*Citrus limon*	Nimbu	Cultivated	Bahraich	Uttar Pradesh	27.61	81.88
51	RS/OPD-55	548594	*Citrus limon*	Nimboo	Cultivated	Bahraich	Uttar Pradesh	27.36	81.59
52	RS/OPD-68	548605	*Citrus limon*	Nimboo	Cultivated	Gonda	Uttar Pradesh	27.22	81.99
53	RS/OPD-69	548606	*Citrus limon*	Nimboo	Cultivated	Gonda	Uttar Pradesh	27.22	81.99
54	RS/OPD-71	548608	*Citrus limon*	Nimboo	Cultivated	Barabanki	Uttar Pradesh	27.05	81.26
55	MD/07/152	558176	*Citrus limon*	Lemon	Cultivated	West Garo hills	Meghalaya	25.13	90.31
56	MD/08/224	568616	*Citrus limon*	Sher phang	Cultivated	Kolasib	Mizoram	24.03	92.40
57	MD-09-23	583266	*Citrus limon*	Assam lemon	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
58	MD-11/39	591397	*Citrus limon*	Assam lemon	Cultivated	Tinsukia	Assam	27.31	95.21
59	MD-11/65	591423	*Citrus limon*	Sopai	Cultivated	Tinsukia	Assam	27.31	95.21
60	MD-11/75	591434	*Citrus limon*	Lemon	Cultivated	Tinsukia	Assam	27.31	95.21
61	MDY-76	395404	*Citrus limon*	Villafranca	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
62	MD/08/208	568600	*Citrus limon*	Sher phang	Cultivated	Kolasib	Mizoram	24.11	92.41
63	MD/08/237	568629	*Citrus limon*	She thur	Cultivated	Aizawl	Mizoram	23.40	92.50
64	MD/08/247	568639	*Citrus limon*	Ser phang	Cultivated	Serchhip	Mizoram	23.28	92.51
65	MD/08/249	568641	*Citrus limon*	Ser phang	Cultivated	Serchhip	Mizoram	23.28	92.51
66	MD/08/251	568643	*Citrus limon*	Ser phang	Cultivated	Lunglei	Mizoram	22.51	92.48
67	MD/08/254	568646	*Citrus limon*	Ser phang	Cultivated	Lunglei	Mizoram	22.51	92.48
68	MD/08/255	568647	*Citrus limon*	Ser thur	Cultivated	Lunglei	Mizoram	22.51	92.48
69	MDY-82	395410	*Citrus limon*	Eureka lemon	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
70	MD-200	417266	*Citrus limon*	Nimbu	Cultivated	West Kameng	Arunachal Pradesh	27.32	92.25
71	MD-203	417269	*Citrus limon*	Nimbu	Cultivated	West Kameng	Arunachal Pradesh	27.36	92.29
72	MD-207	417273	*Citrus limon*	Num	Cultivated	West Kameng	Arunachal Pradesh	27.30	92.36
73	IPSKM-269	322096	*Citrus limon*	Kagzi Kalan	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
74	IPSKM-274	322101	*Citrus limon*	Lemon	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
75	IPSKM-275	322102	*Citrus limon*	Kagzi Kalan	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
76	IPSKM-284	322111	*Citrus limon*	Lemon	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57

77	IPSKM-273	322100	*Citrus pseudolimon*	Galgal	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
78	DMRK-73	278075	*Citrus pseudolimon*	Galgal	Cultivated	Kolasib	Mizoram	24.23	92.67
79	MDY-16	395349	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.81	76.12
80	MDY-17	395350	*Citrus pseudolimon*	Galgal	Cultivated	Hoshiarpur	Himachal Pradesh	31.53	75.91
81	MDY-19	395352	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.81	76.12
82	MDY-22	395355	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.56	76.65
83	MDY-24	395357	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.56	76.65
84	MDY-26	395359	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.65	76.46
85	MDY-28	395361	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.59	76.72
86	MDY-31	395364	*Citrus pseudolimon*	Galgal	Cultivated	Mandi	Himachal Pradesh	31.61	76.73
87	MDY-43	395375	*Citrus pseudolimon*	Galgal	Cultivated	Kangra	Himachal Pradesh	32.16	76.34
88	OPD/RC - 7	415175	*Citrus pseudolimon*	Galgal	Cultivated	Kangra	Himachal Pradesh	32.10	76.27
89	OPD/RC - 8	415176	*Citrus pseudolimon*	Galgal	Cultivated	Kangra	Himachal Pradesh	32.12	76.26
90	MD-169	417236	*Citrus pseudolimon*	Chinara	Cultivated	South Garo Hills	Meghalaya	25.21	90.93
91	MD-180	417247	*Citrus pseudolimon*	Chinara	Cultivated	South Garo Hills	Meghalaya	25.44	90.82
92	MD-182	417248	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.41	90.14
93	MD-188	417254	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.49	90.03
94	MD-194	417260	*Citrus pseudolimon*	Chinara	Cultivated	West Garo Hills	Meghalaya	25.32	90.19
95	MD-409	470324	*Citrus pseudolimon*	Galgal	Cultivated	Dehradun	Uttarakhand	30.35	78.02
96	MD-410	470325	*Citrus pseudolimon*	Galgal	Cultivated	Dehradun	Uttarakhand	30.35	78.02
97	MD-416	470331	*Citrus pseudolimon*	Galgal	Cultivated	Kangra	Himachal Pradesh	32.32	76.12
98	MD-418	470333	*Citrus pseudolimon*	Galgal	Cultivated	Kangra	Himachal Pradesh	32.21	76.13
99	MD-420	470335	*Citrus pseudolimon*	Galgal	Cultivated	Kangra	Himachal Pradesh	32.11	76.29
100	MD-438	470353	*Citrus pseudolimon*	Galgal	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
101	MD/07/103	558127	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.32	90.19
102	MD/07/111	558135	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.29	90.19
103	MD/07/122	558146	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.30	90.20

104	MD/07/125	558149	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
105	MD/07/134	558158	*Citrus pseudolimon*	Chinara	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
106	MD/07/158	558182	*Citrus pseudolimon*	Chinara	Cultivated	South Garo Hills	Meghalaya	25.21	90.43
107	MD/08/207	568599	*Citrus pseudolimon*	Chinara	Cultivated	Kolasib	Mizoram	24.11	92.41
108	MD-11/59	591417	*Citrus pseudolimon*	Galgal	Cultivated	Tinsukia	Assam	27.31	95.21
109	MSA-05	593851	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.35
110	MSA-06	593852	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.35
111	MSA-13	593858	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.44	76. 36
112	MSA-20	593863	*Citrus pseudolimon*	Galgal	Cultivated	Hamirpur	Himachal Pradesh	31.55	76.27
113	DMRK-9	278011	*Citrus jambhiri*	Jambhiri	Cultivated	East Khasi Hills	Meghalaya	25.30	91.70
114	MDY-25	395358	*Citrus jambhiri*	Jambhiri	Cultivated	Hamirpur	Himachal Pradesh	31.65	76.46
115	MDY-27	395360	*Citrus Jambhiri*	Jambhiri	Cultivated	Hamirpur	Himachal Pradesh	31.65	76.46
116	MDY-32	395365	*Citrus jambhiri*	Jambhiri	Cultivated	Mandi	Himachal Pradesh	31.67	76.8
117	MDY-37	395369	*Citrus jambhiri*	Jambhiri	Cultivated	Mandi	Himachal Pradesh	31.67	76.91
118	MDY-38	395370	*Citrus jambhiri*	Jambhiri	Cultivated	Mandi	Himachal Pradesh	31.67	76.91
119	MDY-41	395373	*Citrus jambhiri*	Jambhiri	Cultivated	Mandi	Himachal Pradesh	31.98	76.79
120	MDY-45	395376	*Citrus jambhiri*	Jambhiri	Cultivated	Kangra	Himachal Pradesh	32.16	76.34
121	MDY-62	395392	*Citrus jambhiri*	Jallandhari khatti	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
122	MDY-63	395393	*Citrus jambhiri*	Jatti khatti	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
123	MDY-64	395394	*Citrus jambhiri*	Esteus rough	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
124	MDY-83	395411	*Citrus jambhiri*	Mithi	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
125	OPD/RC - 2	415170	*Citrus jambhiri*	Jatti Khati	Cultivated	Gurdaspur	Punjab	32.27	75.64
126	MD-212	417278	*Citrus jambhiri*	Jambhiri	Cultivated	West Kameng	Arunachal Pradesh	27.37	92.16
127	MD-401	470316	*Citrus jambhiri*	Jamir	Cultivated	Udham Singh Nagar	Uttarakhand	28.99	79.49
128	MD-407	470322	*Citrus jambhiri*	Jamir	Cultivated	Dehradun	Uttarakhand	30.35	78.02
129	MD-421	470336	*Citrus jambhiri*	Jamir	Cultivated	Kangra	Himachal Pradesh	32.11	76.29
130	MD-423	470338	*Citrus jambhiri*	Gambhiri	Cultivated	Kangra	Himachal Pradesh	32.23	76.30

131	MD-435	470350	*Citrus jambhiri*	Jatti Khati	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
132	MD-477	470378	*Citrus Jambhiri*	Grambhir	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
133	MD-478	470379	*Citrus jambhiri*	Jamir	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
134	MD-479	470380	*Citrus jambhiri*	Jamir	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
135	MD-924	553631	*Citrus jambhiri*	Jamir	Cultivated	Mandi	Himachal Pradesh	31.66	76.84
136	MD/07/133	558157	*Citrus jambhiri*	Atol	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
137	MD/08/214	568606	*Citrus jambhiri*	Chambowa	Cultivated	Kolasib	Mizoram	24.11	92.41
138	MD/08/223	568615	*Citrus jambhiri*	Sher hang	Cultivated	Kolasib	Mizoram	24.03	92.40
139	MD/08/243	568635	*Citrus jambhiri*	Chownbula	Cultivated	Serchhip	Mizoram	23.28	92.51
140	MD/08/253	568645	*Citrus jambhiri*	Chawangbawla	Cultivated	Lunglei	Mizoram	22.51	92.48
141	MD-09-05	583248	*Citrus jambhiri*	Jamir	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
142	MD-09-25	583268	*Citrus jambhiri*	Jambhiri	Cultivated	Upper Subansiri	Arunachal Pradesh	28.01	94.42
143	MD-09-31	583274	*Citrus jambhiri*	Jambhiri	Cultivated	West Siang	Arunachal Pradesh	28.02	94.40
144	KARHMD-10/40	586988	*Citrus jambhiri*	Jamir	Cultivated	East Sikkim	Sikkim	27.34	88.62
145	MD-10/53	587001	*Citrus jambhiri*	Jamir	Cultivated	East Sikkim	Sikkim	27.25	88.45
146	MD-10/56	587004	*Citrus jambhiri*	Naity Jamir	Cultivated	West Sikkim	Sikkim	27.28	88.29
147	MD-10/58	587006	*Citrus jambhiri*	Naity Jamir	Cultivated	West Sikkim	Sikkim	27.15	88.25
148	MD-10/68	587016	*Citrus jambhiri*	Naity Jamir	Cultivated	Darjeeling	West Bengal	26.86	88.22
149	MD-11/40	591398	*Citrus jambhiri*	Gol nimbu	Cultivated	Tinsukia	Assam	27.31	95.21
150	MD-11/41	591399	*Citrus jambhiri*	Hathi nimbu	Cultivated	Tinsukia	Assam	27.31	95.21
151	MD-11/54	591412	*Citrus jambhiri*	Sinduri lemon	Cultivated	Tinsukia	Assam	27.31	95.21
152	MD-11/57	591415	*Citrus jambhiri*	Rough lemon	Cultivated	Tinsukia	Assam	27.31	95.21
153	MD-11/60	591418	*Citrus jambhiri*	Rough lemon	Cultivated	Tinsukia	Assam	27.31	95.21
154	MD-11/67	591426	*Citrus jambhiri*	Soh bitter	Cultivated	Tinsukia	Assam	27.31	95.21
155	MD-11/69	591428	*Citrus jambhiri*	Rough lemon	Cultivated	Tinsukia	Assam	27.31	95.21
156	MD-11/76	591435	*Citrus jambhiri*	Nimbu tenga	Cultivated	Tinsukia	Assam	27.31	95.21
157	MD-11/81	591440	*Citrus jambhiri*	Gol nimbu	Cultivated	Tinsukia	Assam	27.57	95.36

158	MD-11/87	591446	*Citrus jambhiri*	Rough lemon	Cultivated	Mokokchung	Nagaland	26.18	94.34
159	MD-11/92	591451	*Citrus jambhiri*	Rough lemon	Cultivated	Mokokchung	Nagaland	26.25	94.36
160	MD-11/93	591452	*Citrus jambhiri*	Hasu	Cultivated	Mokokchung	Nagaland	26.25	94.36
161	MD-11/96	591455	*Citrus jambhiri*	Ganpen	Cultivated	Wokha	Nagaland	26.05	94.22
162	MD-11/97	591456	*Citrus jambhiri*	Rough lemon	Cultivated	Wokha	Nagaland	26.08	94.13
163	MD-11/100	591459	*Citrus jambhiri*	Rough lemon	Cultivated	Kohima	Nagaland	25.57	94.13
164	MSA-25	593866	*Citrus jambhiri*	Rough lemon	Cultivated	Palampur	Himachal Pradesh	32.09	76.25
165	MSA-41	593879	*Citrus jambhiri*	Rough lemon	Cultivated	Kangra	Himachal Pradesh	32.17	75.56
166	IPSKM-278	322105	*Citrus jambhiri*	Rough lemon	Cultivated	Chhatarpur	Madhya Pradesh	24.91	79.59
167	IPSKM-280	322107	*Citrus jambhiri*	Rough lemon	Cultivated	Chhatarpur	Madhya Pradesh	24.91	79.59
168	IPSKM-283	322110	*Citrus jambhiri*	Rough lemon	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
169	IPSKM-266	322093	*Citrus karna*	Karna Khatta	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
170	IPSKM-279	322106	*Citrus karna*	Karna Khatta	Cultivated	Chhatarpur	Madhya Pradesh	24.91	79.59
171	DMRK-197	278199	*Citrus karna*	Karna Khatta	Cultivated	East Khasi Hills	Meghalaya	25.57	91.88
172	MDY-18	395351	*Citrus karna*	Karna Khatta	Cultivated	Hamirpur	Himachal Pradesh	31.81	76.12
173	MDY-20	395353	*Citrus karna*	Karna Khatta	Cultivated	Hamirpur	Himachal Pradesh	31.81	76.12
174	MDY-29	395362	*Citrus karna*	Karna Khatta	Cultivated	Hamirpur	Himachal Pradesh	31.59	76.72
175	MDY-30	395363	*Citrus karna*	Karna Khatta	Cultivated	Hamirpur	Himachal Pradesh	31.59	76.72
176	MDY-34	395367	*Citrus karna*	Karna khatta	Cultivated	Mandi	Himachal Pradesh	31.67	76.8
177	MDY-39	395371	*Citrus karna*	Karna Khatta	Cultivated	Mandi	Himachal Pradesh	31.67	76.91
178	MDY-40	395372	*Citrus karna*	Karna Khatta	Cultivated	Mandi	Himachal Pradesh	31.98	76.79
179	MDY-46	395377	*Citrus karna*	Karna Khatta	Cultivated	Kangra	Himachal Pradesh	32.16	76.34
180	OPD/RC - 3	415171	*Citrus karna*	Karna Khatta	Cultivated	Gurdaspur	Punjab	32.27	75.64
181	MD-403	470318	*Citrus karna*	Duranj	Cultivated	Nainital	Uttarakhand	29.43	79.25
182	MD-414	470329	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.29	76.17
183	MD-424	470339	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.23	76.30
184	MD-480	470381	*Citrus karna*	Karna Khatta	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22

185	MD-603	537668	*Citrus karna*	Karna Khatta	Cultivated	Bilaspur	Himachal Pradesh	31.33	76.77
186	MD/08/215	568607	*Citrus karna*	Sherpharkar	Cultivated	Kolasib	Mizoram	24.11	92.41
187	MD/08/216	568608	*Citrus karna*	Sherpharkar	Cultivated	Kolasib	Mizoram	24.11	92.41
188	MD-09-12	583255	*Citrus karna*	Karma Khatta	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
189	MD-11/56	591414	*Citrus karna*	Karna khatta	Cultivated	Tinsukia	Assam	27.31	95.21
190	MD-11/62	591420	*Citrus karna*	Karna khatta	Cultivated	Tinsukia	Assam	27.31	95.21
191	MSA-01	593849	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.43	76.34
192	MSA-07	593853	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.35
193	MSA-08	593854	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.40
194	MSA-12	593857	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.42	76.40
195	MSA-14	593859	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.44	76. 36
196	MSA-15	593860	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.45	76.33
197	MSA-17	593861	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.50	76.30
198	MSA-19	593862	*Citrus karna*	Duranj	Cultivated	Hamirpur	Himachal Pradesh	31.55	76.27
199	MSA-26	593867	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.09	76.25
200	MSA-28	593869	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.09	76.23
201	MSA-29	593870	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.10	76.22
202	MSA-35	593874	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.09	76.17
203	MSA-37	593875	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.09	76.17
204	MSA-38	593876	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.09	76.15
205	MSA-39	593877	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.09	76.15
206	MSA-40	593878	*Citrus karna*	Duranj	Cultivated	Kangra	Himachal Pradesh	32.13	76.08
207	MD-09-04	583247	*Citrus volkameriana*	Volkomer lemon	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
208	MD-11/51	591409	*Citrus volkameriana*	Volkomer lemon	Cultivated	Tinsukia	Assam	27.31	95.21
209	MD-466	470371	*Citrus pennivesiculata*	Gajanimma	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
210	DMRK-117	278119	*Citrus aurantifolia*	Kagzi lime	Cultivated	Champhai	Mizoram	23.47	93.33
211	MDY-23	395356	*Citrus aurantifolia*	Kagji nimbu	Cultivated	Hamirpur	Himachal Pradesh	31.56	76.65

212	MDY-79	395407	*Citrus aurantifolia*	Coorge lime	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
213	MDY-80	395408	*Citrus aurantifolia*	Sylhet lime	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
214	MDY-89	395417	*Citrus aurantifolia*	Seedless lemon	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
215	MDY-90	395418	*Citrus aurantifolia*	Pant-1 lemon	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
216	OPD/RC - 26	415194	*Citrus aurantifolia*	Nimbu	Cultivated	Dehradun	Uttarakhand	30.35	78.02
217	MD-165	417232	*Citrus aurantifolia*	Nimbu	Cultivated	South Garo Hills	Meghalaya	25.21	90.56
218	MD-168	417235	*Citrus aurantifolia*	Nimbu	Cultivated	South Garo Hills	Meghalaya	25.21	90.93
219	MD-189	417255	*Citrus aurantifolia*	Nimbu	Cultivated	East Garo Hills	Meghalaya	25.49	90.03
220	MD-196	417262	*Citrus aurantifolia*	Atol nimbu	Cultivated	West Garo Hills	Meghalaya	25.54	90.22
221	NSP/OPD-04-10	438459	*Citrus aurantifolia*	Kagji nimbu	Cultivated	Kangra	Himachal Pradesh	32.11	76.53
222	MD-415	470330	*Citrus aurantifolia*	Kagji nimbu	Cultivated	Kangra	Himachal Pradesh	32.32	76.12
223	MD-490	470388	*Citrus aurantifolia*	Nimbu	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
224	MD-496	470391	*Citrus aurantifolia*	Nimbu	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
225	MD-605	537670	*Citrus aurantifolia*	Kagji nimbu	Cultivated	Hamirpur	Himachal Pradesh	31.73	76.45
226	RS/OPD-5	548544	*Citrus aurantifolia*	Nimbu	Cultivated	Pilibhit	Uttar Pradesh	28.75	79.77
227	RS/OPD-40	548579	*Citrus aurantifolia*	Nimbu	Cultivated	Lakhimpur	Uttar Pradesh	27.86	80.64
228	MD/07/128	558152	*Citrus aurantifolia*	Kagzi nimbu	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
229	MD/07/139	558163	*Citrus aurantifolia*	Kaghzi-nimbu	Cultivated	West Garo Hills	Meghalaya	25.15	90.12
230	MD/07/142	558166	*Citrus aurantifolia*	Kaghzi-nimbu	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
231	MD/07/153	558177	*Citrus aurantifolia*	Kaghzi-nimbu	Cultivated	West Garo Hills	Meghalaya	25.13	90.31
232	MD-09-22	583265	*Citrus aurantifolia*	Arunachal lime	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
233	MD-09-26	583269	*Citrus aurantifolia*	Kagzi Nimbu	Cultivated	West Siang	Arunachal Pradesh	28.05	94.39
234	MD-09-34	583277	*Citrus aurantifolia*	Kagzi Nimbu	Cultivated	West Siang	Arunachal Pradesh	27.56	94.46
235	MD-11/47	591405	*Citrus aurantifolia*	Kagzi lime	Cultivated	Tinsukia	Assam	27.31	95.21
236	MSA-04	593850	*Citrus aurantifolia*	Nimbu	Cultivated	Hamirpur	Himachal Pradesh	31.43	76.34
237	IPSKM-260	322087	*Citrus aurantifolia*	Kagzi lime	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
238	IPSKM-264	322091	*Citrus aurantifolia*	Kagzi lime	Cultivated	Tikamgarh	Madhya Pradesh	24.74	78.83

239	IPSKM-265	322092	*Citrus aurantifolia*	Kagzi lime	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
240	IPSKM-267	322094	*Citrus aurantifolia*	Kagzi lime	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
241	IPSKM-271	322098	*Citrus aurantifolia*	Kagzi lime	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
242	IPSKM-276	322103	*Citrus aurantifolia*	Kagzi lime	Cultivated	Chhatarpur	Madhya Pradesh	24.91	79.59
243	MD-177	417244	*Citrus limetta*	Kagzi-wak-ma	Cultivated	South Garo Hills	Meghalaya	25.44	90.82
244	MD/07/117	558141	*Citrus limetta*	Sweet lime	Cultivated	East Garo Hills	Meghalaya	25.29	90.19
245	MD/07/141	558165	*Citrus limetta*	Kagzi-wak-ma	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
246	MD/08/204	568596	*Citrus limetta*	Sweet lime	Cultivated	Kolasib	Mizoram	24.11	92.41
247	MD/08/209	568601	*Citrus limetta*	Sweet lime	Cultivated	Kolasib	Mizoram	24.11	92.41
248	MD/08/212	568604	*Citrus limetta*	Sweet lime	Cultivated	Kolasib	Mizoram	24.11	92.41
249	MD/08/239	568631	*Citrus limetta*	Sweet lime	Cultivated	Serchhip	Mizoram	23.28	92.51
250	MD-09-01	583244	*Citrus limettioides*	Sweet lime	Cultivated	Lower Subansiri	Arunachal Pradesh	27.21	93.46
251	MD-11/73	591432	*Citrus limettioides*	Sweet lime	Cultivated	Tinsukia	Assam	27.31	95.21
252	MD-11/91	591450	*Citrus limettioides*	Sweet lime	Cultivated	Mokokchung	Nagaland	26.23	94.35
253	IPSKM-268	322095	*Citrus limettioides*	Sweet lime	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
254	IPSKM-282	322109	*Citrus limettioides*	Sweet lime	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57
255	IPSKM-277	322104	*Citrus limonia*	Rangpur lime	Cultivated	Chhatarpur	Madhya Pradesh	24.91	79.59
256	MDY-65	395395	*Citrus limonia*	Rangpur lime	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
257	MDY-88	395416	*Citrus limonia*	Rangpur lime	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
258	MD-10/50	586998	*Citrus limonia*	Kole Jamir	Cultivated	East Sikkim	Sikkim	27.30	88.48
259	MD-10/55	587003	*Citrus limonia*	Rangpur lime	Cultivated	South Sikkim	Sikkim	27.27	88.40
260	MD-10/63	587011	*Citrus limonia*	Rangpur lime	Cultivated	Darjeeling	West Bengal	27.04	88.39
261	MD-10/67	587015	*Citrus limonia*	Kole Jamir	Cultivated	Darjeeling	West Bengal	26.86	88.22
262	MD-11/45	591403	*Citrus limonia*	Rangpur lime	Cultivated	Tinsukia	Assam	27.31	95.21
263	MD-11/86	591445	*Citrus limonia*	Tenga	Cultivated	Mokokchung	Nagaland	26.31	94.40
264	MD-11/95	591454	*Citrus limonia*	Rangpur lime	Cultivated	Mokokchung	Nagaland	26.22	94.27

5.3 Characterization

Citrus medica

C. medica is a highly variable group as far as fruit size and shape are concerned. Fruit shape varied from spheroid to ellipsoid. Shape of fruit apex was mammiform. Surface texture of fruits was smooth in most of the cultivars while pitted and rough texture was also recorded. Seeds were ovoid or spheroid in most of the cultivars along with clavate, spheroid, cuneiform or semideltoid in shape with creamish colored cotyledons and reddish chalazal cap. A large variability was recorded in quantitative characters of almost all of the fruit characters. Fruit weight of smallest fruit was 41.67 gm and heaviest was ten times higher which was 451.67 gm in IC591422. TSS value ranged from 4.00 than to 10.00°B in this group. Seed weight showed large variations as smallest seeds as per 10 seeds weight was 0.27 gm (IC470376) and heaviest weight was 1.96 gm (IC591407). The accessions with heaviest fruits (above 400 to 450 gm) were IC591422, IC591424 and IC591421. The higher fruit weight with reasonably high TSS was recorded in accession IC591424. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in Citron are given in Fig. 5.2.

Citrus limon

Fruit shape varied from spheroid to ellipsoid in most of the cultivars. Shape of fruit apex was mammiform in most of the cultivars but also with acute, depressed, truncate and rounded apex. Fruits were greenish to yellowish in color. Fruit surface texture was smooth and rarely with pitted and rough texture. Seed shape was ovoid in most of the cultivars but clavate, cuneiform and spheroid shape were also recorded with creamish colored cotyledons and deep purple to reddish chalazal cap colour. A large variability was recorded in almost all of the fruits characters. Large variation was found in fruit weight, which ranged from 43.67 to 470.50 gm is diverse accessions. TSS value varied from 4.00 to 8.87°B, which was twice from the lowest value. Ten seed weight of smallest seed was 0.60 gm in IC470398 and highest was 1.81 gm in IC395354. The lowest fruit weight with low TSS was recorded in IC395404 and largest fruit with high TSS was observed in IC470385. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in lemon are given in Fig. 5.3.

Citrus pesudolimon

Fruit shape varied from spheroid to ellipsoid with mammiform, rounded or truncate apex. Fruit colour was greenish yellow to dark yellow and with smooth surface and also pitted texture. Large variation was found in seed characters. Seed shape varied from ovoid to semi-deltoid, with clavate and spheroid in some of the cultivars with creamish cotyledons and purple to reddish chalazal spot colour. Fruit weight was ranged from 163.33 to 576.67 gm. TSS value ranged from 4.00 to 11.33°B. Ten seed weight showed large variation as smallest seed weighed 0.68 gm (IC395333) and heaviest weighed 2.97 gm (IC395364 and IC558182). The accessions with heaviest fruits were IC470339 (also good TSS), IC593863 and IC593851. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in hill lemon are given in Fig. 5.4.

Citrus jambhiri

C. jambhiri indicated high variability in fruit shape, size and colour and probably this is the most diverse and highly distributed citrus species of India. Fruit shape varied from spheroid to ellipsoid in most of the accessions; ovoid and pyriform fruit shape was also recorded in some of the accessions. Shape of the fruit apex was mammiform in most of the cultivars with depressed and rounded apex with collared neck, while truncate apex was rarely observed. Large variation was found in fruit color. Fruits were greenish yellow, yellow and orange in colour with rough, smooth and pitted surface texture. Seed shape was ovoid in most of the cultivars with clavate and semi-deltoid shape with light greenish to creamish cotyledons and purple to reddish chalazal spot. Large variation was found in fruit weight. Smallest fruit showed 26.67 gm in IC591452 and heaviest fruit showed 273.33 gm in IC591426. TSS value ranged from 1.00 to 10.00°B. Ten seed weight was minimum (0.35gm) in IC591451 and maximum (1.94gm) in IC591398. The accessions with heavier fruits were IC591426, IC591418 and IC593866 with TSS from 7.0 to 8.5°B. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in rough lemon are given in Fig. 5.5 and 5.6.

Citrus karna

Fruit shape varied from spheroid to ellipsoid with ovoid or blunt mammiform apex. Fruits were yellow to orange in colour with pitted, smooth or rough surface texture. Seed shape varied from ovoid to clavate in most of the

cultivars with reddish chalazal spot colour. Fruit weight ranged from 170.00 (IC593875) to 396.92 (IC470339) gm. TSS of fruits varied from 4.00 to 10.33°B. Ten seed weight varied from 1.05 to 2.87 gm. The accessions having heaviest fruits were IC470339 and IC593874. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in Karna khatta are given in Fig. 5.7.

Citrus aurantifolia

C.aurantifolia is the only cultivated species where several local selection and improvement have been made in India. Fruit shape was spheroid with rounded, acute or slightly mammilated apex in most of the cultivars. Fruits were greenish yellow in color with smooth, rough and pitted surface texture. Seeds were cuneiform, ovoid, fusiform and semi-deltoid in shape with whitish to creamish cotyledons and brown chalazal spot. Fruit weight varied from 29.85 (IC470388) to 150.63 gm (IC470391). TSS of fruits varied from 3.00 to 8.00°B. The ten seed weight also showed large variation. Highest seed weight (1.92 gm) was found in IC558166 and lightest weight (0.44 gm) was found in IC470388, which reflects a great variability in this character. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in sour lime are given in Fig. 5.9 and 5.10.

Citrus limonia

Fruits varied from pyriform to spheroid in shape with depressed, acute, truncate or rounded apex. Fruits were yellowish to orange in color with pitted and smooth surface texture. Seeds were cuneiform in most of the cultivars with semi-deltoid and clavate in shape. Cotyledons were light green to creamish in color with brown, purple and reddish chalazal spot. Fruit weight varied from 43.67 gm to 193.67 gm, which showed a large variation. TSS value also showed large variation, which ranged from 3.00 to 11.33°B. Ten seed weight ranged from 0.42 gm (IC395416) to 3.05 gm (IC586998). The accession IC586998 with heaviest fruit showed high value of TSS. Detailed characterization data of qualitative and quantitative traits is given in Table 5.2 and 5.3. Representative photographs showing phenotypic variability in Rangpur lime are given in Fig. 5.8.

Other *Citrus* species

Two accessions of *C. volkameriana* (Volkomer lemon) and one accession of *C. pennivesiculata* (Gajanimma) had spheroid fruit with rounded apex. Fruits were orange and pitted surface texture in Volkomer lemon, while light yellow with smooth texture in Gajanimma. Seeds were of clavate shape with creamy cotyledon and purple colour chalazal cap in Volkomer lemon, while ovoid shape with white cotyledon and brown clour chalazal cap in Gajanimma. Volkomer fruit weight was 75 gm with TSS 8°B and ten seed weight 1.15 gm in IC583247, whereas fruits were heavier (201 gm) with TSS 6.0°B and ten seed weight 1.05 gm in IC591409. Gajanimma fruits were heavier (218 gm) with TSS 8.07°B and ten seeds weight recorded was 0.39 gm.

C. limettioides fruits were ellipsoid to spheroid with slightly mammiform to rounded fruit apex (Fig. 5.10 E,F). Yellow colour fruit had smooth texture and contained ovoid to spheroid seeds with cream to white cotyledon and brown chalazal spot colour. Fruit weight of sweet lime ranged from 78 to 158 gm, TSS ranged from 8.6 to 11°B and ten seed weight varied from 0.5 to 1.33 gm. Detailed data of qualitative and quantitative traits is given in Table 5.2 and 5.3.

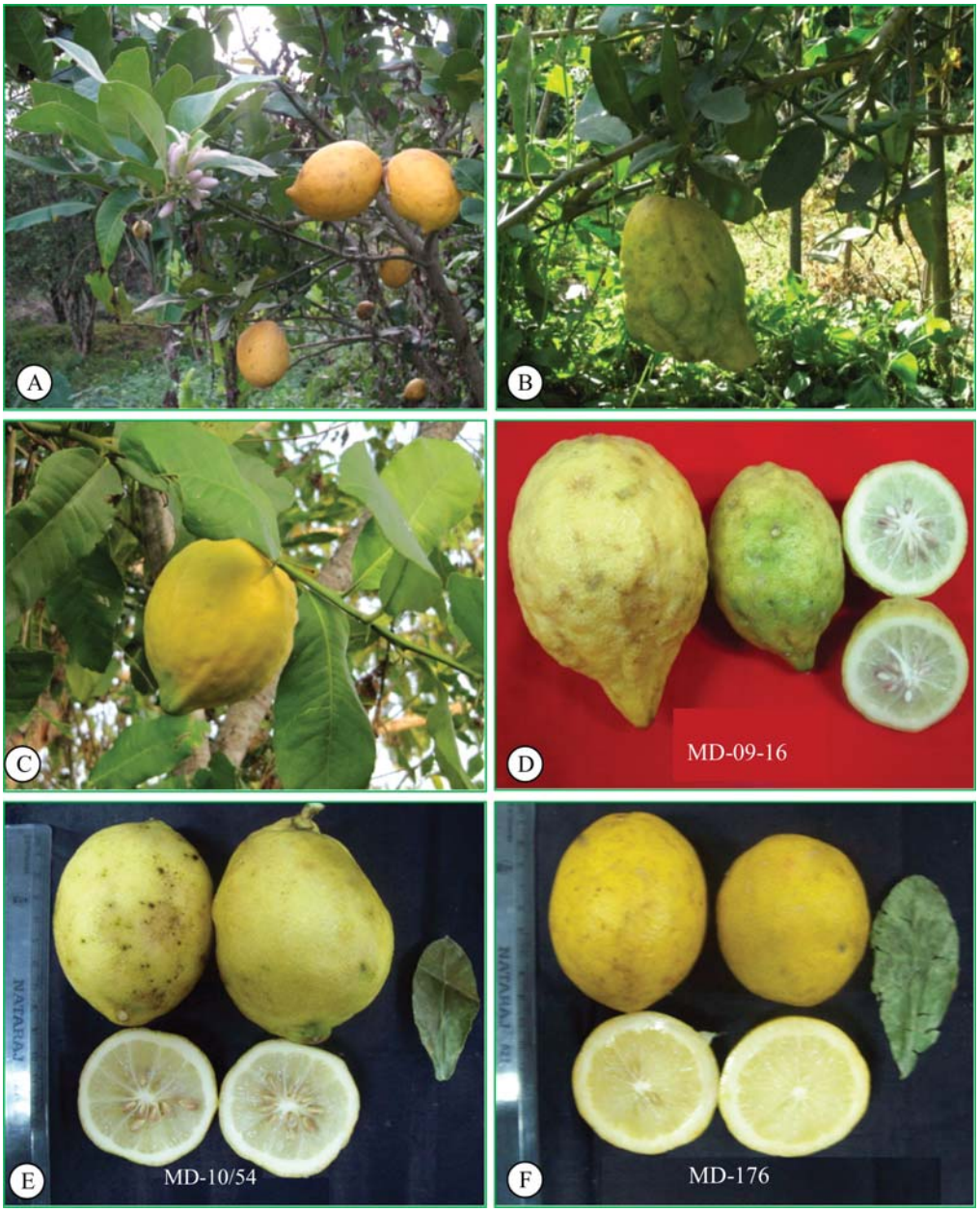

Fig. 5.2. Phenotypic variability in Indigenous cultivars of *Citrus medica* (Citron) collected from Northeast India India, **(A)** Themachhi from Meghalaya; (B) Bora tenga from Mizoram; (C, D) Tayum from Arunachal Pradesh; (E) Bemberia from Sikkim; (F) Themachhi from Meghalaya

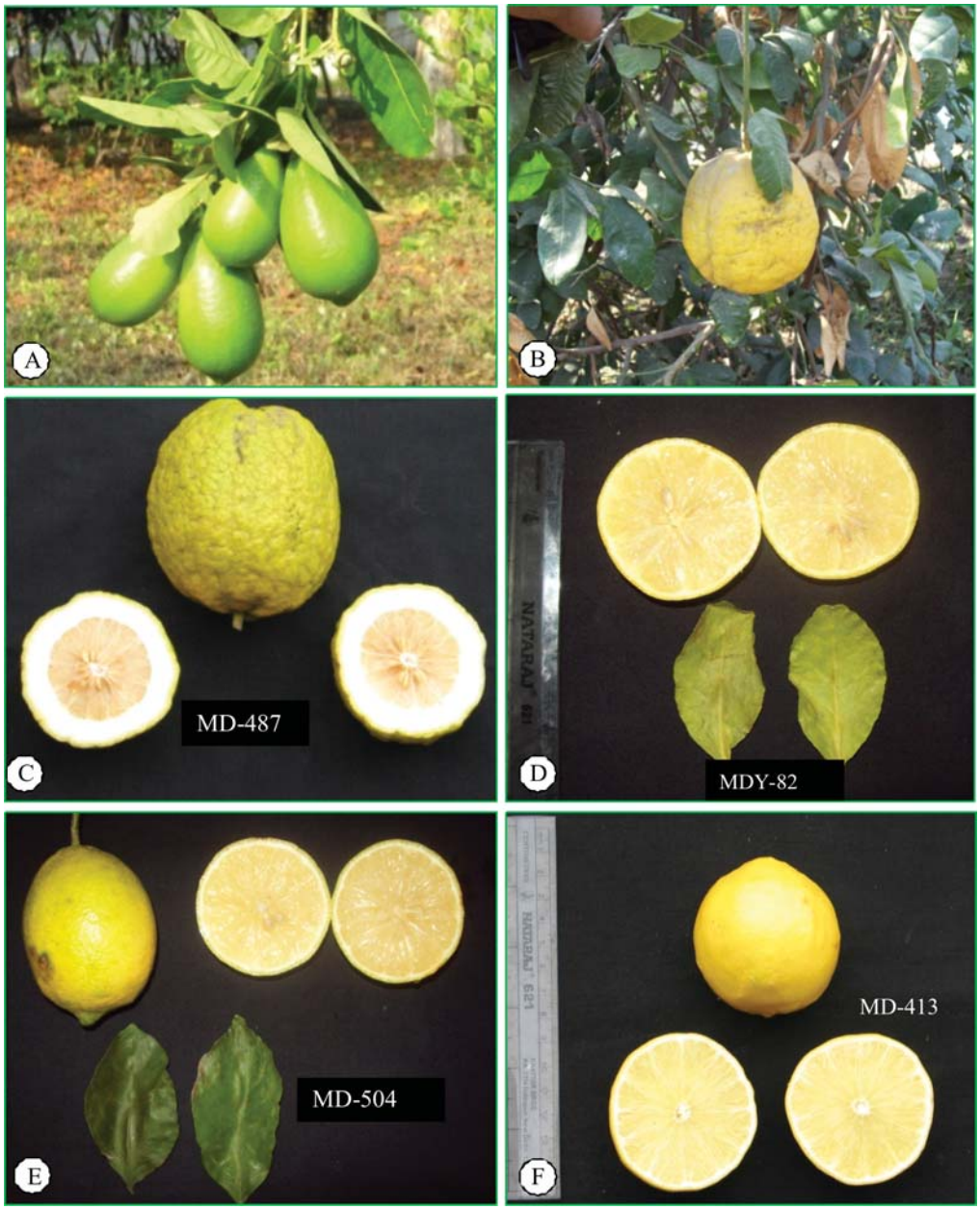

Fig. 5.3. Phenotypic variability in indigenous and exotic cultivars of *Citrus limon* (Lemon) collected from different part of India, (A) Assam lemon from Assam; (B, C) MD-487, Bhadri lemon from Punjab; (D) MDY-82, Eureka lemon from Punjab; (E) MD-504, Villa franca from Punjab; (F) MD-413, Baramasi lemon from Uttarakhand

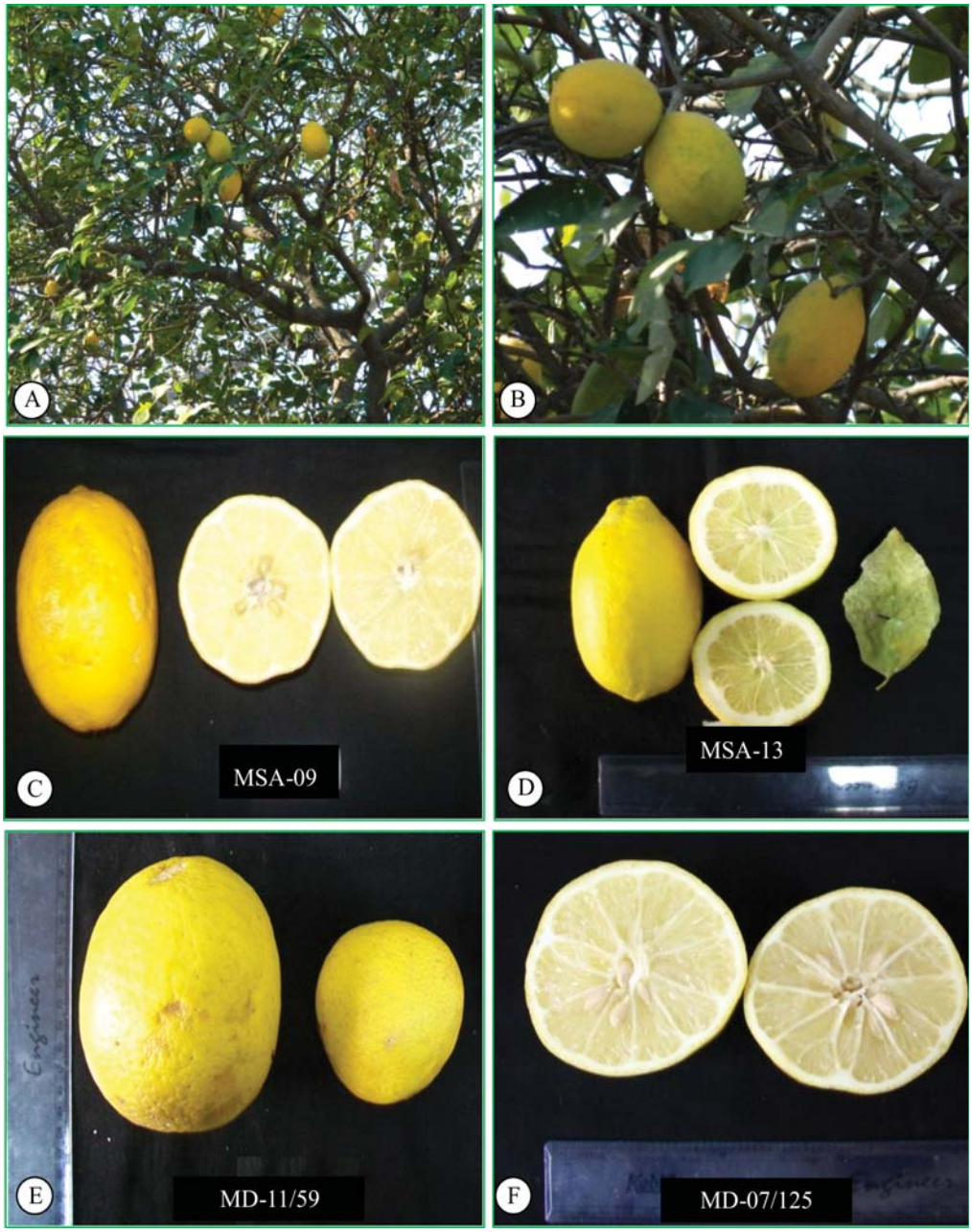

Fig. 5.4. Phenotypic variability in indigenous cultivars of *C. pseudolimon* (Galgal) collected from Himachal Pradesh and Meghalaya, (A-E) Galgal from Himachal Pradesh; (F) MD-07/125, Chinara from Meghalaya

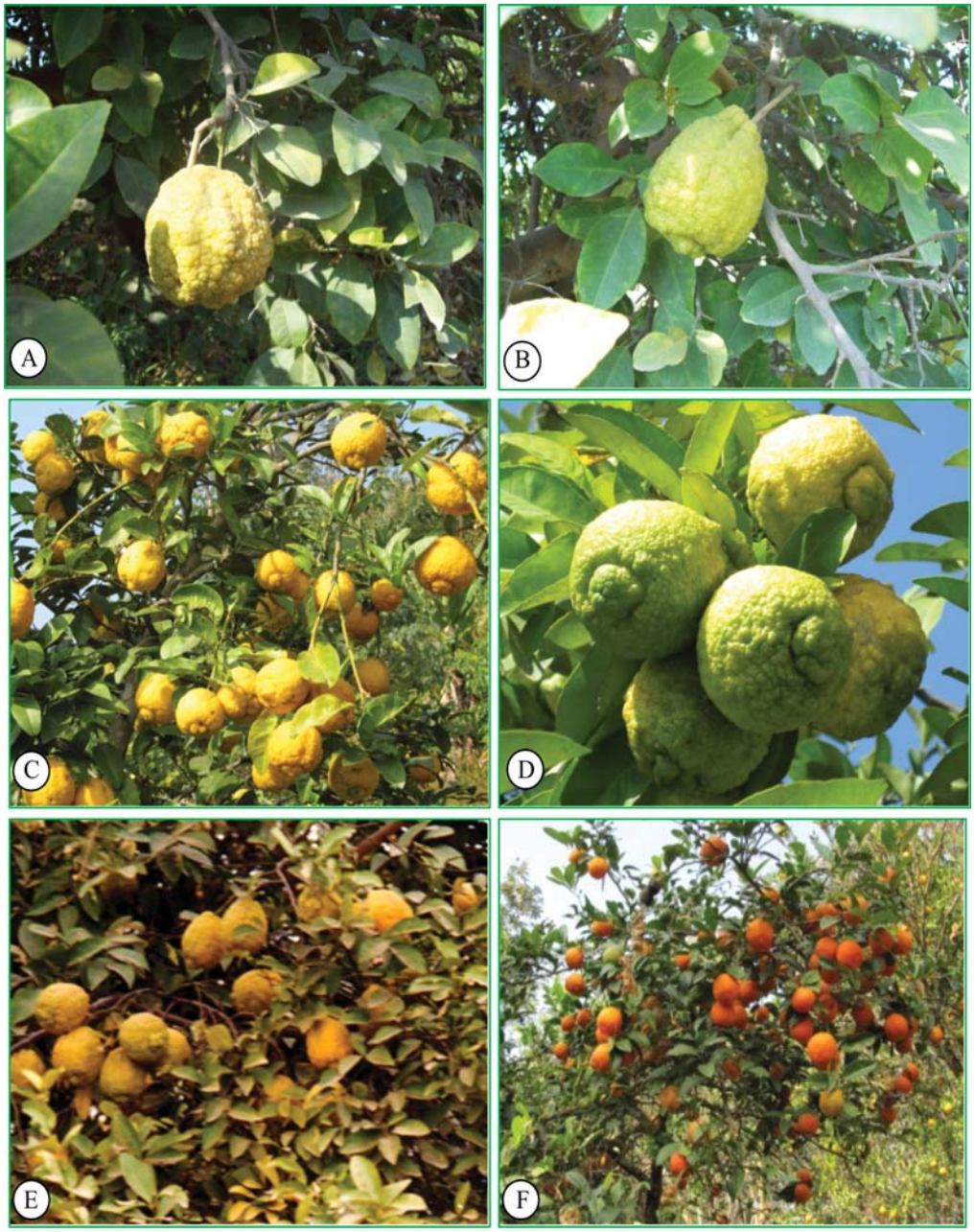

Fig. 5.5. Phenotypic variability in indigenous cultivars of *C. jambhiri* (Rough lemon) collected from different parts of India, (A) Jatti khatti from Punjab; (B) Jalandhari khatti from Punjab; (C) Soh bitter from Assam; (D) Jambhiri from Arunachal Pradesh; (E) Jamir from Himachal Pradesh; (F) Sinduri lemon from Assam

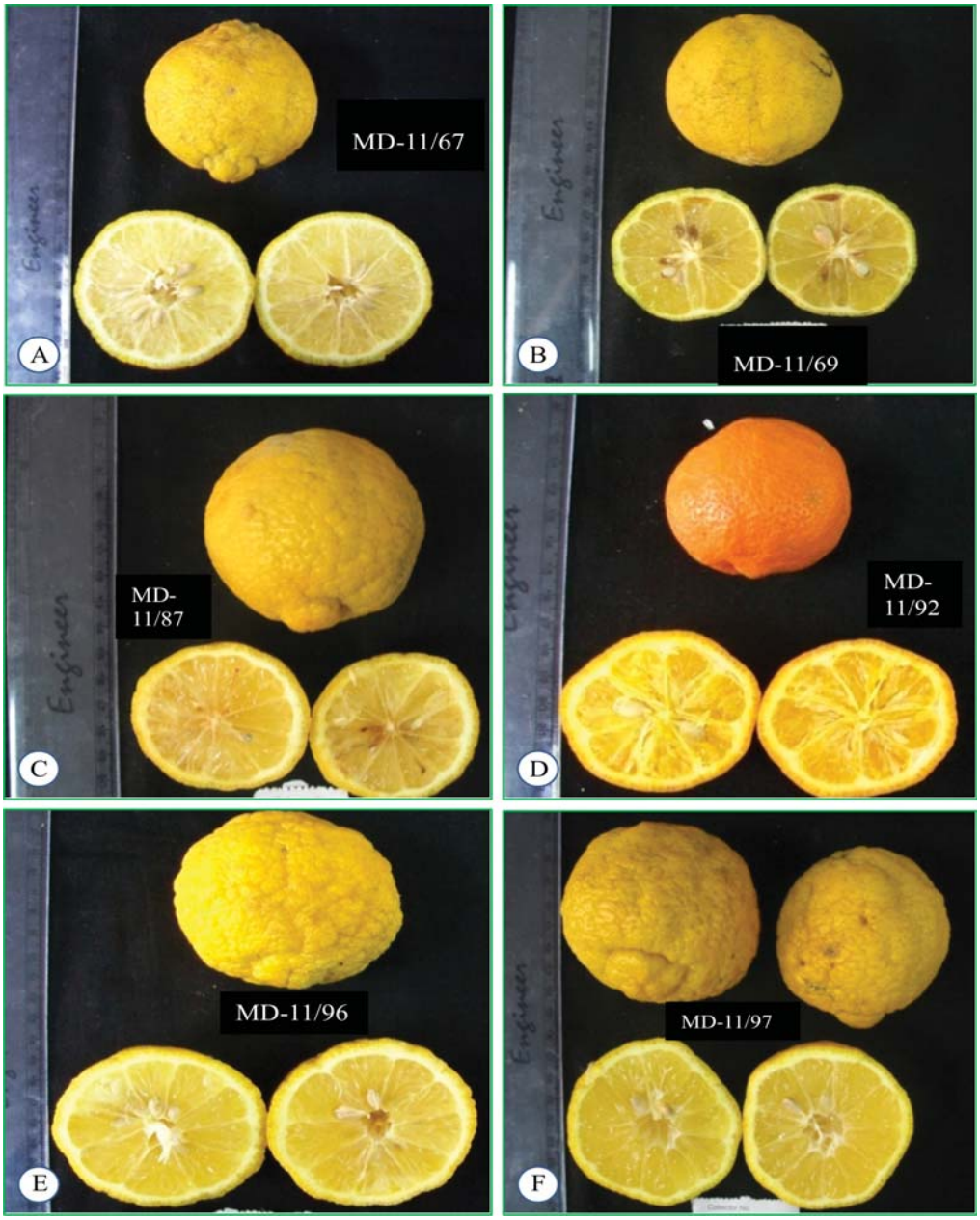

Fig. 5.6. Phenotypic variability in indigenous cultivars of *C. jambhiri* (Rough lemon) collected from different parts of India, (A) MD-11/67, Soh bitter from Assam; (B) MD-11/69, from Assam; (C) MD-11/87, from Nagaland; (D) MD-11/92, from Nagaland; (E) MD-11/96, Ganpen from Nagaland; (F) MD-11/97, from Nagaland

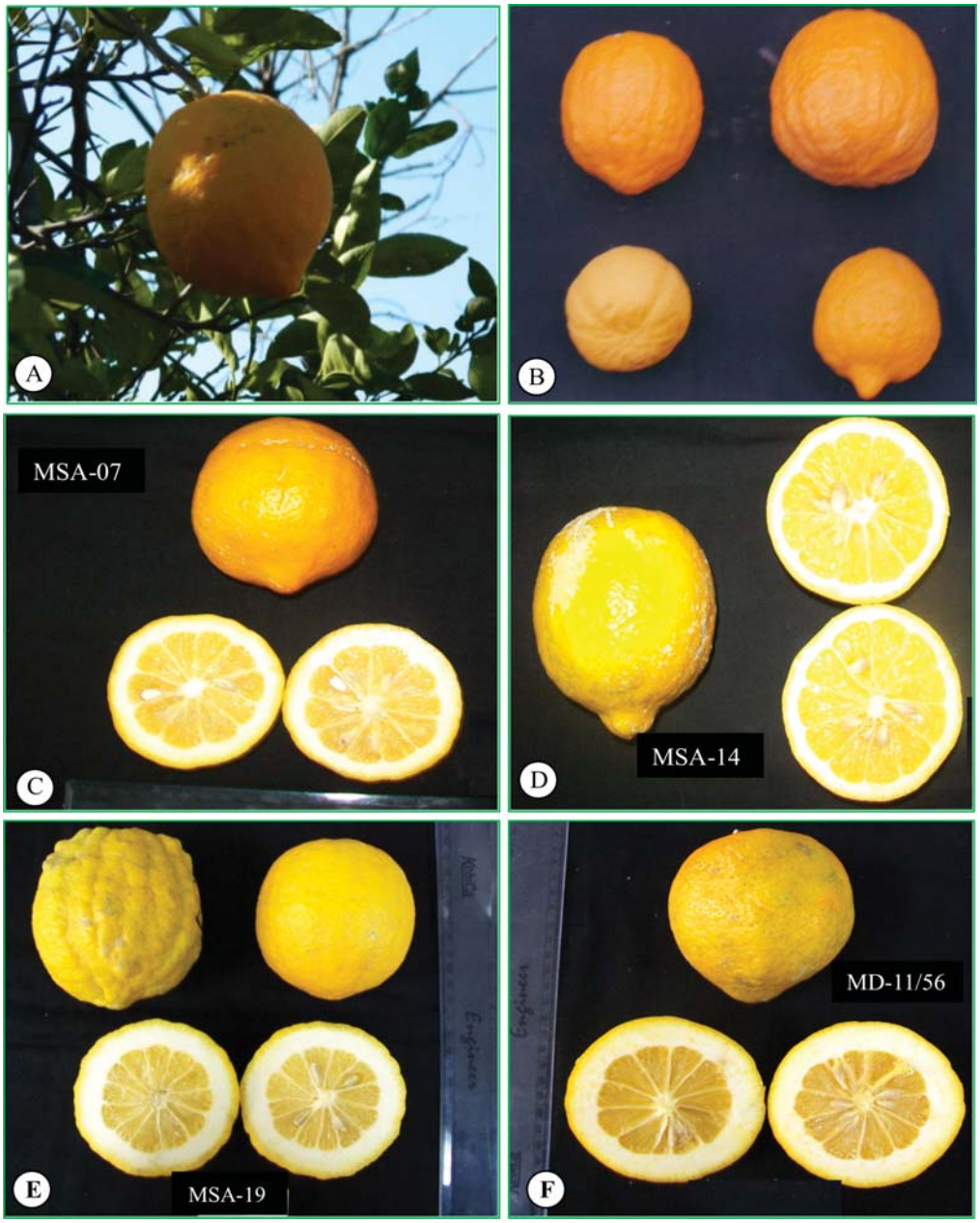

Fig. 5.7. Phenotypic variability in indigenous cultivars of *Citrus karna* (Duranj) collected from different parts of India, (A, B) Duranj from Himachal Pradesh; (C) MSA-07, from H.P; (D) MSA-14 from H.P.; (E) MSA-19, from H.P; (F) MD-11/56, Karna khatta from Assam

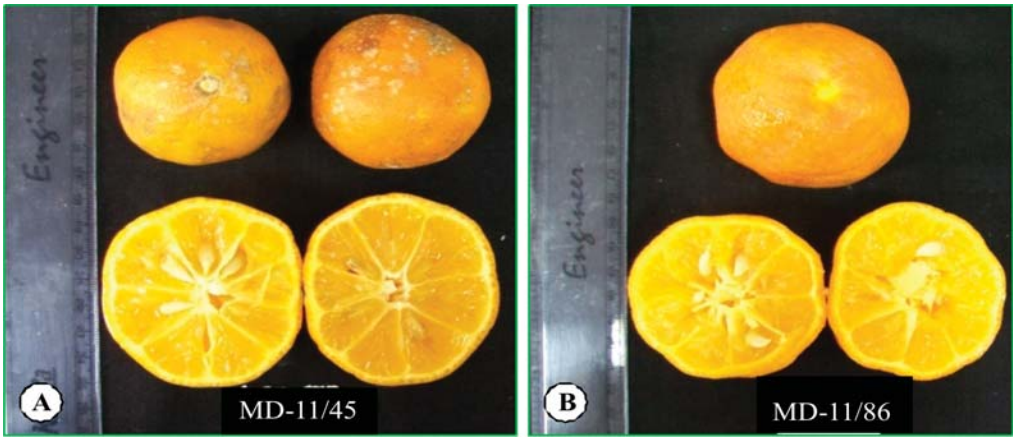

Fig. 5.8. Phenotypic variability in cultivars of *C. limonia* (Rangpur lime) collected from different parts of India, (A) MD-11/45, Rangpur lime from Assam; (B) MD-11/86, Tenga from Nagaland.

Fig. 5.9. Phenotypic variability in indigenous cultivars of *C. aurantifolia* (Lime) collected from Uttar Pradesh, (A) Habit of sour lime (Nimbu); (B) tree bearing mature fruits; (C, D) Variability in fruits

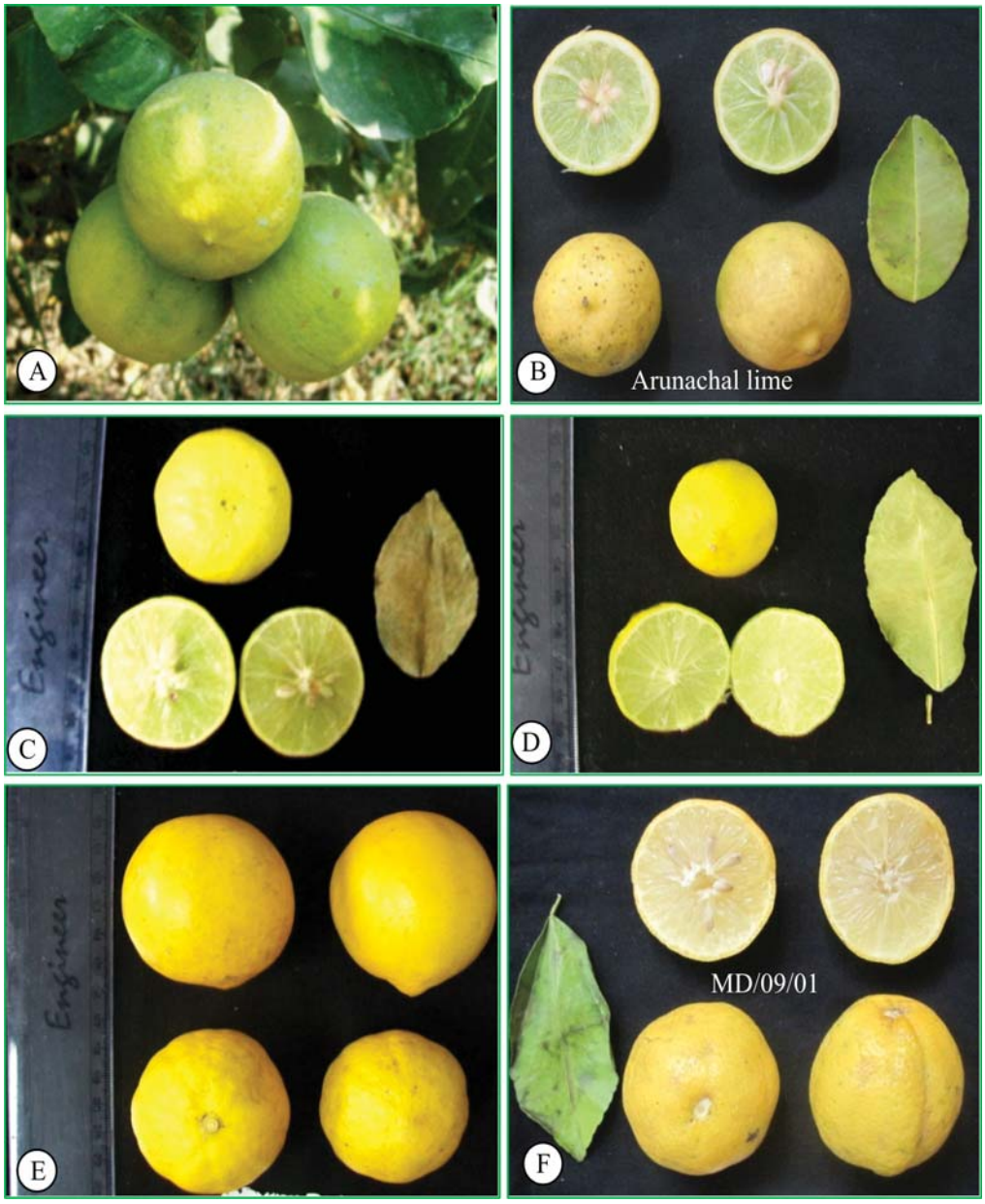

Fig. 5.10. Phenotypic variability in indigenous cultivars of *C. aurantifolia* (Nimbu) and *C. limettioides* collected from different parts of India, (A, B) MD-09-22, Arunachal Lime from Arunachal Pradesh; (C) MD-11/47, Kagzi lime from Assam; (D) MSA-36, Kagji lime from H.P; (E, F) Sweet lime from Andhra Pradesh

Table 5.2. Qualitative parameters of fruit and seed in Acid members group of Citrus

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit shape	Shape of fruit apex	Fruit colour	Fruit surface texture	Adherence of albedo to pulp	Seed shape	Colour of coty-ledons	Chalazal spot colour
MDY-71	395400	*C. medica*	Citron	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Reddish
MD-475	470376	*C. medica*	Citron	Ellipsoid	Mammiform	Yellow	Pitted	Strong	Ovoid	Cream	Reddish
MD/07/115	558139	*C. medica*	Themachhi	Ellipsoid	Mammiform	Yellow	Rough	Strong	Spheroid	Cream	Reddish
MD/07/123	558147	*C. medica*	Themachhi	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Reddish
MD-10/49	586997	*C. medica*	Bemberia	Ellipsoid	Mammiform	Light yellow	Smooth	Strong	Ovoid	Cream	Reddish
MD-10/62	587010	*C. medica*	Bemberia	Ellipsoid	Mammiform	Light yellow	Pitted	Strong	Spheroid	Cream	Reddish
MS-41	587029	*C. medica*	Themachhi	Ellipsoid	Mammiform	Light yellow	Pitted	Strong	Spheroid	Cream	Reddish
MD-11/48	591406	*C. medica*	Pati-jora	Spheroid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Reddish
MD-11/49	591407	*C. medica*	Bira-jora	Spheroid	Mammiform	Yellow	Smooth	Strong	Cuneiform	Cream	Reddish
MD-11/52	591410	*C. medica*	Soh-mondong	Ellipsoid	Mammiform	Yellow	Rough	Strong	Cuneiform	Cream	Reddish
MD-11/63	591421	*C. medica*	Citron	Ellipsoid	Mammiform	Yellow	Pitted	Strong	Semideltoid	Cream	Reddish
MD-11/64	591422	*C. medica*	Gandharaj	Ellipsoid	Mammiform	Yellow	Pitted	Strong	Clavate	Cream	Reddish
MD-11/65A	591424	*C. medica*	Pongam	Ellipsoid	Mammiform	Yellow	Pitted	Strong	Clavate	Cream	Reddish
MD-11/66	591425	*C. medica*	Holong tenga	Ellipsoid	Mammiform	Yellow	Rough	Strong	Spheroid	Cream	Reddish
MD-11/74	591433	*C. medica*	Citron	Ellipsoid	Mammiform	Green yellow	Smooth	Strong	Clavate	Cream	Reddish
MD-11/83	591442	*C. medica*	Bore tenga	Spheroid	Mammiform	Green yellow	Smooth	Strong	Cuneiform	Light cream	Reddish
MD-11/84	591443	*C. medica*	Jora tenga	Spheroid	Mammiform	Green yellow	Smooth	Strong	Cuneiform	Light cream	Reddish
MD-11/85	591444	*C. medica*	Citron	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Reddish
MD-11/99	591458	*C. medica*	Chonchuno	Ellipsoid	Mammiform	Green yellow	Smooth	Strong	Clavate	Light cream	Reddish
MDY-21	395354	*C. limon*	Baramasi lemon	Spheroid	Mammiform	Yellow	Smooth	Strong	Clavate	Cream	Purple
MDY-76	395404	*C. limon*	Villafranca	Ellipsoid	Mammiform	Yellow	Pitted	Strong	Cuneiform	Cream	Reddish
MDY-81	395409	*C. limon*	Harvey lemon	Spheroid	Acute	Green	Smooth	Strong	Ovoid	Cream	Reddish
MDY-82	395410	*C. limon*	Eureka lemon	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Cuneiform	Light green	Brown

MD-413	470328	*C. limon*	Baramasi lemon	Spheroid	Acute	Yellow	Smooth	Strong	Cuneiform	Cream	Dark brown
MD-483	470382	*C. limon*	Lemon	Pyriform	Mammiform	Green yellow	Rough	Strong	Clavate	Cream	Deep purple
MD-487	470385	*C. limon*	Bhadri lemon	Ellipsoid	Acute	Dark yellow	Rough	Strong	Clavate	Cream	Deep purple
MD-489	470387	*C. limon*	Lemon	Pyriform	Depressed	Dark yellow	Smooth	Strong	Ovoid	White	Deep purple
MD-497	470392	*C. limon*	Lemon	Ellipsoid	Mammiform	Green yellow	Smooth	Strong	Ovoid	Cream	Deep purple
MD-504	470398	*C. limon*	Villa Franca	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Reddish
MD-07/152	558176	*C. limon*	Lemon	Spheroid	Truncate	Yellow	Pitted	Medium	Ovoid	Light green	Purple
MD-11/39	591397	*C. limon*	Assam lemon	Ellipsoid	Mammiform	Yellow	Rough	Strong	Spheroid	Cream	Purple
MD-11/75	591434	*C. limon*	Lemon	Spheroid	Rounded	Yellow	Pitted	Strong	Spheroid	Cream	Purple
MDY-16	395349	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Rough	Strong	Ovoid	Cream	Raddish
MDY-17	395350	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Raddish
MDY-19	395352	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Green yellow	Rough	Strong	Ovoid	White	Purple
MDY-22	395355	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Semi-deltoid	Cream	Purple
MDY-24	395357	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Pitted	Strong	Semi-deltoid	White	Reddish
MDY-26	395359	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Semi-deltoid	White	Reddish
MDY-28	395361	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Dark yellow	Pitted	Strong	Semi-deltoid	Cream	Reddish
MDY-31	395364	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	White	Reddish
MDY-43	395375	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Goldenyellow	Rough	Strong	Ovoid	Cream	Reddish
MD-409	470324	*C. pseudolimon*	Galgal	Ellipsoid	Truncate	Dark yellow	Smooth	Medium	Ovoid	Cream	Purple
MD-410	470325	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Green yellow	Pitted	Medium	Semi-deltoid	White	Deep purple
MD-416	470331	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Dark yellow	Pitted	Strong	Ovoid	Cream	Deep purple
MD-418	470333	*C. pseudolimon*	Galgal	Spheroid	Truncate	Dark yellow	Smooth	Medium	Semi-deltoid	White	Brown
MD-420	470335	*C. pseudolimon*	Galgal	Ellipsoid	Rounded	Dark yellow	Smooth	Strong	Ovoid	Cream	Deep purple

MD-438	470353	*C. pseudolimon*	Galgal	Spheroid	Mammiform	Yellow	Smooth	Strong	Clavate	Cream	Deep purple
MD/07/122	558146	*C. pseudolimon*	Chinara	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Clavate	Light green	Purple
MD/07/158	558182	*C. pseudolimon*	Chinara	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Ovoid	Cream	Purple
MD-11/59	591417	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Spheroid	Cream	Purple
MSA-05	593851	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Green Yellow	Smooth	Strong	Spheroid	White	Purple
MSA-06	593852	*C. pseudolimon*	Galgal	Ellipsoid	Rounded	Green Yellow	Pitted	Strong	Ovoid	Cream	Purple
MSA-13	593858	*C. pseudolimon*	Galgal	Ellipsoid	Rounded	Green yellow	Rough	Strong	Spherod	Creamish	Purple
MSA-20	593863	*C. pseudolimon*	Galgal	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Spheroid	Cream	Purple
MDY-25	395358	*C. jambhiri*	Jambhiri	Spheroid	Mammiform	Light orange	Smooth	Strong	Clavate	Light green	Purple
MDY-27	395360	*C. Jambhiri*	Jambhiri	Spheroid	Mammiform	Dark orange	Rough	Medium	Ovoid	Light green	Reddish
MDY-32	395365	*C. jambhiri*	Jambhiri	Spheroid	Mammiform	Golden yellow	Rough	Medium	Ovoid	Light green	Reddish
MDY-37	395369	*C. jambhiri*	Jambhiri	Ellipsoid	Mammiform	Dark yellow	Rough	Strong	Cuneiform	Green	Purple
MDY-38	395370	*C. jambhiri*	Jambhiri	Pyriform	Mammiform	Yellow	Rough	Strong	Ovoid	Cream	Purple
MDY-41	395373	*C. jambhiri*	Jambhiri	Spheroid	Mammiform	Yellow orange	Rough	Medium	Ovoid	Cream	Reddish
MDY-45	395376	*C. jambhiri*	Jambhiri	Spheroid	Mammiform	Light orange	Rough	Medium	Ovoid	Light green	Reddish
MDY-62	395392	*C. jambhiri*	Jallandhari khatti	Ellipsoid	Mammiform	Yellow	Smooth	Medium	Clavate	Green	Purple
MDY-63	395393	*C. jambhiri*	Jatti khatti	Spheroid	Mammiform	Dark yellow	Rough	Strong	Semi-deltoid	Cream	Purple
MDY-64	395394	*C. jambhiri*	Esteus rough	Spheroid	Mammiform	Dark yellow	Rough	Medium	Ovoid	Light green	Reddish
MDY-83	395411	*C. jambhiri*	Mithi	Spheroid	Depressed	Dark yellow	Smooth	Medium	Ovoid	Light green	Reddish
MD-401	470316	*C. jambhiri*	Jamir	Spheroid	Mammiform	Dark yellow	Smooth	Medium	Ovoid	Light green	Reddish
MD-421	470336	*C. jambhiri*	Jamir	Ellipsoid	Mammiform	Dark yellow	Rough	Strong	Clavate	Light green	Reddish

MD-423	470338	*C. jambhiri*	Gambhiri	Spheroid	Mammiform	Dark yellow	Pitted	Medium	Ovoid	Light green	Reddish
MD-435	470350	*C. jambhiri*	Jatti Khati	Pyriform	Truncate	Yellow	Rough	Strong	Clavate	Light green	Reddish
MD-477	470378	*C. jambhiri*	Gambhir	Ellipsoid	Mammiform	Dark yellow	Rough	Strong	Clavate	Cream	Reddish
MD-478	470379	*C. jambhiri*	Jamir	Ovoid	Mammiform	Green	Rough	Strong	Semi-deltoid	Cream	Reddish
MD-479	470380	*C. jambhiri*	Jamir	Spheroid	Truncate	Green yellow	Smooth	Strong	Ovoid	Green	Purple
MD/07/133	558157	*C. jambhiri*	Atol	Spheroid	Mammiform	Yellow	Smooth	Strong	Ovoid	Light green	Reddish
MD-09-05	583248	*C. jambhiri*	Jamir	Spheroid	Mammiform	Green yellow	Rough	Strong	Clavate	Light green	Deep purple
KARHMD-10/40	586988	*C. jambhiri*	Jamir	Spheroid	Mammiform	Green yellow	Pitted	Medium	Clavate	Light green	Deep purple
MD-10/53	587001	*C. jambhiri*	Jamir	Spheroid	Mammiform	Light orange	Smooth	Strong	Ovoid	Light green	Deep purple
MD-10/56	587004	*C. jambhiri*	Naity Jamir	Spheroid	Mammiform	Yellow green	Pitted	Strong	Clavate	Cream	Deep purple
MD-10/58	587006	*C. jambhiri*	Naity Jamir	Spheroid	Mammiform	Yellow	Pitted	Strong	Ovoid	Light green	Deep purple
MD-10/68	587016	*C. jambhiri*	Naity Jamir	Ellipsoid	Mammiform	Green yellow	Pitted	Strong	Spheroid	Cream	Deep purple
MD-11/40	591398	*C. jambhiri*	Gol nimbu	Ellipsoid	Round	Yellow	Smooth	Weak	Ovoid	Light green	Deep purple
MD-11/41	591399	*C. jambhiri*	Hathi nimbu	Spheroid	Mammiform	Green yellow	Pitted	Strong	Ovoid	Light green	Deep purple
MD-11/54	591412	*C. jambhiri*	Sinduri lemon	Spheroid	Rounded	Orange	Pitted	Strong	Ovoid	Light green	Deep purple
MD-11/57	591415	*C. jambhiri*	Rough lemon	Spheroid	Truncate	Orange	Pitted	Medium	Clavate	Light green	Deep purple
MD-11/60	591418	*C. jambhiri*	Rough lemon	Spheroid	Mammiform	Green yellow	Pappilate	Weak	Clavate	Light green	Deep purple
MD-11/67	591426	*C. jambhiri*	Soh bitter	Spheroid	Mammiform	Orange	Pappilate	Medium	Clavate	Light green	Deep purple

MD-11/69	591428	*C. jambhiri*	Rough lemon	Spheroid	Mammiform	Yellow	Pitted	Medium	Clavate	Light green	Deep purple
MD-11/76	591435	*C. jambhiri*	Nimbu tenga	Spheroid	Truncate	Yellow	Smooth	Medium	Clavate	White	Deep purple
MD-11/81	591440	*C. jambhiri*	Gol nimbu	Spheroid	Rounded	Orange	Pitted	Medium	Clavate	Light green	Deep purple
MD-11/87	591446	*C. jambhiri*	Rough lemon	Spheroid	Mammiform	dark yellow	Pitted	Medium	Ovoid	Light green	Deep purple
MD-11/92	591451	*C. jambhiri*	Rough lemon	Spheroid	Mammiform	Orange	Pitted	Weak	Ovoid	Light green	Deep purple
MD-11/93	591452	*C. jambhiri*	Hasu	Spheroid	Mammiform	Orange	Pitted	Medium	Ovoid	White	Deep purple
MD-11/96	591455	*C. jambhiri*	Ganpen	Spheroid	Mammiform	Green orange	Pitted	Medium	Ovoid	Light green	Deep purple
MD-11/97	591456	*C. jambhiri*	Rough lemon	Spheroid	Mammiform	Yellow	Pitted	Medium	Ovoid	Light green	Deep purple
MD-11/100	591459	*C. jambhiri*	Rough lemon	Spheroid	Rounded	Yellow	Smooth	Medium	Ovoid	Light green	Deep purple
MSA-25	593866	*C. jambhiri*	Rough lemon	Spheroid	Mammiform	Green yellow	Pappilate	Medium	Ovoid	Light green	Deep purple
MSA-41	593879	*C. jambhiri*	Rough lemon	Spheroid	Rounded	Dark yellow	Pitted	Medium	Clavate	Light green	Deep purple
MDY-18	395351	*C. karna*	Karna Khatta	Spheroid	Mammiform	Yellow orange	Smooth	Strong	Ovoid	White	Red
MDY-20	395353	*C. karna*	Karna Khatta	Ellipsoid	Mammiform	Green	Smooth	Strong	Ovoid	White	Purple
MDY-29	395362	*C. karna*	Karna Khatta	Spheroid	Mammiform	Orange	Smooth	Strong	Ovoid	Cream	Red
MDY-30	395363	*C. karna*	Karna Khatta	Spheroid	Mammiform	Dark yellow	Smooth	Strong	Clavate	Cream	Red
MDY-34	395367	*C. karna*	Karna khatta	Spheroid	Mammiform	Golden yellow	Smooth	Strong	Clavate	White	Red
MDY-39	395371	*C. karna*	Karna Khatta	Spheroid	Mammiform	Orange	Rough	Strong	Clavate	White	Red
MDY-40	395372	*C. karna*	Karna Khatta	Spheroid	Mammiform	Orange	Pitted	Strong	Clavate	White	Red
MDY-46	395377	*C. karna*	Karna Khatta	Spheroid	Mammiform	Dark yellow	Pitted	Strong	Ovoid	White	Red
MD-403	470318	*C. karna*	Duranj	Ellipsoid	Mammiform	Dark orange	Pitted	Medium	Spheroid	Light yellow	Purple

MD-414	470329	*C. karna*	Duranj	Ellipsoid	Mammiform	Green yellow	Smooth	Strong	Clavate	Cream	Red
MD-424	470339	*C. karna*	Duranj	Ellipsoid	Mammiform	Dark yellow	Pitted	Strong	Clavate	Cream	Red
MD-480	470381	*C. karna*	Karna Khatta	Pyriform	Mammiform	Green yellow	Rough	Strong	Ovoid	White	Red
MD-11/56	591414	*C. karna*	Karna khatta	Spheroid	Mammiform	Orange	Pitted	Strong	Ovoid	Cream	Red
MD-11/62	591420	*C. karna*	Karna khatta	Spheroid	Mammiform	Orange	Smooth	Strong	Semideltoid	Cream	Red
MSA-01	593849	*C. karna*	Duranj	Spheroid	Mammiform	Orange	Pitted	Strong	Ovoid	White	Red
MSA-07	593853	*C. karna*	Duranj	Spheroid	Mammiform	Green Yellow	Pitted	Strong	Ovoid	White	Red
MSA-08	593854	*C. karna*	Duranj	Spheroid	Mammiform	Yellow Orange	Smooth	Strong	Ovoid	White	Red
MSA-12	593857	*C. karna*	Duranj	Spheroid	Mammiform	Yellow Green	Rough	Strong	Ovoid	White	Red
MSA-14	593859	*C. karna*	Duranj	Ellipsoid	Mammiform	Green yellow	Pitted	Strong	Clavate	Cream	Red
MSA-15	593860	*C. karna*	Duranj	Spheroid	Mammiform	Dark Yellow	Pitted	Strong	Clavate	Cream	Red
MSA-17	593861	*C. karna*	Duranj	Spheroid	Mammiform	Orange	Pitted	Strong	Ovoid	Cream	Red
MSA-19	593862	*C. karna*	Duranj	Spheroid	Mammiform	Orange	Rough	Strong	Ovoid	White	Red
MSA-26	593867	*C. karna*	Duranj	Spheroid	Mammiform	Orange	Pitted	Strong	Ovoid	White	Red
MSA-28	593869	*C. karna*	Duranj	Spheroid	Mammiform	Dark yellow	Rough	Strong	Ovoid	White	Red
MSA-29	593870	*C. karna*	Duranj	Spheroid	Mammiform	Yellow	Pitted	Strong	Ovoid	Cream	Red
MSA-35	593874	*C. karna*	Duranj	Spheroid	Mammiform	Green yellow	Pitted	Strong	Semideltoid	Cream	Red
MSA-37	593875	*C. karna*	Duranj	Spheroid	Mammiform	Red orange	Smooth	Strong	Clavate	Cream	Red
MSA-38	593876	*C. karna*	Duranj	Ellipsoid	Mammiform	Orange	Rough	Strong	Clavate	White	Red
MSA-39	593877	*C. karna*	Duranj	Spheroid	Mammiform	Orange	Rough	Strong	Clavate	White	Red
MSA-40	593878	*C. karna*	Duranj	Spheroid	Mammiform	Orange	Pitted	Strong	Semideltoid	White	Red
MD-09-04	583247	*C. volkameriana*	Volkomer lemon	Spheroid	Rounded	Orange	Pitted	Medium	Clavate	Cream	Purple
MD-11/51	591409	*C. volkameriana*	Volkomer lemon	Spheroid	Rounded	Orange	Pitted	Medium	Clavate	Cream	Purple
MD-466	470371	*C. pennivesiculata*	Gajanimma	Spheroid	Rounded	Light yellow	Smooth	Strong	Ovoid	White	Brown
MDY-23	395356	*C. aurantifolia*	Kagji nimbu	Ellipsoid	Acute	Green yellow	Smooth	Strong	Semi-deltoid	Light green	Brown
MDY-79	395407	*C. aurantifolia*	Coorge lime	Spheroid	Truncate	Yellow	Smooth	Strong	Ovoid	Light green	Dark brown
MDY-80	395408	*C. aurantifolia*	Sylhet lime	Ellipsoid	Truncate	Orange	Smooth	Strong	Cuneiform	Light green	Brown

MDY-89	395417	*C. aurantifolia*	Seedless lemon	Spheroid	Mammiform	Yellow	Smooth	Strong	Cuneiform	Cream	Dark brown
MDY-90	395418	*C. aurantifolia*	Pant-1 lemon	Ellipsoid	Truncate	Yellow	Smooth	Strong	Cuneiform	Cream	Dark brown
MD-415	470330	*C. aurantifolia*	Kagji nimbu	Ellipsoid	Mammiform	Yellow	Smooth	Strong	Semi-deltoid	Cream	Dark brown
MD-490	470388	*C. aurantifolia*	Nimbu	Pyriform	Mammiform	Green yellow	Smooth	Strong	Ovoid	Cream	Brown
MD-496	470391	*C. aurantifolia*	Nimbu	Ellipsoid	Mammiform	Orange	Rough	Strong	Fusiform	Cream	Brown
MD/07/139	558163	*C. aurantifolia*	Kaghzi-nimbu	Ellipsoid	Mammiform	Dark yellow	Pitted	Strong	Ovoid	White	Brown
MD/07/142	558166	*C. aurantifolia*	Kaghzi-nimbu	Ellipsoid	Mammiform	Dark yellow	Pitted	Strong	Ovoid	White	Brown
MD/07/153	558177	*C. aurantifolia*	Kaghzi-nimbu	Ellipsoid	Truncate	Green yellow	Pitted	Strong	Ovoid	White	Brown
MD-11/47	591405	*C. aurantifolia*	Kagzi lime	Spheroid	Round	Yellow	Smooth	Strong	Clavate	Cream	Light brown
MSA-04	593850	*C. aurantifolia*	Nimbu	Spheoid	Truncate	Yellow	Smooth	Strong	clavate	Cream	light brown
MD-11/73	591432	*C. limettioides*	Sweet lime	Ellipsoid	Rounded	Yellow	Smooth	Strong	Ovoid	Cream	Brown
MD-11/91	591450	*C. limettioides*	Sweet lime	Spheroid	Mammiform	Yellow	Smooth	Strong	Spheroid	White	Light brown
MDY-65	395395	*C. limonia*	Rangpur lime	Spheroid	Depressed	Dark orange	Smooth	Strong	Cuneiform	Light green	Reddish
MDY-88	395416	*C. limonia*	Rangpur lime	Spheroid	Depressed	Orange	Smooth	Strong	Clavate	Light green	Reddish
MD-10/50	586998	*C. limonia*	Kole Jamir	Spheroid	Truncate	yellow	Pitted	Medium	Semi-deltiod	Cream	Purple
MD-10/63	587011	*C. limonia*	Rangpur lime	Spheroid	Truncate	Orange	Pitted	Medium	Cuneiform	Light green	Purple
MD-10/67	587015	*C. limonia*	Kole Jamir	Pyriform	Acute	Orange	Pitted	Medium	Cuneiform	Cream	Purple
MD-11/45	591403	*C. limonia*	Rangpur lime	Spheroid	Round	Orange	Smooth	Weak	Cuneiform	Cream	Purple
MD-11/86	591445	*C. limonia*	Tenga	Spheroid	Round	Orange	Smooth	Weak	Semideltoid	Light green	Light brown
MD-11/95	591454	*C. limonia*	Rangpur lime	Spheroid	Rounded	Orange	Smooth	Medium	Clavate	Cream	Brown

Table 5.3. Quantitative data of Acid members group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit weight (gm)	Fruit diameter (mm)	Fruit length (mm)	Width of epicarp at equatorial area (mm)	Fruit rind thick-ness (mm)	No. of segments per fruit	TSS (^{0}B)	No. of seed/ fruit	10 Seed wt. (gm)
MDY-71	395400	*C. medica*	Citron	114.98 ±0.78	40.67 ±0.67	72.67 ±1.45	1.74 ±0.26	6.91 ±0.42	10.67 ±0.67	4.00 ±0.10	7.00 ±3.21	0.64 ±0.05
MD-475	470376	*C. medica*	Citron	119.74 ±8.50	52.60 ±7.56	96.58 ±1.87	2.66 ±0.25	7.38 ±0.49	10.67 ±0.67	7.33 ±0.07	3.51 ±2.03	0.27 ±0.02
MD/07/115	558139	*C. medica*	Themachhi	85.00 ±5.70	36.10 ±0.85	87.10 ±0.78	1.83 ±0.17	10.00 ±1.15	10.00 ±0.58	5.80 ±0.78	10.54 ±13.00	0.73 ±0.00
MD/07/123	558147	*C. medica*	Themachhi	83.33 ±8.33	46.00 ±1.00	63.33 ±3.33	2.00 ±0.47	10.33 ±0.33	11.67 ±0.33	7.83 ±0.17	6.00 ±3.00	0.64 ±0.05
MD-10/49	586997	*C. medica*	Bemberia	144.00 ±5.23	61.77 ±1.32	71.10 ±6.25	2.29 ±0.03	9.09 ±0.99	8.67 ±0.67	7.33 ±0.33	2.00 ±0.47	0.65 ±0.05
MD-10/62	587010	*C. medica*	Bemberia	141.33 ±5.20	61.44 ±1.88	82.71 ±4.84	2.17 ±0.17	8.21 ±1.06	10.67 ±0.67	8.00 ±0.00	10.00 ±1.15	0.73 ±0.06
MS-41	587029	*C. medica*	Themachhi	82.00 ±2.00	42.00 ±1.15	43.18 ±0.00	2.33 ±0.17	9.33 ±0.33	11.00 ±0.65	5.60 ±0.45	18.93 ±9.50	0.73 ±0.10
MD-11/48	591406	*C. medica*	Bira-jora	380.00 ±9.75	89.27 ±9.72	98.26 ±8.77	2.54 ±0.06	10.53 ±0.11	11.00 ±0.45	5.80 ±6.00	51.00 ±5.50	1.69 ±0.06
MD-11/49	591407	*C. medica*	Bira-jora	241.67 ±6.01	79.30 ±0.52	81.18 ±0.73	1.09 ±0.01	3.94 ±0.06	13.00 ±0.56	7.13 ±0.13	92.67 ±4.06	1.96 ±0.07
MD-11/52	591410	*C. medica*	Soh-mondong	93.33 ±5.50	52.22 ±0.24	66.95 ±5.68	1.27 ±0.08	3.24 ±0.08	10.00 ±0.45	7.00 ±0.00	13.00 ±1.00	0.93 ±0.03
MD-11/63	591421	*C. medica*	Citron	390.00 ±9.50	80.38 ±5.53	109.04 ±5.29	1.56 ±0.06	8.17 ±0.54	10.00 ±0.60	7.67 ±0.33	95.00 ±7.12	0.77 ±0.16

MD-11/64	591422	*C. medica*	Gandharaj	451.67 ±9.45	80.84 ±5.81	135.24 ±6.45	2.25 ±0.34	7.80 ±0.28	10.00 ±0.65	5.67 ±0.33	24.00 ±6.23	0.84 ±0.14
MD-11/65A	591424	*C. medica*	Pongam	400.00 ±6.50	76.97 ±5.37	88.58 ±6.12	2.15 ±0.05	7.71 ±0.70	10.33 ±0.33	7.67 ±0.33	10.33 ±0.33	0.66 ±0.05
MD-11/66	591425	*C. medica*	Holong tenga	285.00 ±9.50	76.11 ±2.45	101.14 ±2.97	2.39 ±0.16	7.05 ±0.36	11.67 ±0.33	7.67 ±0.33	68.67 ±6.12	0.51 ±0.11
MD-11/74	591433	*C. medica*	Citron	155.00 ±8.26	61.62 ±5.40	79.61 ±5.12	1.52 ±0.10	4.02 ±0.23	10.33 ±0.33	6.50 ±0.29	43.67 ±5.81	1.02 ±0.02
MD-11/83	591442	*C. medica*	Bore tenga	228.33 ±7.26	73.23 ±4.85	93.28 ±2.17	1.58 ±0.08	5.61 ±0.32	10.00 ±0.78	7.00 ±0.94	15.00 ±5.13	0.83 ±0.14
MD-11/84	591443	*C. medica*	Jora tenga	228.33 ±8.45	73.23 ±4.85	93.28 ±2.17	1.58 ±0.08	5.61 ±0.32	10.00 ±0.89	7.00 ±0.05	15.00 ±5.13	0.83 ±0.14
MD-11/85	591444	*C. medica*	Citron	290.00 ±7.45	78.10 ±2.52	114.92 ±5.29	2.68 ±0.27	7.17 ±0.19	11.00 ±0.58	4.83 ±0.17	68.67 ±6.12	1.08 ±0.06
MD-11/99	591458	*C. medica*	Chonchuno	41.67 ±4.41	39.30 ±1.06	51.02 ±2.43	1.38 ±0.10	7.42 ±0.13	10.33 ±0.33	10.00 ±0.65	7.67 ±0.88	1.12 ±0.07
MDY-21	395354	*C. limon*	Baramasi lemon	218.71 ±6.16	64.70 ±0.12	60.30 ±0.37	1.00 ±0.56	1.67 ±0.20	14.33 ±0.33	4.00 ±0.00	18.67 ±1.45	1.81 ±0.04
MDY-76	395404	*C. limon*	Villa Franca	43.67 ±10.71	97.30 ±0.43	71.30 ±0.32	1.27 ±0.17	0.10 ±0.05	10.33 ±0.67	4.00 ±0.00	58.33 ±4.84	0.69 ±0.04
MDY-81	395409	*C. limon*	Harvey lemon	123.67 ±2.03	58.30 ±0.33	51.30 ±0.41	3.64 ±0.12	0.40 ±0.86	13.67 ±0.33	5.00 ±0.00	58.33 ±4.84	1.76 ±0.03
MDY-82	395410	*C. limon*	Eureka lemon	150.00 ±5.26	60.22 ±0.58	73.87 ±0.56	2.10 ±0.25	3.50 ±0.56	8.00 ±0.00	6.00 ±0.00	12.00 ±0.00	0.69 ±0.08
MD-413	470328	*C. limon*	Baramasi lemon	148.42 ±9.87	62.32 ±2.81	66.05 ±4.94	1.73 ±0.11	2.02 ±0.22	13.00 ±0.58	7.27 ±0.07	2.00 ±1.00	0.91 ±0.01
MD-483	470382	*C. limon*	Lemon	166.44 ±9.16	68.39 ±4.83	79.14 ±8.56	2.87 ±0.21	1.31 ±0.15	10.67 ±0.33	7.13 ±0.07	15.00 ±0.05	1.17 ±0.02

MD-487	470385	*C. limon*	Bhadri lemon	470.50 ±8.21	92.51 ±2.49	122.23 ±2.01	4.96 ±0.23	14.47 ±2.11	12.33 ±0.33	8.87 ±0.07	74.67 ±8.57	1.17 ±0.01
MD-489	470387	*C. limon*	Lemon	250.26 ±9.32	81.26 ±2.88	86.21 ±1.69	4.41 ±0.38	8.52 ±0.61	9.33 ±0.33	8.87 ±0.07	16.33 ±3.53	1.16 ±0.07
MD-497	470392	*C. limon*	Lemon	184.19 ±9.30	63.86 ±3.83	89.30 ±9.50	1.83 ±0.16	1.18 ±0.11	9.67 ±0.33	8.87 ±0.07	5.00 ±2.31	0.69 ±0.01
MD-504	470398	*C. limon*	Villa Franca	134.41 ±8.20	59.18 ±3.34	72.09 ±7.50	1.91 ±0.19	3.24 ±0.56	8.67 ±0.67	5.13 ±0.07	9.33 ±2.60	0.60 ±0.06
MD/07/152	558176	*C. limon*	Lemon	88.33 ±4.41	35.93 ±0.75	45.30 ±0.03	0.10 ±0.56	0.13 ±0.03	10.33 ±0.33	7.60 ±0.23	15.00 ±3.00	1.09 ±0.06
MD-11/39	591397	*C. limon*	Assam lemon	121.67 ±5.50	51.50 ±1.36	89.03 ±5.29	1.96 ±0.10	3.68 ±0.04	13.33 ±0.33	7.17 ±0.17	3.67 ±2.03	1.53 ±0.04
MD-11/75	591434	*C. limon*	Lemon	173.33 ±9.50	78.71 ±8.18	82.90 ±7.61	2.16 ±0.04	4.42 ±0.27	12.00 ±0.58	7.60 ±0.49	5.69 ±0.05	0.69 ±0.15
MDY-16	395349	*C. pseudolimon*	Galgal	63.33 ±6.01	35.53 ±0.30	45.27 ±0.29	1.50 ±0.06	1.31 ±0.15	11.67 ±0.33	4.00 ±0.56	18.67 ±1.45	0.94 ±0.06
MDY-17	395350	*C. pseudolimon*	Galgal	65.0 ±5.00	37.07 ±0.57	46.60 ±0.10	1.13 ±0.03	14.47 ±2.11	10.00 ±0.58	4.00 ±0.45	18.67 ±1.45	0.94 ±0.06
MDY-19	395352	*C. pseudolimon*	Galgal	338.33 ±9.30	62.50 ±0.07	83.33 ±0.33	2.17 ±0.03	8.52 ±0.61	11.67 ±0.33	5.00 ±0.59	21.00 ±3.79	1.81 ±0.04
MDY-22	395355	*C. pseudolimon*	Galgal	123.33 ±7.12	41.17 ±0.78	47.90 ±0.06	1.10 ±0.07	2.40 ±0.45	11.00 ±0.58	4.00 ±0.63	18.67 ±1.45	0.68 ±0.06
MDY-24	395357	*C. pseudolimon*	Galgal	123.33 ±9.25	43.23 ±0.64	52.50 ±0.59	2.11 ±0.14	2.50 ±0.12	10.00 ±0.58	4.00 ±0.00	21.00 ±3.79	1.11 ±0.13
MDY-26	395359	*C. pseudolimon*	Galgal	123.33 ±8.23	45.20 ±0.58	51.57 ±0.18	1.10 ±0.06	2.10 ±0.00	10.33 ±0.33	4.00 ±0.00	3.00 ±0.00	0.95 ±0.03
MDY-28	395361	*C. pseudolimon*	Galgal	105.00 ±2.89	38.00 ±0.59	42.50 ±0.50	1.50 ±0.96	4.54 ±0.37	10.00 ±0.00	5.00 ±0.26	18.67 ±1.45	0.72 ±0.08

MDY-31	395364	*C. pseudolimon*	Galgal	113.33 ±9.65	42.00 ±0.50	52.30 ±0.10	2.50 ±0.36	4.99 ±0.14	10.00 ±0.36	4.00 ±0.53	18.67 ±1.45	2.97 ±0.26
MDY-43	395375	*C. pseudolimon*	Galgal	193.67 ±6.20	52.53 ±0.38	63.30 ±0.20	1.72 ±0.01	2.67 ±0.20	10.00 ±1.45	4.00 ±0.46	20.00 ±1.25	0.70 ±0.06
MD-409	470324	*C. pseudolimon*	Galgal	326.70 ±6.30	83.48 ±0.26	92.17 ±2.35	2.55 ±0.47	9.20 ±0.92	9.00 ±0.25	6.07 ±0.07	26.67 ±2.03	1.31 ±0.03
MD-410	470325	*C. pseudolimon*	Galgal	346.20 ±6.60	99.65 ±0.75	128.71 ±1.71	3.64 ±0.12	20.20 ±0.70	13.00 ±0.00	6.07 ±0.07	84.33 ±1.76	2.23 ±0.06
MD-416	470331	*C. pseudolimon*	Galgal	277.09 ±9.30	75.21 ±6.74	101.61 ±8.46	2.50 ±0.36	4.11 ±0.45	10.67 ±0.33	4.87 ±0.07	19.67 ±3.76	2.08 ±0.09
MD-418	470333	*C. pseudolimon*	Galgal	576.67 ±7.50	120.40 ±0.58	126.81 ±5.12	2.04 ±0.29	14.47 ±2.79	15.33 ±0.33	8.20 ±0.00	25.67 ±6.50	2.41 ±0.09
MD-420	470335	*C. pseudolimon*	Galgal	291.80 ±7.10	74.67 ±1.03	93.40 ±3.82	1.72 ±0.01	3.70 ±0.09	10.67 ±0.33	5.73 ±0.07	17.00 ±0.00	1.34 ±0.07
MD-438	470353	*C. pseudolimon*	Galgal	256.67 ±5.50	62.56 ±2.05	156.48 ±8.50	1.94 ±0.01	3.56 ±0.27	10.00 ±0.07	7.17 ±0.17	12.67 ±0.88	2.16 ±0.08
MD-07/122	558146	*C. pseudolimon*	Chinara	338.33 ±5.50	62.33 ±0.33	69.00 ±0.14	2.10 ±0.00	4.59 ±0.06	12.00 ±0.29	5.67 ±0.17	44.00 ±5.03	0.70 ±0.45
MD/07/158	558182	*C. pseudolimon*	Chinara	338.33 ±5.50	65.33 ±0.33	71.00 ±0.29	2.10 ±0.00	5.40 ±0.06	10.00 ±0.58	5.67 ±0.17	44.00 ±5.03	2.97 ±0.26
MD-11/59	591417	*C. pseudolimon*	Galgal	291.67 ±7.50	78.26 ±5.51	93.07 ±9.61	2.38 ±0.20	4.50 ±0.14	11.00 ±0.45	5.83 ±0.17	10.00 ±3.61	1.51 ±0.09
MSA-05	593851	*C. pseudolimon*	Galgal	356.67 ±5.50	82.56 ±2.05	176.48 ±8.50	2.14 ±0.01	4.56 ±0.27	11.00 ±0.09	7.17 ±0.17	13.67 ±0.88	2.36 ±0.08
MSA-06	593852	*C. pseudolimon*	Galgal	213.33 ±5.75	101.35 ±1.78	71.50 ±0.93	2.16 ±0.02	6.10 ±0.07	8.00 ±0.25	10.00 ±0.07	4.33 ±0.67	1.69 ±0.09
MSA-13	593858	*C. pseudolimon*	Galgal	190.00 ±7.50	68.58 ±1.06	104.27 ±3.44	2.68 ±0.22	10.56 ±0.33	11.33 ±0.33	11.33 ±0.33	13.33 ±3.93	2.34 ±0.10

MSA-20	593863	*C. pseudolimon*	Galgal	411.67 ±8.82	75.00 ±2.52	107.83 ±0.37	2.46 ±0.16	6.15 ±0.06	10.33 ±0.33	10.00 ±0.15	19.67 ±1.86	1.58 ±0.12
MDY-25	395358	*C. jambhiri*	Jambhiri	119.01 ±8.42	43.30 ±0.00	54.00 ±0.00	2.52 ±0.18	3.13 ±0.03	9.00 ±0.58	3.00 ±0.00	6.67 ±1.67	0.99 ±0.03
MDY-27	395360	*C. jambhiri*	Jambhiri	148.25 ±8.45	47.77 ±0.15	55.60 ±0.21	1.14 ±0.09	2.87 ±0.38	9.67 ±0.67	4.00 ±0.15	17.33 ±2.03	0.99 ±0.03
MDY-32	395365	*C. jambhiri*	Jambhiri	105.54 ±8.45	54.70 ±0.15	65.67 ±0.44	2.87 ±0.42	3.69 ±0.46	9.33 ±0.33	4.00 ±0.45	13.33 ±4.33	0.77 ±0.01
MDY-37	395369	*C. jambhiri*	Jambhiri	156.68 ±7.50	57.00 ±0.36	65.43 ±0.41	1.05 ±0.16	4.47 ±0.73	8.67 ±0.33	4.00 ±0.00	22.00 ±3.21	0.77 ±0.01
MDY-38	395370	*C. jambhiri*	Jambhiri	101.88 ±3.25	56.37 ±0.09	66.30 ±0.10	2.84 ±0.54	3.67 ±0.16	12.33 ±0.33	4.00 ±0.25	15.67 ±0.88	0.77 ±0.01
MDY-41	395373	*C. jambhiri*	Jambhiri	131.67 ±4.41	54.73 ±0.18	67.67 ±7.14	2.88 ±0.45	3.27 ±0.03	9.67 ±0.33	4.00 ±0.26	31.33 ±1.67	1.46 ±0.01
MDY-45	395376	*C. jambhiri*	Jambhiri	120.00 ±7.64	54.93 ±0.18	65.80 ±0.20	2.49 ±0.54	3.23 ±0.03	9.33 ±0.33	4.00 ±0.00	31.33 ±1.67	1.46 ±0.01
MDY-62	395392	*C. jambhiri*	Jallandhari khatti	100.00 ±10.00	55.70 ±0.46	66.90 ±0.06	2.52 ±0.18	3.20 ±0.00	11.00 ±0.58	3.00 ±0.00	20.00 ±2.31	0.64 ±0.02
MDY-63	395393	*C. jambhiri*	Jatti khatti	95.00 ±7.50	59.00 ±0.00	67.80 ±0.17	1.14 ±0.09	2.77 ±0.37	9.00 ±0.58	3.67 ±0.33	20.00 ±2.31	0.64 ±0.02
MDY-64	395394	*C. jambhiri*	Esteus rough	101.67 ±6.01	33.83 ±7.25	46.47 ±0.15	2.87 ±0.42	6.52 ±0.11	9.00 ±0.58	4.00 ±0.12	23.33 ±0.88	0.64 ±0.02
MDY-83	395411	*C. jambhiri*	Mithi	116.67 ±8.82	55.33 ±0.09	66.13 ±0.15	1.27 ±0.03	2.27 ±0.03	10.67 ±0.33	1.00 ±0.00	9.67 ±1.45	0.71 ±0.06
MD-401	470316	*C. jambhiri*	Jamir	101.88 ±3.25	55.91 ±0.87	55.55 ±1.09	1.42 ±0.19	1.80 ±0.14	8.33 ±0.33	1.00 ±0.00	17.67 ±1.76	0.71 ±0.06
MD-421	470336	*C. jambhiri*	Jamir	119.01 ±8.23	54.95 ±1.84	62.21 ±3.69	2.84 ±0.54	2.87 ±0.38	8.00 ±0.04	5.67 ±0.07	17.33 ±2.03	0.84 ±0.01

MD-423	470338	*C. jambhiri*	Gambhiri	148.25 ±8.25	56.43 ±2.13	60.56 ±0.44	2.88 ±0.45	2.69 ±0.46	9.67 ±0.33	5.93 ±0.07	13.33 ±4.33	1.04 ±0.03
MD-435	470350	*C. jambhiri*	Jatti Khati	105.54 ±7.42	64.51 ±0.76	67.47 ±0.72	2.49 ±0.54	4.47 ±0.73	9.00 ±1.00	10.00 ±0.16	22.00 ±3.21	0.71 ±0.04
MD-477	470378	*C. jambhiri*	Grambhir	156.68 ±7.50	67.89 ±3.14	81.73 ±2.50	3.94 ±0.53	3.67 ±0.16	10.33 ±0.33	6.67 ±0.07	15.67 ±0.88	0.91 ±0.04
MD-478	470379	*C. jambhiri*	Jamir	152.15 ±8.81	66.72 ±0.84	74.97 ±4.46	3.15 ±0.20	2.26 ±0.39	8.33 ±0.33	6.93 ±0.07	12.00 ±0.58	0.73 ±0.07
MD-479	470380	*C. jambhiri*	Jamir	106.39 ±3.15	61.02 ±1.10	53.16 ±0.33	1.22 ±0.06	1.13 ±0.03	9.33 ±0.33	6.93 ±0.07	11.00 ±1.00	0.77 ±0.01
MD/07/133	558157	*C. jambhiri*	Atol	125.33 ±0.33	57.00 ±0.58	63.67 ±0.33	2.05 ±0.12	3.13 ±0.03	9.00 ±0.58	6.93 ±0.07	6.67 ±1.67	0.80 ±0.01
MD-09-05	583248	*C. jambhiri*	Jamir	101.67 ±6.01	56.30 ±0.04	66.38 ±0.10	3.46 ±0.23	5.73 ±0.57	9.67 ±1.45	6.67 ±0.33	9.67 ±1.45	0.90 ±0.05
KARHMD-10/40	586988	*C. jambhiri*	Jamir	95.00 ±8.45	59.53 ±1.75	61.81 ±0.93	3.84 ±0.70	8.78 ±0.73	8.67 ±0.33	7.67 ±0.33	9.67 ±1.45	0.90 ±0.00
MD-10/53	587001	*C. jambhiri*	Jamir	98.00 ±6.50	37.17 ±2.89	36.20 ±2.05	1.59 ±0.20	2.91 ±0.96	9.00 ±0.58	7.90 ±1.24	9.67 ±1.45	0.72 ±0.00
MD-10/56	587004	*C. jambhiri*	Naity Jamir	127.00 ±6.81	62.84 ±0.37	69.65 ±2.66	3.12 ±0.47	7.22 ±0.78	9.00 ±0.58	6.67 ±0.33	25.00 ±0.67	1.20 ±0.00
MD-10/58	587006	*C. jambhiri*	Naity Jamir	69.67 ±3.71	52.78 ±1.25	51.65 ±0.66	2.98 ±0.10	6.81 ±0.33	9.67 ±0.33	9.50 ±0.76	12.00 ±1.45	0.97 ±0.00
MD-10/68	587016	*C. jambhiri*	Naity Jamir	81.33 ±5.21	56.54 ±1.57	43.67 ±18.81	2.55 ±0.23	6.52 ±0.11	10.67 ±0.33	9.00 ±0.00	23.33 ±0.88	0.92 ±0.00
MD-11/40	591398	*C. jambhiri*	Gol nimbu	153.33 ±9.28	55.56 ±0.59	94.52 ±5.45	1.71 ±0.09	4.30 ±0.12	10.33 ±0.33	8.17 ±0.17	22.33 ±3.71	1.94 ±0.08
MD-11/41	591399	*C. jambhiri*	Hathi nimbu	203.33 ±5.50	74.63 ±1.09	74.04 ±1.90	4.56 ±0.15	8.03 ±0.05	10.00 ±0.06	7.50 ±0.05	28.67 ±1.67	1.77 ±0.06

MD-11/54	591412	*C. jambhiri*	Sinduri lemon	115.00 ±7.64	59.06 ±1.46	60.93 ±0.93	1.69 ±0.02	4.11 ±0.01	9.00 ±0.02	9.00 ±0.01	15.67 ±5.70	0.26 ±0.03
MD-11/57	591415	*C. jambhiri*	Rough lemon	213.33 ±8.50	74.05 ±1.09	71.00 ±3.91	1.16 ±0.04	4.52 ±0.20	9.00 ±0.12	6.00 ±0.00	23.33 ±0.88	1.48 ±0.13
MD-11/60	591418	*C. jambhiri*	Rough lemon	263.33 ±8.56	80.77 ±3.26	79.29 ±2.45	2.31 ±0.12	6.09 ±0.03	10.00 ±0.15	8.50 ±0.29	24.00 ±1.15	0.64 ±017
MD-11/67	591426	*C. jambhiri*	Soh bitter	273.33 ±9.50	74.24 ±1.57	77.99 ±3.66	2.16 ±0.03	4.52 ±0.29	10.67 ±0.33	7.67 ±0.33	23.33 ±4.67	1.15 ±0.02
MD-11/69	591428	*C. jambhiri*	Rough lemon	100.00 ±9.50	58.29 ±2.98	54.33 ±5.93	1.49 ±0.09	2.58 ±0.17	11.00 ±0.02	8.50 ±0.50	20.00 ±2.89	1.13 ±0.08
MD-11/76	591435	*C. jambhiri*	Nimbu tenga	58.33 ±4.41	45.96 ±1.96	46.15 ±3.50	1.18 ±0.04	7.13 ±0.38	10.00 ±0.06	6.84 ±0.32	38.67 ±7.50	0.56 ±0.15
MD-11/81	591440	*C. jambhiri*	Gol nimbu	88.33 ±7.26	53.83 ±2.23	53.20 ±2.73	1.09 ±0.04	1.74 ±0.12	8.67 ±0.33	10.00 ±0.00	11.00 ±0.58	0.63 ±0.09
MD-11/87	591446	*C. jambhiri*	Rough lemon	101.67 ±1.67	57.87 ±1.60	59.30 ±0.15	2.62 ±0.19	5.84 ±0.20	11.00 ±0.33	6.67 ±0.88	11.00 ±0.06	0.58 ±0.16
MD-11/92	591451	*C. jambhiri*	Rough lemon	56.67 ±3.33	51.93 ±1.32	55.26 ±1.64	2.88 ±0.32	3.58 ±0.64	7.33 ±0.33	5.00 ±0.29	10.33 ±0.67	0.35 ±0.06
MD-11/93	591452	*C. jambhiri*	Hasu	26.67 ±1.67	39.00 ±0.53	42.52 ±1.49	1.03 ±0.03	2.55 ±0.08	7.67 ±0.67	8.00 ±0.02	6.00 ±0.58	1.20 ±0.04
MD-11/96	591455	*C. jambhiri*	Ganpen	121.67 ±8.50	75.09 ±0.57	80.84 ±5.98	2.63 ±0.13	7.74 ±0.06	10.00 ±0.00	9.00 ±0.03	13.00 ±0.00	1.30 ±0.10
MD-11/97	591456	*C. jambhiri*	Rough lemon	178.33 ±8.50	72.82 ±3.19	74.11 ±1.58	4.41 ±0.13	6.66 ±0.15	10.33 ±0.33	7.50 ±0.05	24.33 ±1.86	1.11 ±0.05
MD-11/100	591459	*C. jambhiri*	Rough lemon	50.00 ±2.89	37.52 ±2.55	36.83 ±1.62	1.65 ±0.12	2.16 ±0.03	8.33 ±0.67	7.33 ±0.17	13.67 ±3.84	0.79 ±0.03
MSA-25	593866	*C. jambhiri*	Rough lemon	215.00 ±7.50	74.27 ±2.14	72.62 ±1.25	3.35 ±0.12	4.95 ±0.33	10.33 ±0.33	7.00 ±0.58	24.33 ±1.45	1.48 ±0.02

MSA-41	593879	*C. jambhiri*	Rough lemon	83.33 ±7.50	55.32 ±3.98	57.60 ±4.19	2.06 ±0.05	4.11 ±0.03	9.00 ±0.42	8.00 ±0.15	23.67 ±1.45	1.32 ±0.03
MDY-18	395351	*C. karna*	Karna Khatta	351.97 ±8.20	69.67 ±6.49	56.67 ±1.67	3.45 ±0.48	8.17 ±0.44	9.00 ±0.58	4.00 ±0.03	17.00 ±3.35	1.58 ±0.61
MDY-20	395353	*C. karna*	Karna Khatta	338.33 ±7.30	71.73 ±0.27	87.00 ±0.10	2.10 ±0.00	5.18 ±0.11	10.67 ±0.67	4.00 ±0.12	3.00 ±0.09	1.81 ±0.04
MDY-29	395362	*C. karna*	Karna Khatta	351.97 ±8.20	91.67 ±8.33	90.33 ±7.33	3.48 ±0.44	9.17 ±0.44	12.00 ±1.00	4.00 ±0.03	9.00 ±6.50	1.58 ±0.62
MDY-30	395363	*C. karna*	Karna Khatta	351.97 ±8.20	59.00 ±1.00	51.33 ±3.76	3.38 ±0.54	10.57 ±0.30	9.00 ±3.34	4.00 ±1.59	15.66 ±3.18	1.58 ±0.02
MDY-34	395367	*C. karna*	Karna khatta	351.97 ±9.75	103.50 ±8.50	92.50 ±2.04	3.55 ±0.82	9.71 ±0.88	12.00 ±0.58	4.00 ±1.48	20.67 ±3.18	1.58 ±0.02
MDY-39	395371	*C. karna*	Karna Khatta	351.97 ±9.50	82.00 ±6.50	71.33 ±6.50	3.61 ±1.38	8.17 ±4.18	11.67 ±5.22	5.00 ±2.35	8.00 ±8.00	1.58 ±0.63
MDY-40	395372	*C. karna*	Karna Khatta	351.97 ±8.50	81.67 ±7.25	68.33 ±6.32	3.45 ±1.33	9.00 ±3.90	9.00 ±4.29	4.67 ±1.70	24.67 ±5.25	1.58 ±0.62
MDY-46	395377	*C. karna*	Karna Khatta	351.97 ±9.75	81.00 ±37.67	73.00 ±33.92	3.45 ±1.36	9.23 ±4.12	10.67 ±4.80	4.67 ±2.12	36.67 ±6.50	1.58 ±0.65
MD-403	470318	*C. karna*	Duranj	216.49 ±7.10	67.09 ±3.15	74.82 ±2.51	2.25 ±0.38	6.72 ±0.81	11.33 ±0.33	6.07 ±0.07	18.67 ±1.45	1.05 ±0.06
MD-414	470329	*C. karna*	Duranj	315.33 ±9.50	84.13 ±5.98	86.97 ±6.36	3.47 ±035	8.17 ±0.44	11.00 ±0.58	6.67 ±0.07	20.67 ±3.18	1.50 ±0.07
MD-424	470339	*C. karna*	Duranj	396.92 ±8.49	77.14 ±2.66	106.87 ±3.13	2.71 ±0.16	8.89 ±0.59	9.33 ±0.33	6.40 ±0.02	8.00 ±2.08	1.28 ±0.33
MD-480	470381	*C. karna*	Karna Khatta	351.97 ±8.20	95.35 ±0.19	92.01 ±7.50	3.65 ±1.44	9.67 ±0.33	11.33 ±0.33	7.07 ±0.18	36.67 ±7.84	1.58 ±0.60
MD-11/56	591414	*C. karna*	Karna khatta	305.00 ±8.12	91.54 ±6.23	96.27 ±7.31	3.10 ±1.66	16.83 ±5.52	11.00 ±4.10	8.33 ±3.03	28.00 ±7.50	1.51 ±0.62

MD-11/62	591420	*C. karna*	Karna khatta	315.00 ±8.23	85.25 ±6.50	82.94 ±6.75	2.25 ±1.57	11.24 ±5.66	10.33 ±4.23	9.00 ±3.09	23.33 ±6.50	2.25 ±0.67
MSA-01	593849	*C. karna*	Duranj	186.67 ±9.45	69.36 ±7.50	74.50 ±6.33	2.88 ±1.28	6.95 ±3.76	10.67 ±4.07	6.53 ±1.88	23.00 ±6.25	2.35 ±0.71
MSA-07	593853	*C. karna*	Duranj	226.00 ±8.50	76.36 ±7.50	85.90 ±6.50	5.55 ±1.48	10.17 ±3.73	10.00 ±4.02	9.00 ±2.40	31.00 ±6.12	2.87 ±0.77
MSA-08	593854	*C. karna*	Duranj	258.33 ±9.65	82.03 ±6.23	84.73 ±5.26	2.82 ±1.48	9.38 ±3.52	10.33 ±3.89	8.00 ±2.67	26.00 ±6.23	1.52 ±0.84
MSA-12	593857	*C. karna*	Karna khatta	248.33 ±8.50	78.30 ±6.43	83.04 ±7.43	5.65 ±1.58	12.80 ±3.99	9.00 ±3.75	6.00 ±2.64	21.67 ±5.22	1.49 ±0.73
MSA-14	593859	*C. karna*	Duranj	210.00 ±9.50	75.47 ±6.50	80.66 ±5.23	3.91 ±1.56	7.45 ±3.95	11.00 ±3.83	9.00 ±2.78	26.00 ±6.23	1.64 ±0.74
MSA-15	593860	*C. karna*	Duranj	171.67 ±8.50	71.83 ±6.33	77.76 ±6.25	2.98 ±1.55	8.84 ±3.87	11.00 ±3.89	7.50 ±2.77	36.00 ±6.50	1.72 ±0.74
MSA-17	593861	*C. karna*	Duranj	221.33 ±9.56	81.09 ±8.50	79.97 ±8.34	5.07 ±1.63	9.89 ±4.38	11.00 ±3.94	6.00 ±2.84	29.00 ±6.50	1.68 ±0.73
MSA-19	593862	*C. karna*	Duranj	253.33 ±8.50	83.58 ±6.50	89.85 ±7.80	4.38 ±1.63	13.67 ±4.48	11.00 ±3.96	6.67 ±2.79	20.00 ±6.40	1.53 ±0.73
MSA-26	593867	*C. karna*	Duranj	280.00 ±9.80	80.07 ±6.63	91.11 ±8.50	4.43 ±1.66	12.17 ±4.46	10.33 ±3.96	10.33 ±2.94	36.00 ±6.50	1.82 ±0.73
MSA-28	593869	*C. karna*	Duranj	205.00 ±9.75	71.36 ±5.33	81.96 ±7.64	1.88 ±1.66	8.11 ±4.47	12.00 ±4.01	6.67 ±2.92	24.33 ±6.35	1.36 ±0.73
MSA-29	593870	*C. karna*	Duranj	248.33 ±9.50	78.93 ±6.30	84.41 ±8.33	4.61 ±1.67	16.71 ±4.64	11.00 ±4.02	7.33 ±2.92	40.00 ±6.23	1.93 ±0.73
MSA-35	593874	*C. karna*	Duranj	366.67 ±9.45	82.10 ±6.50	79.07 ±8.12	4.86 ±1.70	19.83 ±5.23	11.00 ±3.99	8.00 ±2.96	26.67 ±6.50	1.26 ±0.73
MSA-37	593875	*C. karna*	Duranj	170.00 ±9.56	65.56 ±6.23	79.54 ±8.50	2.68 ±1.70	8.40 ±5.19	10.00 ±3.93	7.00 ±2.96	32.00 ±5.20	1.74 ±0.72

MSA-38	593876	*C. karna*	Duranj	256.67 ±9.50	76.91 ±6.12	86.23 ±8.23	3.89 ±1.69	10.98 ±5.13	10.00 ±3.78	6.17 ±2.96	26.67 ±6.50	1.52 ±0.71
MSA-39	593877	*C. karna*	Duranj	209.00 ±9.50	75.45 ±5.23	69.00 ±6.50	4.36 ±1.71	13.16 ±5.66	12.00 ±3.86	6.00 ±2.96	38.67 ±6.50	1.38 ±0.71
MSA-40	593878	*C. karna*	Duranj	235.00 ±9.50	78.28 ±6.50	89.51 ±8.23	3.47 ±1.72	5.98 ±4.80	10.00 ±3.94	9.00 ±3.06	34.33 ±5.50	1.55 ±0.71
MD-09-04	583247	*C. volkameriana*	Volkamer lemon	75.000 ±7.63	52.67 ±0.23	54.00 ±0.10	2.31 ±0.12	2.90 ±0.42	8.66 ±0.88	8.00 ±0.00	14.66 ±1.85	1.05 ±0.02
MD-11/51	591409	*C. volkameriana*	Volkamer lemon	201.67 ±6.50	71.13 ±4.26	70.41 ±4.57	1.71 ±0.07	4.01 ±0.05	8.00 ±0.05	6.00 ±0.03	22.67 ±3.71	1.05 ±0.02
MD-466	470371	*C. pennivesiculata*	Gajanimma	218.7 ±5.50	81.77 ±2.05	67.62 ±2.44	2.61 ±0.14	7.73 ±1.16	12.67 ±0.67	8.07 ±0.07	1.00 ±0.00	0.39 ±0.00
MDY-23	395356	*C. aurantifolia*	Kaghzi nimbu	123.33 ±6.36	54.50 ±0.06	64.00 ±0.15	1.73 ±0.11	2.11 ±0.45	11.00 ±0.58	4.00 ±0.10	8.50 ±1.22	0.94 ±0.06
MDY-79	395407	*C. aurantifolia*	Coorge lime	123.33 ±9.75	56.77 ±0.15	65.97 ±0.23	1.73 ±0.11	2.20 ±0.92	9.00 ±0.58	3.00 ±0.02	18.00 ±1.53	0.94 ±0.06
MDY-80	395408	*C. aurantifolia*	Sylhet lime	148.42 ±7.90	60.00 ±0.31	64.63 ±0.12	1.73 ±0.11	2.95 ±1.01	12.33 ±0.67	4.00 ±0.04	2.00 ±1.00	0.52 ±0.01
MDY-89	395417	*C. aurantifolia*	Seedless lime	148.42 ±8.30	52.07 ±0.18	56.53 ±0.18	1.73 ±0.11	2.68 ±1.43	13.33 ±0.33	3.00 ±0.00	18.00 ±1.53	0.91 ±0.01
MDY-90	395418	*C. aurantifolia*	Pant-1 lime	148.42 ±9.87	56.00 ±0.53	54.63 ±0.21	1.43 ±0.19	1.99 ±0.12	12.33 ±1.15	4.00 ±0.00	18.00 ±2.65	0.52 ±0.02
MD-415	470330	*C. aurantifolia*	Kagji nimbu	40.18 ±2.76	25.07 ±0.20	23.97 ±0.26	1.11 ±0.09	1.89 ±0.00	8.33 ±0.33	5.07 ±0.07	4.00 ±0.58	0.52 ±0.01
MD-490	470388	*C. aurantifolia*	Nimbu	29.85 ±3.45	35.73 ±1.59	45.93 ±2.09	0.85 ±0.03	1.09 ±0.07	10.00 ±0.58	6.33 ±0.07	3.00 ±0.00	0.44 ±0.00
MD-496	470391	*C. aurantifolia*	Nimbu	150.63 ±9.60	66.08 ±9.30	84.38 ±2.12	1.39 ±0.23	2.95 ±0.24	10.67 ±0.33	5.87 ±0.24	4.33 ±3.33	0.95 ±0.05

MD/07/139	558163	*C. aurantifolia*	Kaghzi nimbu	145.00 ±9.30	56.50 ±0.68	68.53 ±0.38	1.10 ±0.00	3.20 ±0.03	8.33 ±0.33	6.23 ±0.15	15.00 ±3.00	1.80 ±0.04
MD/07/142	558166	*C. aurantifolia*	Kaghzi nimbu	113.33 ±7.32	58.17 ±0.33	62.27 ±0.37	1.17 ±0.03	2.20 ±0.02	10.33 ±0.33	4.67 ±0.33	2.00 ±1.00	1.92 ±0.05
MD/07/153	558177	*C. aurantifolia*	Kaghzi nimbu	105.00 ±2.89	46.57 ±0.35	56.13 ±0.09	1.10 ±0.06	2.20 ±0.12	9.33 ±0.33	5.67 ±0.17	15.33 ±1.20	1.81 ±0.04
MD-11/47	591405	*C. aurantifolia*	Kagzi lime	56.67 ±7.26	40.10 ±2.25	48.44 ±2.26	1.18 ±0.05	1.51 ±0.04	10.00 ±0.04	8.00 ±0.02	11.33 ±1.67	0.82 ±0.04
MSA-04	593850	*C. aurantifolia*	Nimbu	53.33 ±1.67	36.91 ±0.62	37.63 ±0.45	1.17 ±0.02	1.63 ±0.09	10.67 ±0.33	6.17 ±0.17	16.67 ±1.67	1.10 ±0.02
MD-11/73	591432	*C. limettioides*	Sweet lime	158.33 ±6.50	66.28 ±3.51	69.95 ±4.33	0.51 ±0.03	2.37 ±0.16	11.00 ±0.06	11.00 ±0.29	30.67 ±0.88	0.54 ±0.08
MD-11/91	591450	*C. limettioides*	Sweet lime	78.33 ±8.33	47.98 ±2.57	48.79 ±2.07	1.45 ±0.32	3.49 ±0.14	11.00 ±0.58	8.67 ±0.33	6.00 ±2.08	1.33 ±0.06
MDY-65	395395	*C. limonia*	Rangpur lime	99.73 ±09.71	59.72 ±0.39	67.02 ±0.06	1.08 ±0.10	2.50 ±0.12	7.67 ±0.33	3.00 ±0.04	18.67 ±1.45	1.76 ±0.02
MDY-88	395416	*C. limonia*	Rangpur lime	65.00 ±5.00	35.53 ±0.37	36.43 ±0.58	2.02 ±0.32	3.99 ±0.14	8.00 ±0.02	4.00 ±0.06	15.33 ±3.53	0.42 ±0.05
MD-10/50	586998	*C. limonia*	Kole Jamir	193.67 ±6.50	71.49 ±0.51	73.84 ±4.34	4.24 ±0.14	9.54 ±0.37	10.33 ±0.33	11.33 ±0.67	26.67 ±3.33	3.05 ±0.00
MD-10/63	587011	*C. limonia*	Rangpur lime	123.67 ±2.03	60.78 ±0.49	61.93 ±1.10	1.79 ±0.11	4.99 ±0.14	8.33 ±0.88	6.67 ±0.33	16.67 ±1.67	0.72 ±0.00
MD-10/67	587015	*C. limonia*	Kole Jamir	43.67 ±5.50	48.04 ±5.22	49.59 ±5.46	1.49 ±0.06	4.08 ±0.13	6.00 ±0.58	5.93 ±0.43	4.33 ±0.67	0.67 ±0.00
MD-11/45	591403	*C. limonia*	Rangpur lime	91.67 ±5.50	55.22 ±2.58	52.93 ±6.36	2.17 ±0.03	4.88 ±0.06	8.00 ±0.05	7.17 ±0.17	11.33 ±0.33	1.11 ±0.19
MD-11/86	591445	*C. limonia*	Tenga	101.67 ±5.50	59.32 ±2.36	56.91 ±2.17	1.56 ±0.16	2.69 ±0.42	8.67 ±0.33	6.67 ±0.33	10.33 ±0.88	1.69 ±0.15
MD-11/95	591454	*C. limonia*	Rangpur lime	105.00 ±5.50	58.40 ±5.27	55.93 ±2.70	1.34 ±0.04	1.88 ±0.36	8.00 ±0.04	8.13 ±0.37	15.00 ±1.00	0.59 ±0.10

6. Pummelos and Grapefruits

6.1 Genetic resources

***Citrus maxima* (Burm.) Merril**

Common name: Pummelo

Vernacular name: Chakotra, Jambura, Kimb, Ser-tawk, Soh-ba, Rabab

Description

The Pummelo trees are 15 to 45 ft in height with irregular branches. The young branchlets are angular and often densely hairy, spines on the branchlets, and old branches. Leaf lamina is ovate, ovate-oblong, or elliptic, 5-20 cm long, 2-12 cm wide, leathery, dull-green and glossy above. Leaves have a distinctly broad winged petiole. The flowers are fragrant, borne singly or in clusters of 2 to 10 in the leaf axils, calyx hairy, the 4 to 5 petals, yellowish-white, 1.5-3.5 cm long, stamens white, prominent, in bundles of 4 to 5. The fruits are round to oblate, spheroid or pear-shaped. Fruit surface smooth with pitted texture, greenish-yellow or pale-yellow, minutely hairy, dotted with tiny green glands. The pulp varies from greenish-yellow or pale-yellow to pink or red, 11 to 18 segments and very juicy. The flavor of the pulp varies from mildly sweet and bland to sub-acidic or rather acidic. Seeds are of large size, flat with wrinkled seed coat surface, creamish cotyledon, chalazal cap brown, and monoembryonic.

***Citrus megaloxycarpa* Lush.**

Common name: Sour pummelo

Vernacular name: Amilbed, Sisuphal

Description

C. megaloxycarpa is medium sized tree, spreading, with moderately dense foliage and very thorny. Leaves are ovate to oblong or elliptic with narrowly winged petiole. Fruit is almost spherical to slightly turbinate, light yellow surface, smooth to sub-warty surface. Fruit juice of this species is reported to be very sour, hence it is known as “Sour Pummelo”. Seed are medium sized, ovoid or

semi-deltoid shape, cream colour, cotyledon white, chalazal cap dark brown, monoembryonic.

***Citrus paradisi* Macf.**

Common name: Grapefruit

Vernacular name: Serbial, Chamba, Soh-khyllah, Champa umtambi

Description

A large, round-topped tree upto 30 ft tall with dense foliage; twigs angular when young, glabrous; leaves ovate, bluntly tipped and broadly rounded at the base, glabrous; petioles rather broadly winged but not so broad as those of the pummelo, oblanceolate to obovate in shape; flowers large, borne singly or in small clusters in the axils of the leaves, white or creamish; fruits round to spheroid, smooth surface, yellow colour, shiny, segment 12-18, juicy pulp, white or pinkish flesh, slightly sour and sweet juice; seeds medium size, white, colyledon creamish, chalazal cap brown, polyembroynic.

6.2 Exploration and Collection

Germplasm of pummelos and grapefruits was collected from different parts of India to study the existence of genetic variability and area of occurrence of these *Citrus* species. During the surveys, a total of 79 accessions of *C. maxima* (pummelo) representing several cultivars/types, viz. Jambura red flesh and white flesh, Triumph, Chakotra, Soronga, Kimb, Ser-tawk, Rabab and Foxey were collected from Northeastern states, Sikkim, Himachal Pradesh, Punjab, Uttar Pradesh and Uttarakhand. In the pummelo, high level of phenotypic variability was found in Northeast India especially in Garo, Khasi and Jaintia Hills of Meghalaya, however, this species is distributed throughout India and grown by the people for their sweet and tasty fruit. Farmers usually prefer to grow only red fleshed pummelo. Diversity of sour pummelo (*C. megaloxycarpa*) is very low and people do not prefer to grow this species due to no economic value. A total of 6 accessions of this species were collected from Mizoram, Asssam,Tripura and Himachal Pradesh. Only few individuals are found to grow in Northeast India as semi-domesticated state. Recently, cultivars of sour pummelo viz. Hukma tenga and Holong tenga have been collected from South Tripura. In India, both indigenous as well as exotic cultivars of *C. paradisi* (Grapefruit) are cultivated for medicinal and nutritional properties of their fruits. A total of 18 accessions of grapefruit representing cultivars/types, viz. Foster pink, Duncan, Marsh seedless,

Red flesh, Thompson seedless, Chamba, Serbial, Soh-khyllah, Champa-umtambi, and Smooth flat were collected from Assam, Meghalaya, Mizoram, West Bengal, Uttar Pradesh, Punjab and Rajasthan.

Passport data of all the collected accessions of pummelos and grapefruits are given in Table 6.1 and collection sites are shown in Fig. 6.1.

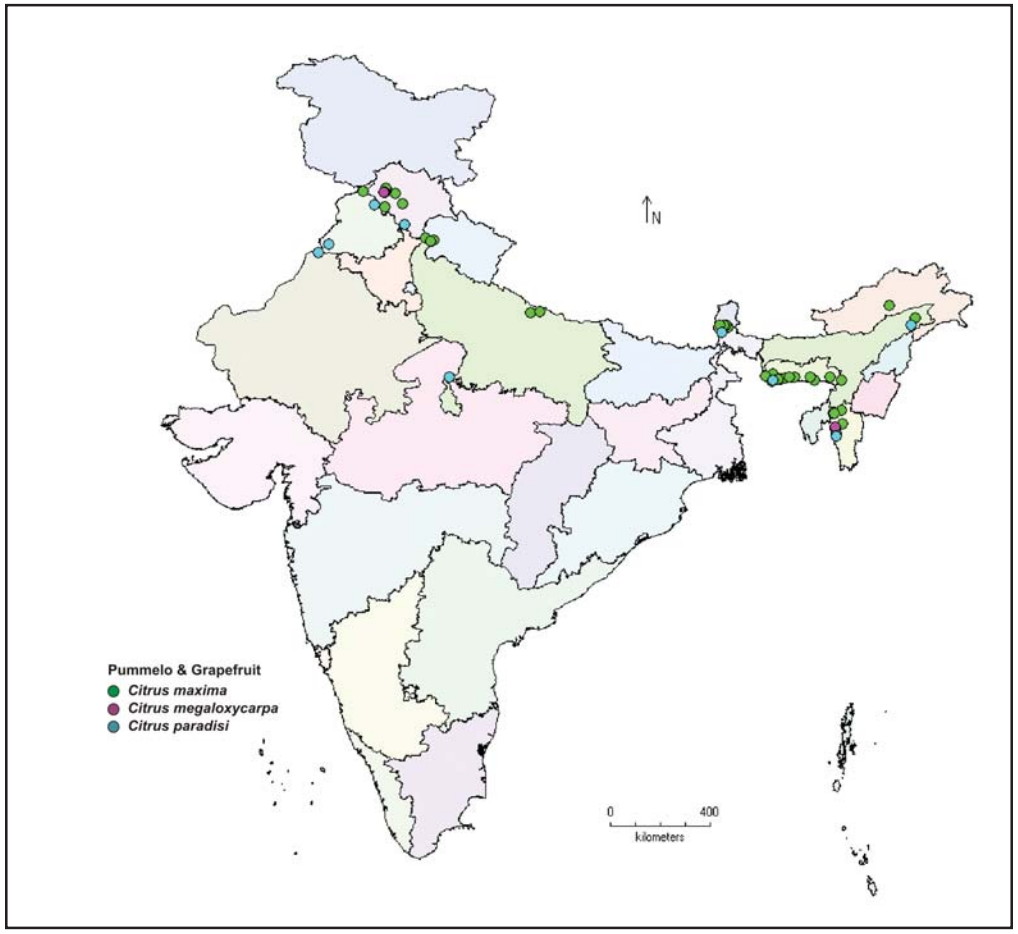

Fig. 6.1. Map of India showing collection sites of pummelo and grapefruit culivars

Table 6.1. Passport data of pummelo and grapefruit group (*C. maxima*, *C. megaloxycarpa* and *C. paradisi*) collected from different parts of India

S. No.	Collector Number	IC No.	Botanical Name	Common/Vern. /Cult. Name	Biological status	District	State	Lati-tude	Longi-tude
1	MSA-24	593865	*Citrus maxima*	Pummelo	Cultivated	Kangra	Himachal Pradesh	31.55	76.27
2	MSA-30	593871	*Citrus maxima*	Pummelo	Cultivated	Kangra	Himachal Pradesh	32.10	76.22
3	MSA-32	593873	*Citrus maxima*	Pummelo	Cultivated	Kangra	Himachal Pradesh	32.10	76.22
4	DMRK-42	278044	*Citrus maxima*	Jambura	Cultivated	Kolasib	Mizoram	24.23	92.67
5	MD-505	470399	*Citrus maxima*	Triumph	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
6	MD-506	470400	*Citrus maxima*	Pummelo red flesh	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
7	MD/07/120	558144	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
8	MD/07/121	558145	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
9	DMRK-1	278003	*Citrus maxima*	Pummelo	Cultivated	East Khasi Hills	Meghalaya	25.30	91.70
10	DMRK-144	278146	*Citrus maxima*	Jambura	Cultivated	Aizawl	Mizoram	23.73	92.72
11	DMRK-191	278193	*Citrus maxima*	Pummelo	Cultivated	Jaintia Hills	Meghalaya	25.33	92.67
12	MDY-9	395344	*Citrus maxima*	Pummelo	Cultivated	Hoshiarpur	Punjab	31.65	75.89
13	MDY-42	395374	*Citrus maxima*	Pummelo	Cultivated	Mandi	Himachal Pradesh	31.66	76.88
14	MDY-47	395378	*Citrus maxima*	Chakotra	Cultivated	Kangra	Himachal Pradesh	32.16	76.34
15	MDY-68	395397	*Citrus maxima*	Yamaponda	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
16	MDY-77	395405	*Citrus maxima*	Triumph	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
17	OPD/RC - 1	415169	*Citrus maxima*	Chakotra	Cultivated	Gurdaspur	Punjab	32.11	75.46
18	OPD/RC - 23	415191	*Citrus maxima*	Chakotra	Cultivated	Dehradun	Uttarakhand	30.45	77.73
19	OPD/RC - 25	415193	*Citrus maxima*	Chakotra	Cultivated	Dehradun	Uttarakhand	30.35	78.02
20	MD-155	417223	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
21	MD-164	417231	*Citrus maxima*	Jambura	Cultivated	South Garo Hills	Meghalaya	25.21	90.56

22	MD-166	417233	*Citrus maxima*	Jambura	Cultivated	South Garo Hills	Meghalaya	25.21	90.66
23	MD-171	417238	*Citrus maxima*	Jambura	Cultivated	South Garo Hills	Meghalaya	25.21	90.93
24	MD-172	417239	*Citrus maxima*	Jambura	Cultivated	South Garo Hills	Meghalaya	25.21	90.93
25	MD-173	417240	*Citrus maxima*	Soronga	Cultivated	South Garo Hills	Meghalaya	25.44	90.82
26	MD-178	417246	*Citrus maxima*	Soronga	Cultivated	South Garo Hills	Meghalaya	25.44	90.82
27	MD-198	417264	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.54	90.22
28	NSP/OPD-04-8	438457	*Citrus maxima*	Chakotra	Cultivated	Kangra	Himachal Pradesh	32.03	76.63
29	MD-406	470321	*Citrus maxima*	Chakotra	Cultivated	Dehradun	Uttarakhand	30.34	77.95
30	MD-408	470323	*Citrus maxima*	Chakotra	Cultivated	Dehradun	Uttarakhand	30.35	78.02
31	MD-411	470326	*Citrus maxima*	Chakotra	Cultivated	Dehradun	Uttarakhand	30.34	77.91
32	MD-412	470327	*Citrus maxima*	Chakotra	Cultivated	Dehradun	Uttarakhand	30.34	77.91
33	MD-419	470334	*Citrus maxima*	Kimb	Cultivated	Kangra	Himachal Pradesh	32.11	76.29
34	MD-422	470337	*Citrus maxima*	Kimb	Cultivated	Kangra	Himachal Pradesh	32.23	76.30
35	MD-425	470340	*Citrus maxima*	Chakotra	Cultivated	Kangra	Himachal Pradesh	32.23	76.30
36	MD-436	470351	*Citrus maxima*	Chakotra	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
37	RS/OPD-53	548592	*Citrus maxima*	Chakotra	Cultivated	Bahraich	Uttar Pradesh	27.75	81.48
38	RS/OPD-65	548604	*Citrus maxima*	Chakotra	Cultivated	Shravasti	Uttar Pradesh	27.78	81.83
39	MD/07/101	558125	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.32	90.19
40	MD/07/102	558126	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.32	90.19
41	MD/07/108	558132	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.29	90.19
42	MD/07/113	558137	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.29	90.19
43	MD/07/114	558138	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.29	90.19
44	MD/07/124	558148	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
45	MD/07/130	558154	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.30	90.20

46	MD/07/135	558159	*Citrus maxima*	Jambura	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
47	MD/07/138	558162	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.15	90.12
48	MD/07/144	558168	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
49	MD/07/145	558169	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
50	MD/07/147	558171	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
51	MD/07/149	558173	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
52	MD/07/150	558174	*Citrus maxima*	Jambura	Cultivated	West Garo Hills	Meghalaya	25.15	90.11
53	MD/07/162	558186	*Citrus maxima*	Jambura	Cultivated	South Garo Hills	Meghalaya	25.21	90.43
54	MD/08/202	568594	*Citrus maxima*	Ser tawk	Cultivated	Kolasib	Mizoram	24.12	92.40
55	MD/08/205	568597	*Citrus maxima*	Ser tawk	Cultivated	Kolasib	Mizoram	24.11	92.41
56	MD/08/217	568609	*Citrus maxima*	Ser tawk	Cultivated	Kolasib	Mizoram	24.11	92.41
57	MD/08/218	568610	*Citrus maxima*	Ser towk	Cultivated	Kolasib	Mizoram	24.11	92.41
58	MD/08/233	568625	*Citrus maxima*	Ser manmoh	Cultivated	Aizawl	Mizoram	23.48	92.38
59	MD/08/234	568626	*Citrus maxima*	Ser tawk	Cultivated	Aizawl	Mizoram	23.48	92.38
60	MD/08/235	568627	*Citrus maxima*	Ser tawk	Cultivated	Aizawl	Mizoram	23.40	92.51
61	MD/08/236	568628	*Citrus maxima*	Ser tawk	Cultivated	Aizawl	Mizoram	23.40	92.51
62	MD/08/241	568633	*Citrus maxima*	Ser towk	Cultivated	Serchhip	Mizoram	23.28	92.51
63	MD/08/246	568638	*Citrus maxima*	Ser towk	Cultivated	Serchhip	Mizoram	23.28	92.51
64	MD/08/261	568653	*Citrus maxima*	Ser towk	Cultivated	Mamit	Mizoram	23.53	92.29
65	MD/08/263	568655	*Citrus maxima*	Ser towk	Cultivated	Mamit	Mizoram	23.49	92.29
66	MD/08/266	568658	*Citrus maxima*	Ser towk (Red)	Cultivated	Mamit	Mizoram	23.49	92.29
67	MD/08/267	568659	*Citrus maxima*	Soh ba (white)	Cultivated	East Khasi Hills	Meghalaya	25.42	92.27
68	MD/08/268	568660	*Citrus maxima*	Soh nagrim (white)	Cultivated	East Khasi Hills	Meghalaya	25.42	92.27

69	MD-09-28	583271	*Citrus maxima*	Rabab	Cultivated	West Siang	Arunachal Pradesh	28.02	94.40
70	MD-09-29	583272	*Citrus maxima*	Rabab	Cultivated	West Siang	Arunachal Pradesh	28.02	94.40
71	MD-10/44	586992	*Citrus maxima*	Foxey	Cultivated	East Sikkim	Sikkim	27.22	88.58
72	MD-10/47	586995	*Citrus maxima*	Foxey	Cultivated	East Sikkim	Sikkim	27.21	88.62
73	MD-10/48	586996	*Citrus maxima*	Foxey	Cultivated	East Sikkim	Sikkim	27.29	88.53
74	MD-10/51	586999	*Citrus maxima*	Foxey	Cultivated	East Sikkim	Sikkim	27.30	88.47
75	MD-10/57	587005	*Citrus maxima*	Foxey	Cultivated	West Sikkim	Sikkim	27.28	88.29
76	MS-06	587024	*Citrus maxima*	Jambura	Cultivated	Ri-Bhoi	Meghalaya	25.41	91.55
77	MD-11/38	591396	*Citrus maxima*	Pummelo	Cultivated	Tinsukia	Assam	27.31	95.21
78	MD-11/55	591413	*Citrus maxima*	Pummelo red	Cultivated	Tinsukia	Assam	27.31	95.21
79	MD-11/80	591439	*Citrus maxima*	Rubab tenga	Cultivated	Tinsukia	Assam	27.57	95.36
80	MD/08/264	568656	*Citrus megaloxycarpa*	Sishuphal	Cultivated	Mamit	Mizoram	23.49	92.29
81	MD/08/265	568657	*Citrus megaloxycarpa*	Sishuphal	Cultivated	Mamit	Mizoram	23.49	92.29
82	MD-11/46	591404	*Citrus megaloxycarpa*	Sour pummelo	Cultivated	Tinsukia	Assam	27.31	95.21
83	MD-11/50	591408	*Citrus megaloxycarpa*	Sour pummelo	Cultivated	Tinsukia	Assam	27.31	95.21
84	MSA-27	593868	*Citrus megaloxycarpa*	Sour pummelo	Cultivated	Kangra	Himachal Pradesh	32.09	76.25
85	MSA-31	593872	*Citrus megaloxycarpa*	Sour Pummelo	Cultivated	Kangra	Himachal Pradesh	32.10	76.22
86	MDY-10	395345	*Citrus paradisi*	Grapefruit	Cultivated	Hoshiarpur	Punjab	31.65	75.89
87	MDY-91	395419	*Citrus paradisi*	Foster pink	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
88	MDY-93	395420	*Citrus paradisi*	Duncan	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
89	MD-446	470361	*Citrus paradisi*	Grapefruit red flesh	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
90	MD-447	470362	*Citrus paradisi*	Marsh seedless	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
91	MD-448	470363	*Citrus paradisi*	Thompson seedless	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87

92	MD-454	470366	*Citrus paradisi*	Marsh seedless	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
93	MD/07/119	558143	*Citrus paradisi*	Chamba	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
94	MD/07/126	558150	*Citrus paradisi*	Chamba	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
95	MD/07/131	558155	*Citrus paradisi*	Chamba	Cultivated	East Garo Hills	Meghalaya	25.30	90.20
96	MD/08/245	568637	*Citrus paradisi*	Serbial	Cultivated	Serchhip	Mizoram	23.28	92.51
97	MD-11/37	591395	*Citrus paradisi*	Grapefruit	Cultivated	Tinsukia	Assam	27.31	95.21
98	MD-11/58	591416	*Citrus paradisi*	Soh-khayllah	Cultivated	Tinsukia	Assam	27.31	95.21
99	MD-11/61	591419	*Citrus paradisi*	Champa umthambi	Cultivated	Tinsukia	Assam	27.31	95.21
100	MD-11/72	591431	*Citrus paradisi*	Grapefruit	Cultivated	Tinsukia	Assam	27.31	95.21
101	MDY-1	395336	*Citrus paradisi*	Grapefruit	Cultivated	Sirmour	Himachal Pradesh	30.91	76.96
102	MD-10/65	587013	*Citrus paradisi*	Smooth flat	Cultivated	Darjeeling	West Bengal	27.04	88.39
103	IPSKM-261	322088	*Citrus paradisi*	Grapefruit	Cultivated	Jhansi	Uttar Pradesh	25.44	78.57

6.3 Characterization

Citrus maxima

Fruit shape varied from pyriform, obloid to spheroid. Fruit apex showed large variation in shape with depressed, rounded and truncate shape. Fruits were yellow and greenish yellow in colour with smooth pitted and papillated texture. Seeds also showed large variation in shape. Seeds were semi-deltoid, clavate, spheroid and cunieform in shape with white to creamish cotyledons and brown chalazal spot colour. Fruit weight ranged from 123.33 gm (IC591439) to 1387.80 gm (IC470351). TSS value varied from 3.00 to 11.33°B. Ten seed weight ranged from 0.37 gm (IC470337) to 3.39 gm (IC553132). Detailed characterization data of qualitative and quantitative traits is given in Table 6.2 and 6.3. Representative photographs of phenotypic variability in pummelo cultivars are given in Fig. 6.2.

Citrus megaloxycarpa

Fruit shape varied from ellipsoid to spheroid with rounded or truncate apex. Fruits were yellowish in colour with pitted and smooth surface texture. Seed shape varied from ovoid to semi-deltoid with creamish and whitish cotyledons and dark brown chalazal spot. A sizable variability was recorded in almost all of the fruit and seed characters. Fruit weight ranged from 201.67 gm (IC591404) to 732 gm (IC593868). TSS value varied from 7.17 to 8.67°B, which is limited difference between the cultivars. Ten seed weight varied from 1.69 gm (IC593868) to 2.98 gm (IC593872). Detailed characterization data of qualitative and quantitative traits is given in Table 6.2 and 6.3. Representative photographs of phenotypic variability in sour pummelo are given in Fig. 6.3.

Citrus paradisi

Fruit shape varied from pyriform to spheroid with apex showing a large variability of depressed, truncate and rounded shape. Fruits were green yellow, dark yellow and yellowish in colour with pitted to smooth surface texture. Seeds were ovoid, semi-deltoid and cuneiform in shape. Cotyledons were creamish in most of the cultivars with green and white colour also seen with brown and creamish chalazal spot. Fruit weight varied from 126.67 gm (IC591419) to 765.77 gm (IC395336). TSS value of the fruit ranged from 2.00 to 10.33°B. Ten seed weight varied from 0.52 gm (IC470363) to 3.11 gm (IC591416). Detailed characterization data of qualitative and quantitative traits are given in Table 6.2 and 6.3. Representative photographs of phenotypic variability in grapefruit cultivars are given in Fig. 6.4.

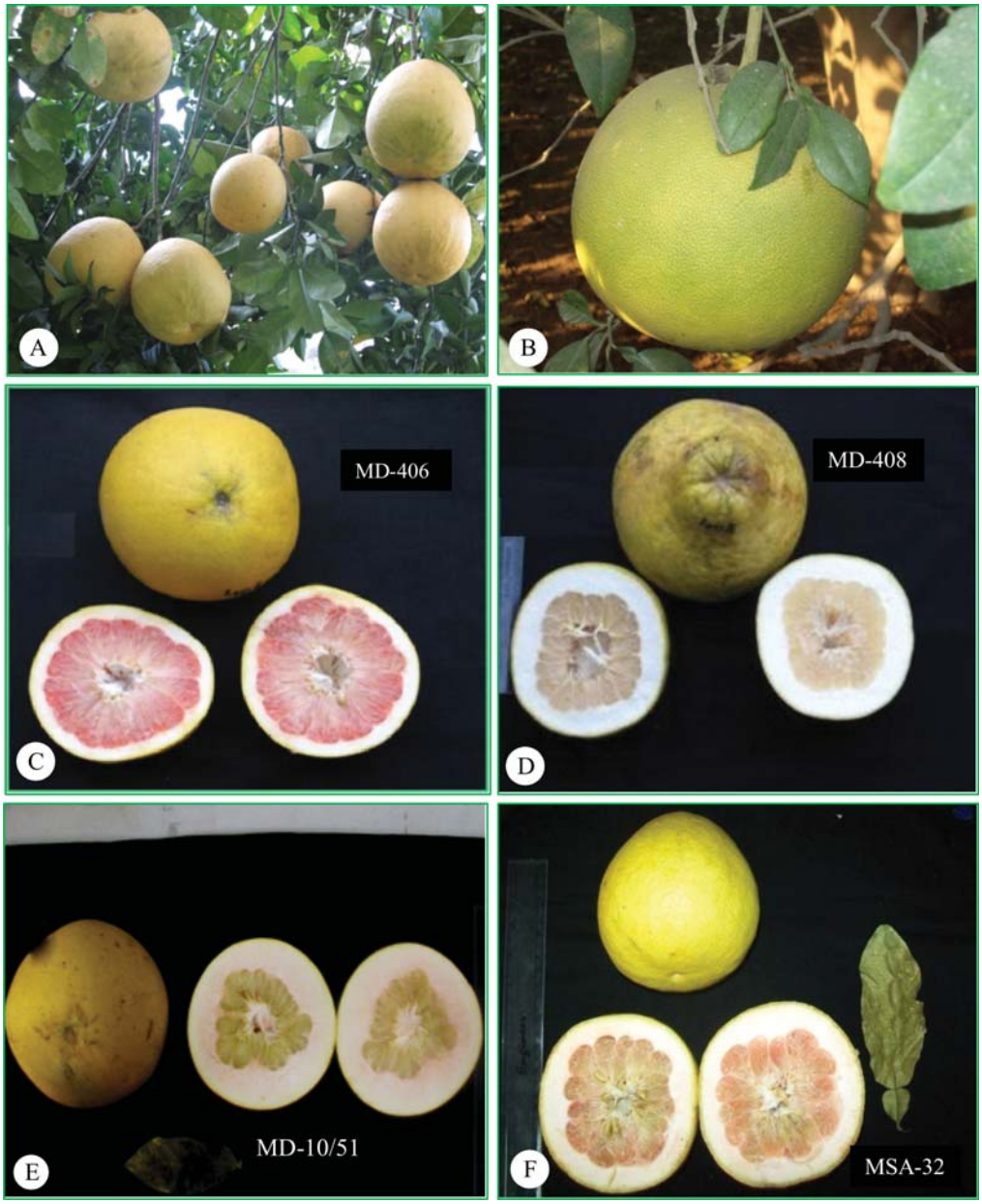

Fig. 6.2. Phenotypic variability in indigenous cultivars of *Citrus maxima* (Pummelo) collected from different parts of India, (A) Pummelo from Mizoram; (B) Chakotra from Himachal Pradesh; (C) MD-406, Chakotra (Red flesh) from Uttarakhand; (D) MD-408, Chakotra (White flesh) from Uttarakhand; (E) MD-10/51, Foxey from Sikkim; (F) MSA-32, Chakotra from Himachal Pradesh

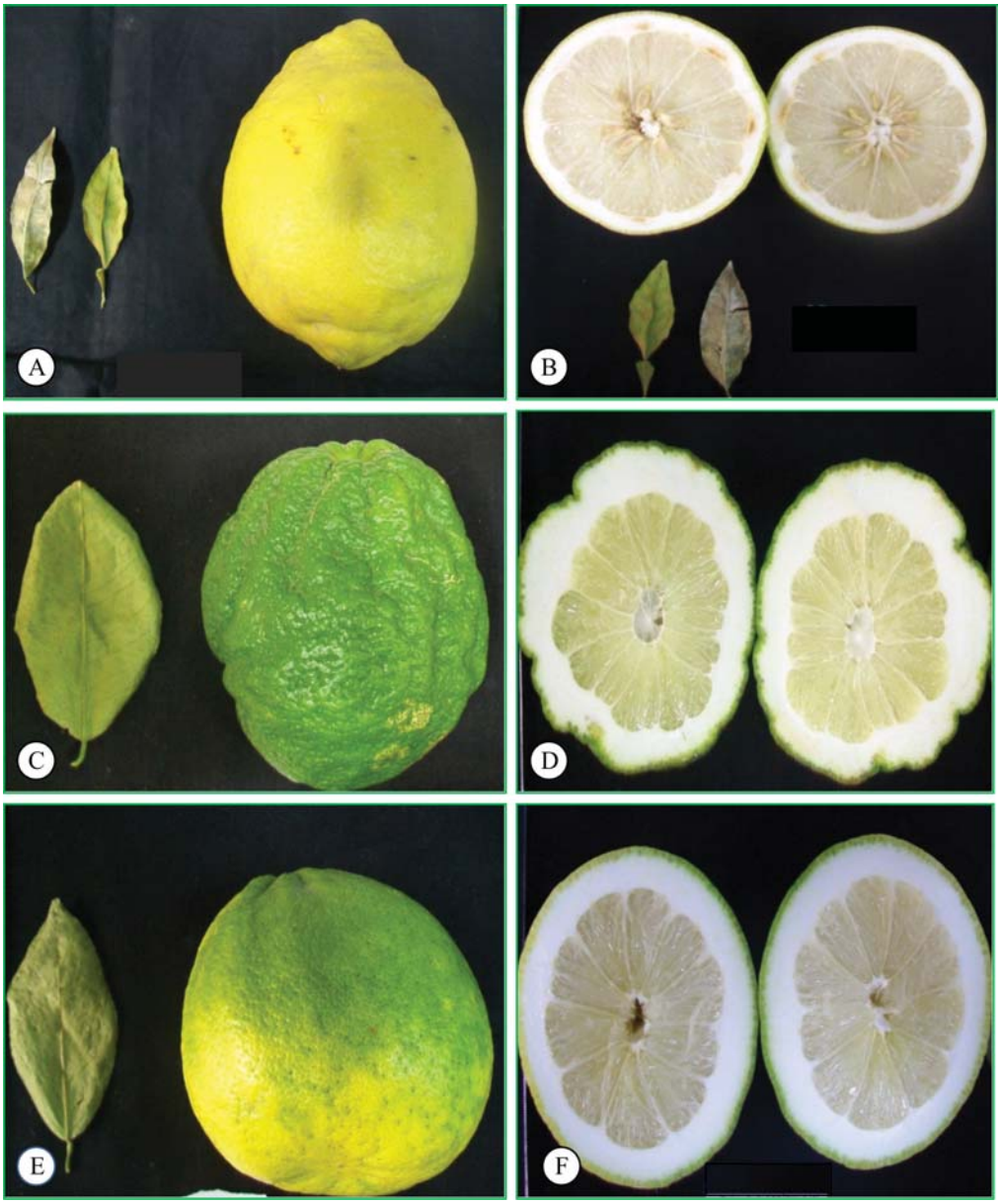

Fig. 6.3. Phenotypic variability in indigenous cultivars of *Citrus megaloxycarpa* (Sour pummelo) collected from different parts of India, (A,B) MSA-27, Sour pummelo from H.P; (C,D) Holong tenga from Tripura; (E,F) Hukma tenga from Tripura

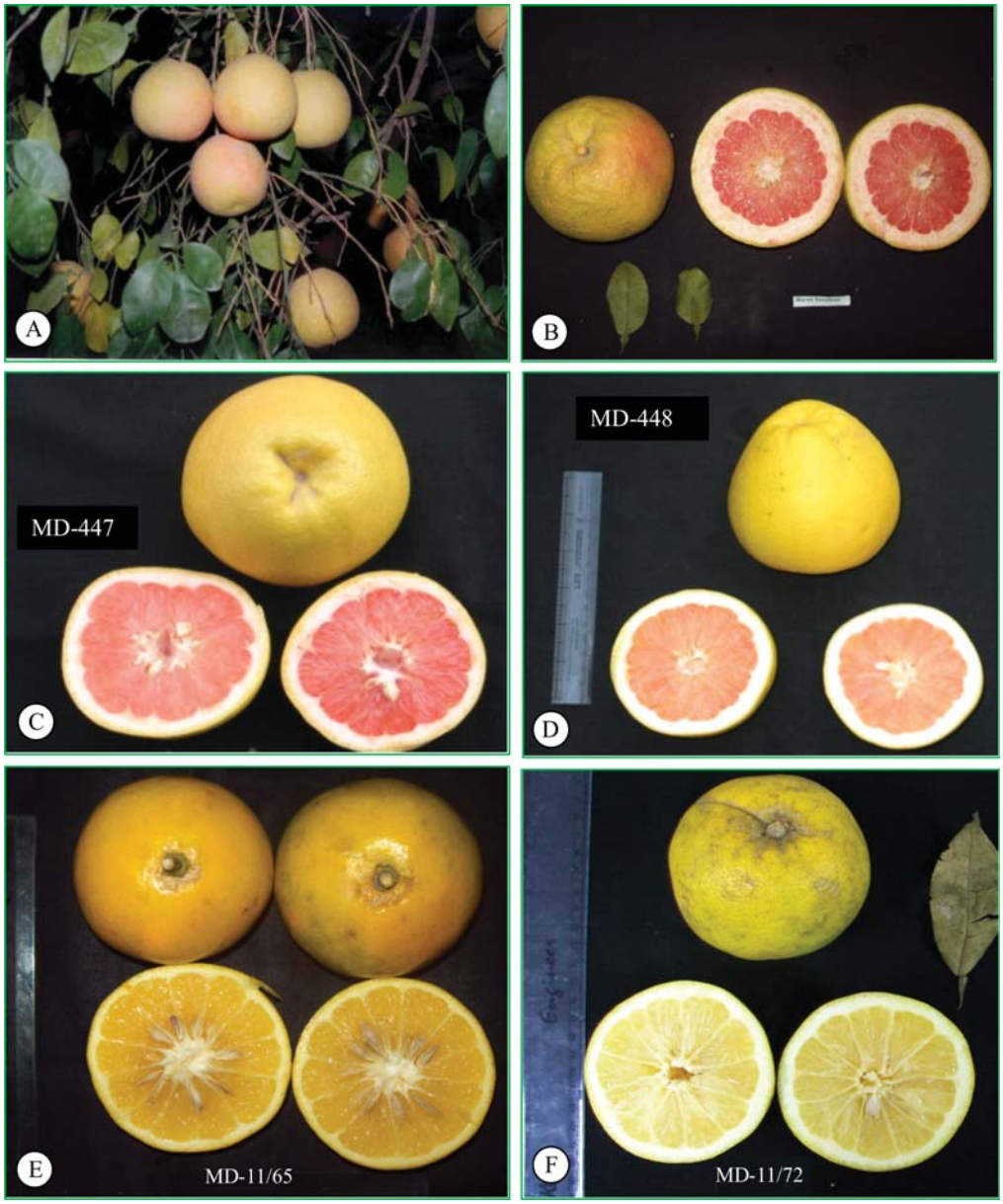

Fig. 6.4 . Phenotypic variability in indigenous and exotic cultivars of *Citrus paradisi* (Grapefruit) collected from different parts of India (A, B) MD-454, Marsh seedless from Punjab; (C) MD-447, from Rajasthan; (D) MD-448, Thompson seedless from Rajasthan; (E) MD-11/65, Smooth Flat from Sikkim; (F) MD-11/72, Grapefruit from Assam

Table 6.2. Qualitative parameters of Pummelo and Grapefruit group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit shape	Shape of fruit apex	Fruit colour	Fruit surface texture	Adherence of albedo to pulp	Seed shape	Colour of coty-ledons	Chalazal spot colour
MDY-9	395344	*C. maxima*	Pummelo	Pyriform	Truncate	Yellow	Smooth	Strong	Semi-deltoid	White	Light brown
MDY-42	395374	*C. maxima*	Pummelo	Obloid	Truncate	Yellow	Papillate	Strong	Semi-deltoid	White	Brown
MDY-47	395378	*C. maxima*	Chakotra	Pyriform	Truncate	Yellow	Pitted	Strong	Semi-deltoid	White	Dark brown
MDY-68	395397	*C. maxima*	Yamaponda	Spheroid	Truncate	Yellow	Smooth	Medium	Semi-deltoid	White	Dark brown
MDY-77	395405	*C. maxima*	Triumph	Pyriform	Rounded	Yellow	Smooth	Strong	Clavate	White	Dark brown
MD-406	470321	*C. maxima*	Chakotra	Ellipsoid	Rounded	Dark yellow	Smooth	Strong	Semi-deltoid	White	Brown
MD-408	470323	*C. maxima*	Chakotra	Pyriform	Depressed	Yellow	Papillate	Strong	Semi-deltoid	Cream	Brown
MD-411	470326	*C. maxima*	Chakotra	Pyriform	Depressed	Green	Smooth	Strong	Semi-deltoid	Cream	Brown
MD-412	470327	*C. maxima*	Chakotra	Spheroid	Rounded	Dark yellow	Smooth	Strong	Semi-deltoid	White	Brown
MD-419	470334	*C. maxima*	Kimb	Pyriform	Truncate	Dark yellow	Pitted	Strong	Ovoid	Cream	Dark brown
MD-422	470337	*C. maxima*	Kimb	Pyriform	Truncate	Green yellow	Pitted	Strong	Clavate	White	Dark brown
MD-425	470340	*C. maxima*	Chakotra	Ellipsoid	Truncate	Yellow	Pitted	Strong	Semi-deltoid	White	Brown
MD-436	470351	*C. maxima*	Chakotra	Spheroid	Truncate	Dark yellow	Smooth	Strong	Spheroid	Cream	Brown
MD-505	470399	*C. maxima*	Triumph	Pyriform	Rounded	Yellow	Smooth	Strong	Ovoid	Cream	Brown
MD-506	470400	*C. maxima*	Pummelo red flesh	Oblique	Depressed	Dark yellow	Smooth	Strong	Semi deltoid	Cream	Brown
MD/07/101	558125	*C. maxima*	Jambura	Pyriform	Truncate	Yellow	Smooth	Strong	Spheroid	Cream	Dark brown
MD/07/108	558132	*C. maxima*	Jambura	Spheroid	Rounded	Green yellow	Smooth	Medium	Cuneiform	Cream	Brown
MD/07/124	558148	*C. maxima*	Jambura	Spheroid	Truncate	Yellow	Rough	Strong	Semi-deltoid	White	Brown
MD/07/138	558162	*C. maxima*	Jambura	Pyriform	Truncate	Yellow	Smooth	Strong	Ovoid	White	Dark brown

MD/07/145	558169	*C. maxima*	Jambura	Pyriform	Truncate	Yellow	Smooth	Strong	Ovoid	Cream	Dark brown
MD/07/149	558173	*C. maxima*	Jambura	Spheroid	Rounded	Green yellow	Bumpy	Medium	Cuneiform	Cream	Brown
MD/07/162	558186	*C. maxima*	Jambura	Eillpsoid	Truncate	Yellow	Rough	Strong	Spheroid	Light green	Brown
MD-11/38	591396	*C. maxima*	Pummelo	Spheroid	Truncate	Yellow	Pitted	Medium	Semideltoid	Cream	Dark brown
MD-11/55	591413	*C. maxima*	Pummelo red	Spheroid	Truncate	Yellow	Pappilated	Medium	Ovoid	Cream	Dark brown
MD-11/80	591439	*C. maxima*	Rubab tenga	Spheroid	Rounded	Dark yellow	Smooth	Medium	Semideltoid	Cream	Light brown
MSA-24	593865	*C. maxima*	Pummelo	Spheroid	Truncate	Greenish yellow	Rough	Strong	Ovoid	White	Light brown
MSA-30	593871	*C. maxima*	Pummelo	Spheroid	Rounded	Yellow	Pitted	Strong	Semideltoid	White	Dark brown
MSA-32	593873	*C. maxima*	Pummelo	Pyriform	Truncate	Greenish yellow	Pitted	Medium	Semideltoid	White	Brown
MD-11/46	591404	*C. megaloxycarpa*	Sour pummelo	Spheroid	Round	Yellow	Smooth	Strong	Ovoid	Cream	Dark brown
MD-11/50	591408	*C. megaloxycarpa*	Sour pummelo	Spheroid	Rounded	Yellow	Smooth	Strong	Ovoid/flat	Cream	Dark brown
MSA-27	593868	*C. megaloxycarpa*	Sour pummelo	Ellipsoid	Rounded	Yellowish Green	Pitted	Medium	Semideltoid	White	Dark brown
MSA-31	593872	*C. megaloxycarpa*	Sour Pummelo	Spheroid	Truncate	Yellow	Pitted	Medium	Ovoid	White	Brown
MDY-1	395336	*C. paradisi*	Grapefruit	Spheroid	Rounded	yellow	Smooth	Strong	Semi-deltoid	Cream	Brown
MDY-10	395345	*C. paradisi*	Grapefruit	Spheroid	Rounded	yellow	Smooth	Strong	Ovoid	Cream	Light brown
MDY-91	395419	*C. paradisi*	Foster pink	Pyriform	Rounded	Green yellow	Smooth	Strong	Ovoid	Cream	Light brown
MDY-93	395420	*C. paradisi*	Duncan	Spheroid	Rounded	yellow	Smooth	Strong	Semi-deltoid	Cream	Light brown
MD-446	470361	*C. paradisi*	Grapefruit red flesh	Spheroid	Truncate	Yellow	Smooth	Strong	Ovoid	White	Light brown

MD-447	470362	*C. paradisi*	Marsh seedless	Pyriform	Truncate	Yellow	Smooth	Strong	Semi-deltoid	White	Light brown
MD-448	470363	*C. paradisi*	Thompson seedless	Pyriform	Truncate	Yellow	Smooth	Strong	Semi-deltoid	Cream	Light brown
MD-454	470366	*C. paradisi*	Marsh seedless	Spheroid	Rounded	Dark yellow	Smooth	Medium	Semi-deltoid	Cream	Brown
MD/07/131	558155	*C. paradisi*	Chamba	Spheroid	Depressed	Green yellow	Smooth	Medium	Ovoid	Green	Cream
MD-10/65	587013	*C. paradisi*	Smooth flat	Spheroid	Truncate	Green yellow	Smooth	Medium	Clavate	White	Brown
MD-11/58	591416	*C. paradisi*	Soh-khayllah	Spheroid	Rounded	Green yellow	Pitted	Medium	Ovoid	Cream	Dark brown
MD-11/61	591419	*C. paradisi*	Champa umthambi		Spheroid	Rounded	Yellow	Smooth	Strong	Cuneiform	Cream Brown
MD-11/72	591431	*C. paradisi*	Grapefruit	Spheroid	Rounded	Green yellow	Smooth	Medium	Semideltoid	Cream	Light brown

Table 6.3. Quantitative parameters of Pummelo and Grapefruit group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit weight (gm)	Fruit diameter (mm)	Fruit length (mm)	Width of epicarp at equatorial area (mm)	Fruit rind thick-ness (mm)	No. of segments per fruit	TSS (°B)	No. of seed/ fruit	10 Seed wt. (gm)
MDY-09	395344	*C. maxima*	Pummelo	317.10 ±0.00	71.50 ±0.50	72.30 ±0.90	2.48 ±0.14	12.67 ±0.60	15.00 ±0.58	3.00 ±0.89	60.00 ±0.00	2.93 ±0.12
MDY-42	395374	*C. maxima*	Pummelo	317.10 ±0.00	70.33 ±0.33	72.67 ±0.88	2.04 ±0.29	17.50 ±0.50	17.33 ±0.88	5.50 ±0.78	10.67 ±4.67	2.93 ±0.12
MDY-47	395378	*C. maxima*	Chakotra	1317.80 ±8.40	83.83 ±0.60	85.00 ±0.53	3.09 ±0.23	14.60 ±0.00	14.33 ±0.33	3.00 ±0.58	25.67 ±6.50	2.93 ±0.12
MDY-68	395397	*C. maxima*	Yamaponda	687.80 ±9.50	64.00 ±0.00	74.00 ±0.00	3.36 ±0.26	14.60 ±0.00	11.00 ±0.00	8.40 ±0.78	5.33 ±0.67	2.93 ±0.12
MDY-77	395405	*C. maxima*	Triumph	557.50 ±9.50	52.17 ±0.17	60.33 ±0.33	3.72 ±0.06	17.67 ±0.60	11.67 ±0.33	8.40 ±0.71	60.00 ±0.00	2.41 ±0.09
MD-406	470321	*C. maxima*	Chakotra	765.77 ±8.50	118.21 ±3.20	119.74 ±7.53	2.03 ±0.24	9.60 ±1.60	16.33 ±0.33	5.13 ±0.07	60.00 ±0.00	2.45 ±0.12
MD-408	470323	*C. maxima*	Chakotra	663.14 ±7.50	121.52 ±1.91	131.62 ±6.49	2.22 ±0.12	30.57 ±5.62	14.67 ±0.67	7.07 ±0.07	76.67 ±7.50	2.92 ±0.17
MD-411	470326	*C. maxima*	Chakotra	1247.00 ±0.00	121.52 ±1.91	131.62 ±6.49	2.18 ±0.16	29.70 ±4.78	15.00 ±0.00	8.40 ±0.00	25.67 ±5.50	2.41 ±0.09
MD-412	470327	*C. maxima*	Chakotra	1132.83 ±5.50	142.06 ±7.54	126.81 ±5.12	2.48 ±0.14	11.21 ±1.63	16.67 ±0.88	8.40 ±0.00	25.67 ±6.50	2.93 ±0.12
MD-419	470334	*C. maxima*	Kimb	630.00 ±7.50	107.83 ±0.74	125.71 ±1.94	2.55 ±0.37	9.35 ±0.91	11.33 ±0.33	6.20 ±0.00	40.00 ±10.00	1.54 ±0.07
MD-422	470337	*C. maxima*	Kimb	444.13 ±6.50	96.11 ±2.29	105.06 ±2.37	2.56 ±0.24	16.67 ±0.61	16.00 ±0.00	8.53 ±0.07	2.00 ±0.00	0.37 ±0.00
MD-425	470340	*C. maxima*	Chakotra	1367.80 ±8.50	139.95 ±5.50	213.69 ±6.12	3.00 ±0.23	39.58 ±0.87	13.00 ±0.00	7.93 ±0.07	25.67 ±6.50	2.41 ±0.09
MD-436	470351	*C. maxima*	Chakotra	1387.80 ±9.50	149.95 ±5.50	223.69 ±6.50	3.09 ±0.23	40.58 ±0.87	14.00 ±0.00	9.67 ±0.07	10.67 ±4.67	1.27 ±0.08
MD-505	470399	*C. maxima*	Triumph	336.66	87.53	102.08	2.99	8.06	11.33	9.67	26.00	1.95

				±6.50	±2.34	±7.45	±0.47	±0.56	±0.67	±0.07	±3.46	±0.06
MD-506	470400	*C. maxima*	Pummelo red flesh	317.10 ±0.00	101.47 ±9.44	97.39 ±9.87	1.68 ±0.33	19.14 ±1.83	18.67 ±0.33	9.27 ±0.07	28.00 ±5.50	1.69 ±0.06
MD/07/101	558125	*C. maxima*	Jambura	765.77 ±8.50	54.00 ±0.00	55.00 ±0.53	3.56 ±0.24	17.67 ±0.60	11.67 ±0.33	8.40 ±0.58	25.67 ±6.50	1.80 ±0.05
MD/07/108	558132	*C. maxima*	Jambura	350.00 ±0.00	57.47 ±0.47	62.97 ±0.03	3.10 ±0.12	12.20 ±0.75	11.13 ±0.67	8.40 ±0.00	25.67 ±0.00	2.28 ±0.00
MD/07/124	558148	*C. maxima*	Jambura	540.00 ±0.00	58.00 ±0.00	67.20 ±0.00	2.22 ±0.12	13.60 ±0.12	10.00 ±0.00	8.40 ±0.63	25.67 ±6.50	1.40 ±0.03
MD/07/138	558162	*C. maxima*	Jambura	752.77 ±8.50	53.00 ±0.00	55.00 ±0.53	2.55 ±0.37	15.67 ±0.60	11.67 ±0.33	8.40 ±0.69	25.67 ±6.50	2.23 ±0.04
MD/07/145	558169	*C. maxima*	Jambura	780.00 ±0.00	58.00 ±0.00	62.00 ±0.00	3.21 ±0.14	11.50 ±0.00	15.00 ±0.00	8.40 ±0.96	52.00 ±0.00	3.02 ±0.02
MD/07/149	558173	*C. maxima*	Jambura	323.33 ±6.50	53.17 ±1.36	55.97 ±0.32	2.13 ±0.03	12.17 ±0.09	12.33 ±0.33	4.33 ±0.33	14.00 ±5.13	1.06 ±0.49
MD/07/162	558186	*C. maxima*	Jambura	300.00 ±0.00	55.47 ±0.47	56.97 ±0.03	2.10 ±0.06	11.20 ±0.45	11.33 ±0.67	7.40 ±0.60	45.00 ±1.00	3.39 ±0.09
MD-11/38	591396	*C. maxima*	Pummelo	641.67 ±6.01	112.93 ±1.51	104.81 ±1.35	1.57 ±0.12	8.05 ±0.02	14.67 ±0.33	10.33 ±0.17	3.33 ±2.40	1.72 ±0.03
MD-11/55	591413	*C. maxima*	Pummelo red	1054.00 ±5.50	136.53 ±2.94	135.60 ±2.02	2.37 ±0.14	7.59 ±0.07	13.00 ±0.00	10.00 ±0.08	112.67 ±6.57	2.22 ±0.05
MD-11/80	591439	*C. maxima*	Rubab tenga	123.33 ±6.50	63.67 ±6.13	53.70 ±4.29	2.16 ±0.32	25.58 ±5.50	15.33 ±1.45	7.00 ±0.58	1.18 ±0.12	1.90 ±0.33
MSA-24	593865	*C. maxima*	Pummelo	565.00 ±6.50	102.09 ±2.07	103.01 ±4.51	2.88 ±0.32	10.72 ±0.30	12.00 ±0.58	7.17 ±0.38	82.00 ±1.53	2.43 ±0.10
MSA-30	593871	*C. maxima*	Pummelo	711.67 ±8.50	113.51 ±2.19	85.86 ±6.50	1.70 ±0.34	21.20 ±0.53	12.00 ±0.58	11.33 ±0.33	0.64 ±0.06	1.60 ±0.00
MSA-32	593873	*C. maxima*	Pummelo	700.00 ±6.50	112.46 ±1.19	118.42 ±2.59	2.80 ±0.39	22.07 ±1.39	12.67 ±1.20	10.33 ±0.33	66.67 ±5.50	2.99 ±0.38
MD-11/46	591404	*C. megaloxycarpa*	Sour pummelo	201.67 ±6.50	74.73 ±3.11	63.89 ±9.67	1.57 ±0.05	5.51 ±0.13	13.00 ±0.00	7.17 ±0.17	30.67 ±9.68	2.21 ±0.06
MD-11/50	591408	*C. megaloxycarpa*	Sour pummelo	396.6 ±5.50	89.72 ±2.51	91.99 ±2.65	1.26 ±0.03	3.78 ±0.03	12.00 ±0.00	8.33 ±0.17	61.67 ±5.50	1.72 ±0.03

MSA-27	593868	*C. megaloxycarpa*	Sour pummelo	732.00 ±8.50	103.04 ±2.48	134.79 ±5.39	3.10 ±0.64	11.50 ±0.67	10.33 ±0.33	8.33 ±0.33	46.33 ±2.19	1.69 ±0.39
MSA-31	593872	*C. megaloxycarpa*	Sour Pummelo	516.67 ±9.50	100.04 ±7.60	95.54 ±5.50	1.72 ±0.42	6.12 ±0.30	10.33 ±0.33	8.67 ±0.33	17.00 ±5.51	2.98 ±0.37
MDY-01	395336	*C. paradisi*	Grapefruit	765.77 ±6.50	87.67 ±0.17	97.30 ±0.10	1.56 ±0.24	7.12 ±0.65	13.33 ±0.33	3.00 ±0.08	5.33 ±0.67	2.41 ±0.09
MDY-10	395345	*C. paradisi*	Grapefruit	567.77 ±8.50	78.67 ±0.33	88.24 ±0.14	2.55 ±0.37	6.86 ±0.83	12.33 ±0.33	2.00 ±0.08	15.00 ±1.73	2.41 ±0.09
MDY-91	395419	*C. paradisi*	Foster pink	745.77 ±8.50	79.43 ±0.52	82.33 ±0.61	2.55 ±0.37	6.48 ±0.31	12.00 ±0.58	2.00 ±0.12	0.00 ±0.36	2.41 ±0.09
MDY-93	395420	*C. paradisi*	Duncan	715.77 ±8.50	71.40 ±0.21	78.67 ±0.33	1.56 ±0.24	7.71 ±0.21	12.00 ±0.08	2.00 ±0.06	25.67 ±6.50	2.41 ±0.09
MD-446	470361	*C. paradisi*	Grapefruit red flesh	388.32 ±6.50	59.20 ±0.06	69.17 ±0.23	2.07 ±0.09	7.93 ±0.64	12.67 ±0.33	7.27 ±0.07	5.33 ±0.67	1.01 ±0.03
MD-447	470362	*C. paradisi*	Marsh seedless	406.26 ±6.50	97.64 ±1.40	86.22 ±2.41	3.36 ±0.26	6.86 ±0.83	12.33 ±0.33	9.33 ±0.07	2.67 ±0.33	1.79 ±0.08
MD-448	470363	*C. paradisi*	Thompson seedless	426.92 ±6.50	104.23 ±2.89	103.93 ±3.14	3.72 ±0.06	7.71 ±0.21	12.67 ±0.67	9.13 ±0.07	2.00 ±0.05	0.52 ±0.12
MD-454	470366	*C. paradisi*	Marsh seedless	320.79 ±7.50	86.80 ±6.37	74.33 ±5.01	3.21 ±0.14	6.48 ±0.31	11.67 ±0.33	11.67 ±0.00	46.67 ±5.78	1.19 ±0.45
MD/07/131	558155	*C. paradisi*	Chamba	173.473 ±6.50	52.96 ±1.92	55.55 ±1.39	2.11 ±0.38	6.87 ±0.38	11.00 ±0.47	8.80 ±1.50	24.66 ±0.66	0.75 ±0.02
MD-10/65	587013	*C. paradisi*	Smooth flat	240.67 ±5.50	68.81 ±2.25	57.13 ±2.53	1.96 ±0.39	5.67 ±0.37	11.33 ±0.67	10.00 ±1.00	15.00 ±1.73	1.12 ±0.12
MD-11/58	591416	*C. paradisi*	Soh-khayllah	378.33 ±7.50	89.77 ±4.72	90.19 ±4.93	2.22 ±0.05	7.17 ±0.08	11.00 ±0.36	9.50 ±0.00	24.00 ±2.08	3.11 ±0.01
MD-11/61	591419	*C. paradisi*	Champa umthambi	126.67 ±6.67	62.96 ±1.92	60.55 ±1.39	2.11 ±0.38	10.87 ±0.38	11.00 ±0.48	8.67 ±0.33	16.00 ±2.00	1.93 ±0.39
MD-11/72	591431	*C. paradisi*	Grapefruit	290.00 ±6.50	86.21 ±0.95	74.73 ±2.15	1.22 ±0.04	4.13 ±0.09	11.00 ±0.41	10.33 ±0.33	10.67 ±4.48	2.84 ±0.20

7. Papeda and other wild species

7.1 Genetic resources

***Citrus indica* Tanaka**

Common name: Indian Wild Orange

Vernacular name: Memang narang

Description

The tree is small bushy shrub upto 3.0 m tall, very spiny with brownish tip, branchlets green, angular when young (Fig. 7.2). Leaves are unifiolate, petiole 5-10 mm long, margined to very narrowly winged; lamina 5-8 x 2-2.5 cm, elliptic-lanceolate, margins finely crenate, serrulate towards apex, glandular, apex acuminate, base acute, gland dotted. Flowers are solitary, axillary, buds oblong, up to 12 mm long, apex 5- angular, petals creamy white in bud and open flowers, pedicel greenish-white, 3 mm long, calyx copular greenish-white, sepals 5, prominent, greenish glandular, petals 5, white, linear-oblong, thin, 12 mm long, 1.5 mm broad, gland dotted above; stamens about 22. Fruits are small, spherical or oblate shape, surface deep orange red to scarlet, truncate base or sometimes concave, truncate or depressed apex; red-orange skin colour; thin epicarp, surface smooth to bumpy towards apex; weak adheherence of albido (mesocarp) to pulp (endocarp), juice very sour. Seeds are ovoid and plumpy in shape, cotyledon greenish, chalazal cap brown and monoembryonic.

***Citrus latipes* (Swingle) Tanaka**

Common name: Khasi Papeda

Vernacular name: Soh-shyrkhoit or Soh-kymphorshrieh

Description

It is a medium to large tree, 20-30 ft. in height, spreading densely foliaged, thorny, stout, as big as 3-6 cm long spine (Fig. 7.2). Leaf lamina is ovate-lanceolate or broadly lanceolate with sub-acute apex. Petiole is broadly winged as equal or slightly longer than lamina, oblong-spathulate shape, obtuse apex and crenate margin. Flowers are in cluster (2-8), occasionally solitary, cymes, pedicel 6-8

mm long, glabrous, calyx medium coriaceous, stamens 20-30. Fruit shape is globular or spherical, moderately depressed at both ends, colour light yellow or greenish yellow; surface smooth, papillate; base obtuse, almost even, occasionally ribbed; apex obtuse to slightly truncate, smooth; rind medium thick, thickness 5-6 mm, adherence strong, mesocarp (albedo) white, spongy, texture medium soft, tasteless, axis solid, segments 9-11, adherence strong; seeds 25-60 per fruit, shape ovoid, slightly wrinkled, white testa, chalazal spot Indian red, cotyledon white and monoembryonic.

***Citrus macroptera* Montr.**

Common name: Melanesian Papeda

Vernacular name: Satkara, Hatkara

Description

The plant is a medium to large tree, 30-50 ft. ht, erect, profusely branched and densely foliaged with very long stout spines, big ones usually 5-8 cm. long, arising almost at right angle; young branches angular, glabrous (Fig. 7.5). Leaf lamina is ovate-elliptic in shape, base almost obtuse, apex obtuse, emarginated, margin sub-entire or very slightly crenate; petiole broadly winged, obovate or obcordately oblong, long as lamina, base abruptly attenuated, apex retuse, margin almost entire to very slightly crenate, mid-rib prominent on both sides, glabrous, articulated. Fruits are more or less oblate to globular shape, yellowish in colour and smooth surface or slightly rough. Seeds are large in size, cuneate or triangular shape, 20-40 per fruit, micropylar end either flat or slightly pointed, surface smooth on both sides, testa cream white, tegmen very light brown, chalazal spot light red, cotyledon white and polyembryonic.

***Citrus ichangensis* Swingle**

Common name: Ichang Papeda

Vernacular name: Ketsa Chüpfü

Description

It is a medium sized very hardy tree usually 10-18 ft. high, having very large and sharp spines up to 7.0 cm long and broadly winged petioles as long as leaf lamina (Fig. 7.6). Fruits are oblong in shape with gradual tapering at both the end, size 6.0-8.0 cm height, 4.0-6.0 cm in diameter. Fruits are full of extremely large and thick seeds, 1.2-2.2 cm long, 1.0-2.1 cm broad and 0.8-1.6 cm thick.

Seeds have dented and reticulate impressions on the rounded end, white testa, brown colour chalazal spot, white cotyledon and monoembryonic.

***Citrus assamensis* Dutta & Bhattacharya**

Common name: Ada-jamir

Description

The plant is medium to large tree, spreading, moderately branched and foliaged with long stout spines. Leaf lamina is elliptic to broadly lanceolate with narrowly winged petiole. Fruit is almost spherical to slightly turbinate, light lemon yellow colour with slight greenish tinge and smooth surface having many ovate shaped seeds (Fig. 7.7). Seeds are polyembryonic.

7.2 Exploration and Collection

C. indica is found to grow naturally in the Garo Hills of Meghalaya as absolutely wild. Maximum diversity of this species was found in two populations namely Daribokgre in East Garo Hills and Rongwak in South Garo Hills. However, limited number of plants were observed in other locations namely Chandgre, Mandalgre, Sasatgre, Nokrek peak, Dura Kalakgre and Rengsangre in and around Nokrek Biosphere Reserve. A total of 30 accessions of this species were collected by NBPGR from East, West and South Garo Hills in Meghalaya. During the surveys, a bold fruited 'Memang narang' type ('Memang athur') was also collected from the South Garo Hills, which was found intermediate between *C. indica* and *C. medica* (Malik *et al.*, 2006).

The recent survey reported that *C. macroptera* is commercially cultivated on small scale in some areas of Mizoram (Aizawl, Kolasib, Mamit, Lunglei), Tripura (Jumpui Hills) and in Meghalaya as demands of fresh fruits, juice and dried fruit peels for various purposes is increasing in the local market of Mizoram. Local people take interest to grow this plant in home garden and their fields for commercial purposes. A total of 17 accessions of this species were collected from Mizoram and Meghalaya, where this species is locally known as Aatkara or Hatkara.

C. latipes (Khasi papeda) is found to grow in Khasi Hills of Meghalaya in semi-domesticated state. A total of 7 accessions of this species were collected from Khasi hills of Meghalaya and Tinsukhia, Assam. *C. ichangensis* is a very interesting wild species of genus Citrus and probably most hardy and cold tolerant. Recent survey revealed that natural population of *C. ichangensis* is found to

grow in the forest near Khonoma village in the Naga Hills in natural wild state. Two different accessions of this species were collected from nearby Khonoma village, Nagaland. Fruits of this species are not edible due to the large number of big sized seeds in the fruits and scanty pulp. One accession of *C. assamensis* was collected from Jaintia Hills of Meghalaya.

Passport details of all the collected accessions of wild species are given in Table 7.1 and collection sites are shown in Fig. 7.1.

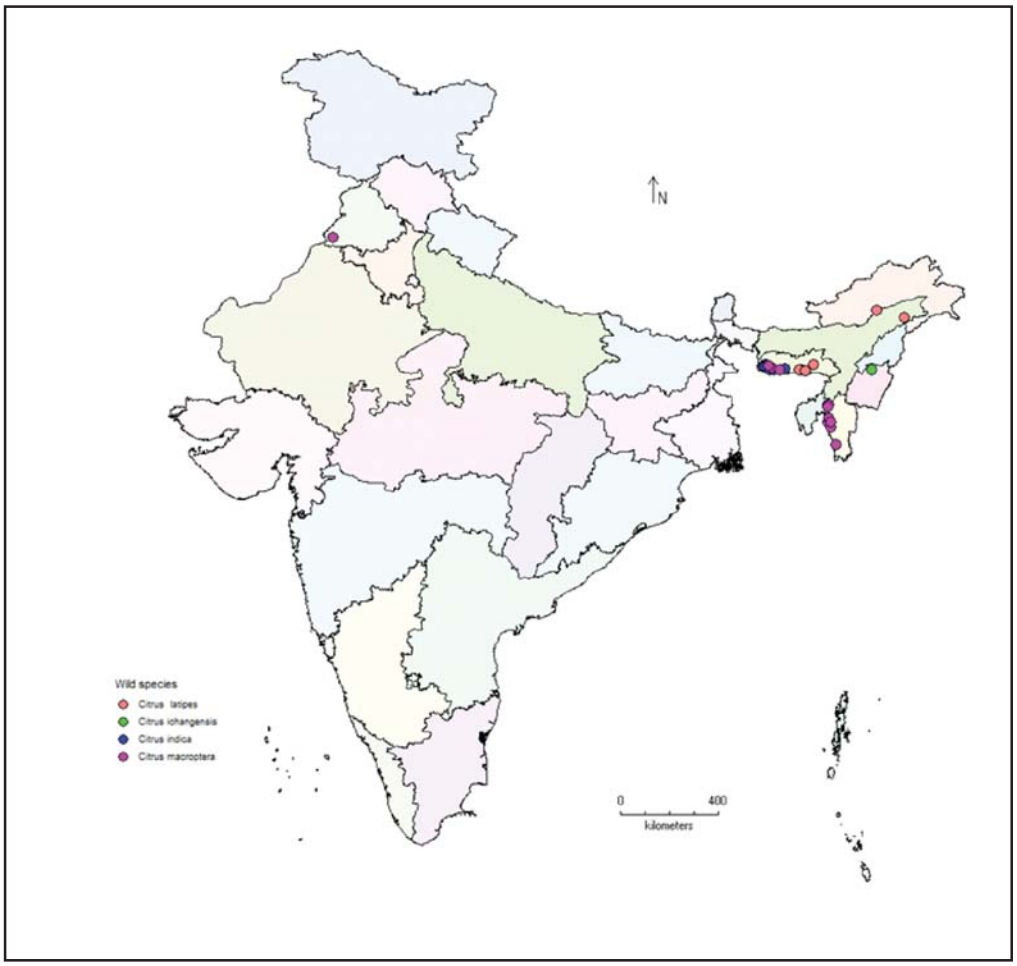

Fig. 7.1. Map of India showing collection sites of Papeda and other wild species of *Citrus*

Table 7.1. Passport data of *Papeda* and other wild species group (*C. indica*, *C. macroptera*, *C. latipes* and *C. ichangensis*) collected from different parts of India

S. No.	Collector Number	IC No.	Botanical Name	Common/Vern. /Cult. Name	Biological status	District	State	Lati-tude	Longi-tude
1	MD-151	417219	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.30	90.20
2	MD-152	417220	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.30	90.20
3	MD-156	417224	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.45	90.17
4	MD-157	417225	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.45	90.17
5	MD-158	417226	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.45	90.17
6	MD-160	417228	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.54	90.17
7	MD-174	417241	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.44	90.82
8	MD-175	417242	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.44	90.82
9	MD-183	417249	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.57	90.12
10	MD-184	417250	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.52	90.17
11	MD-187	417253	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.49	90.03
12	MD-190	417256	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.49	90.03
13	MD-192	417258	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.50	90.10
14	MD-193	417259	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.50	90.10
15	MD-197	417263	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.54	90.22
16	MD-227	417293	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.54	90.22
17	MD/07/104	558128	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19

18	MD/07/105	558129	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19
19	MD/07/106	558130	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19
20	MD/07/107	558131	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19
21	MD/07/109	558133	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19
22	MD/07/110	558134	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19
23	MD/07/112	558136	*Citrus* x *indica*	Memang athur	Wild	East Garo Hills	Meghalaya	25.29	90.19
24	MD/07/118	558142	*Citrus indica*	Memang narang	Wild	East Garo Hills	Meghalaya	25.29	90.19
25	MD/07/146	558170	*Citrus indica*	Memang narang	Wild	West Garo Hills	Meghalaya	25.15	90.11
26	MD/07/154	558178	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.16	90.39
27	MD/07/155	558179	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.16	90.39
28	MD/07/156	558180	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.16	90.39
29	MD/07/159	558183	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.21	90.43
30	MD/07/161	558185	*Citrus indica*	Memang narang	Wild	South Garo Hills	Meghalaya	25.21	90.43
31	MDY-60	395391	*Citrus macroptera*	Satkara	Wild	Abohar (Ferozpur)	Punjab	30.21	74.22
32	MD/08/203	568595	*Citrus macroptera*	Satkara	Wild	Kolasib	Mizoram	24.12	92.40
33	MD/08/210	568602	*Citrus macroptera*	Hatkora	Wild	Kolasib	Mizoram	24.11	92.41
34	MD/08/213	568605	*Citrus macroptera*	Hatkora	Wild	Kolasib	Mizoram	24.11	92.41
35	MD/08/222	568614	*Citrus macroptera*	Hatkora	Wild	Kolasib	Mizoram	24.03	92.40
36	MD/08/231	568623	*Citrus macroptera*	Hatkora	Wild	Aizawl	Mizoram	23.48	92.39
37	MD/08/232	568624	*Citrus macroptera*	Hatkora	Wild	Aizawl	Mizoram	23.48	92.38
38	MD/08/240	568632	*Citrus macroptera*	Hatkora	Wild	Serchhip	Mizoram	23.28	92.51

39	MD/08/248	568640	*Citrus macroptera*	Hatkora	Wild	Serchhip	Mizoram	23.28	92.51
40	MD/08/256	568648	*Citrus macroptera*	Hatkora	Wild	Lunglei	Mizoram	22.54	92.52
41	MD/08/258	568650	*Citrus macroptera*	Hatkora	Wild	Mamit	Mizoram	23.53	92.29
42	MD/08/270	568662	*Citrus macroptera*	Hatkora	Wild	Mamit	Mizoram	23.49	92.29
43	MD/08/272	568664	*Citrus macroptera*	Hatkora	Wild	Mamit	Mizoram	23.49	92.29
44	MD/08/273	568665	*Citrus macroptera*	Hatkora	Wild	Mamit	Mizoram	23.49	92.29
45	MD/07/137	558161	*Citrus macroptera*	Chambal	Wild	West Garo Hills	Meghalaya	25.15	90.12
46	MD/07/160	558184	*Citrus macroptera*	Chambal	Wild	South Garo Hills	Meghalaya	25.21	90.43
47	MD-195	417261	*Citrus macroptera*	Chambal	Wild	East Garo Hills	Meghalaya	25.54	90.22
48	MS-10	587026	*Citrus latipes*	Soh-kymphor	Wild	East Khasi Hills	Meghalaya	25.25	91.47
49	MS-14	587027	*Citrus latipes*	Soh-kymphor	Wild	East Khasi Hills	Meghalaya	25.19	91.43
50	MS-17	587028	*Citrus latipes*	Soh-kymphor	Wild	East Khasi Hills	Meghalaya	25.35	91.58
51	DMRK-198	278200	*Citrus latipes*	Soh-kymphor	Wild	East Khasi Hills	Meghalaya	25.57	91.88
52	MD-09-20	583263	*Citrus latipes*	Soh-kymphor	Wild	Upper Subansiri	Arunachal Pradesh	27.56	94.20
53	MD-11/68	591427	*Citrus latipes*	Soh-kymphor	Wild	Tinsukhia	Assam	27.31	95.21
54	MD-11/70	591429	*Citrus latipes*	Soh-kymphor	Wild	Tinsukhia	Assam	27.31	95.21
55	MD-11/101	591460	*Citrus ichangensis*	Ketsa chüpfü	Wild	Kohima	Nagaland	25.37	94.01
56	MD-11/102	591461	*Citrus ichangensis*	Ketsa chüpfü	Wild	Kohima	Nagaland	25.37	94.01
57	IPS/RS-114	285355	*Citrus assamensis*	Ada jamir	Cultivated	Jaintia Hills	Meghalaya	25.33	92.67

7.3 Characterization

Citrus indica

Fruit shape varied from obloid to spheroid with depressed, rounded or truncate apex (Fig. 7.2C). Fruits were yellow to dark orange in colour with smooth texture. Seeds were ovoid, semi-deltoid and spheroid in shape with light green cotyledons and brown chalazal spot. Fruit weight varied from 48.62 gm (IC558129) to 73.33 gm (IC558179). TSS value of fruits ranged from 5.23 to 9.03°B. Ten seed weight varied from 0.60 gm to 4.84 gm. The accession with high value of TSS and maximum seed weight was IC558133 and with low TSS value and minimum seed weight was IC558130. Detailed characterization data of qualitative and quantitative traits is given in Table 7.2 and 7.3. Representative photographs of phenotypic variability in *Citrus indica* are given in Fig. 7.2.

Fruit shape of 'Memang athur' was spheroid with mammilated fruit apex and longitudinal ridges (Fig.7.3). Fruit surface was slightly rough, shiny and yellowish in colour. Seeds was ovoid in shape, light green cotyledous and brown calazal cap.

Citrus latipes

Fruits were spheroid in shape with rounded and truncate apex. There were yellowish in colour with pitted surface texture (Fig. 7.4). Seeds were ovoid, semi-deltoid and semi-spheroid in shape with creamish cotyledons and dark brown chalazal spot. Fruit weight varied from 230.00 gm (IC587027) to 388.23 gm (IC591427). TSS value of fruits ranged from 5.80 to 10.33°B. Ten seed weight varied from 2.31 gm (IC587028) to 4.12 gm (IC591429). The accessions which have highest TSS value was IC591427. Detailed characterization data of qualitative and quantitative traits is given in Table 7.2 and 7.3

Citrus macroptera

Fruits were spheroid in shape with depressed and truncate apex (Fig.7.5). Fruit colour varied from yellow to greenish yellow with pitted and smooth texture. Seeds were clavate, cuneiform and semi-deltoid in shape with creamish colour of cotyledons and brown chalazal spot. Fruit weight varied from 238.33 gm (IC558161) to 280.67 gm (IC395391). TSS value of fruits ranged from 4.00 to 8.30°B. Ten Seed weight varied from 2.01 to 2.36 gm. The accession which has highest fruit weight with lowest value of TSS is IC395391. Detailed characterization data of qualitative and quantitative traits are given in Table 7.2 and 7.3.

Citrus ichangensis

Fruit shape varied from spheroid to pyriform with rounded fruit apex (Fig.7.6 B, C). Fruits were yellowish in colour with pitted surface texture. Seeds were very large, semi-deltoid in shape with creamish cotyledons and light brown chalazal spot (Fig.7.6 D). Fruit weight varied from 73.33 to 82.33 gm. TSS value ranged from 4.8 to 6.07°B and ten seed weight varied from 23.33 to 25.00 gm. Hence, accession IC591461 had highest fruit weight and TSS. Detailed characterization data of qualitative and quantitative traits is given in Table 7.2 and 7.3.

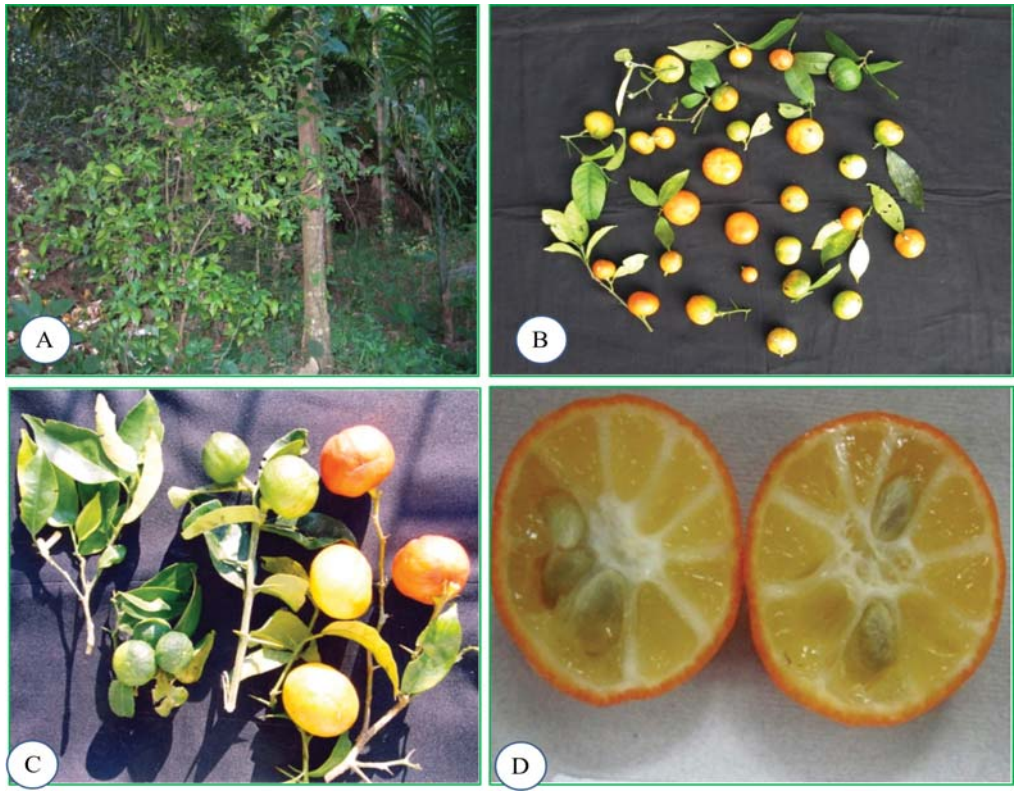

Fig. 7.2. *Citrus indica* (A) Natural wild population in Daribokgre, East Garo Hills; (B, C) Phenotypic diversity in mature fruits; (D) Internal structure of matured fruit

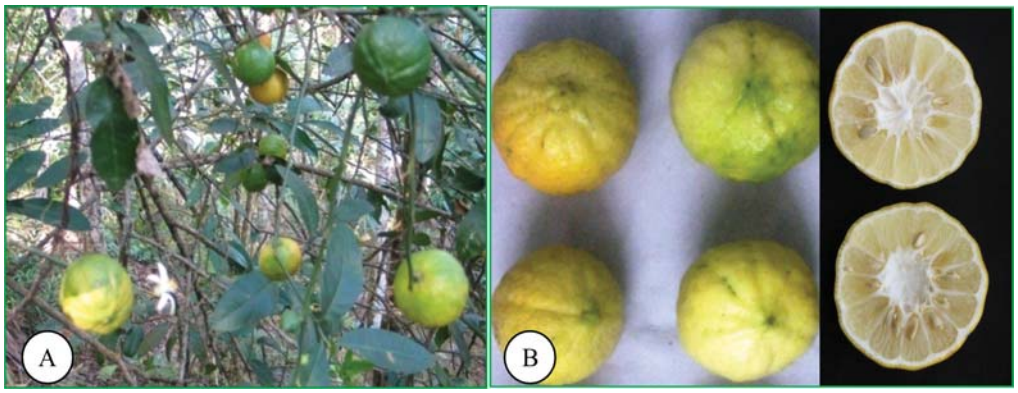

Fig. 7.3. *Citrus* sp. 'Memang athur' (Probable natural hybrid) collected from South Garo Hills, Meghalaya, (A) Tree bearing fruits, (B) Phenotypic diversity in mature fruits and internal structure of fruit

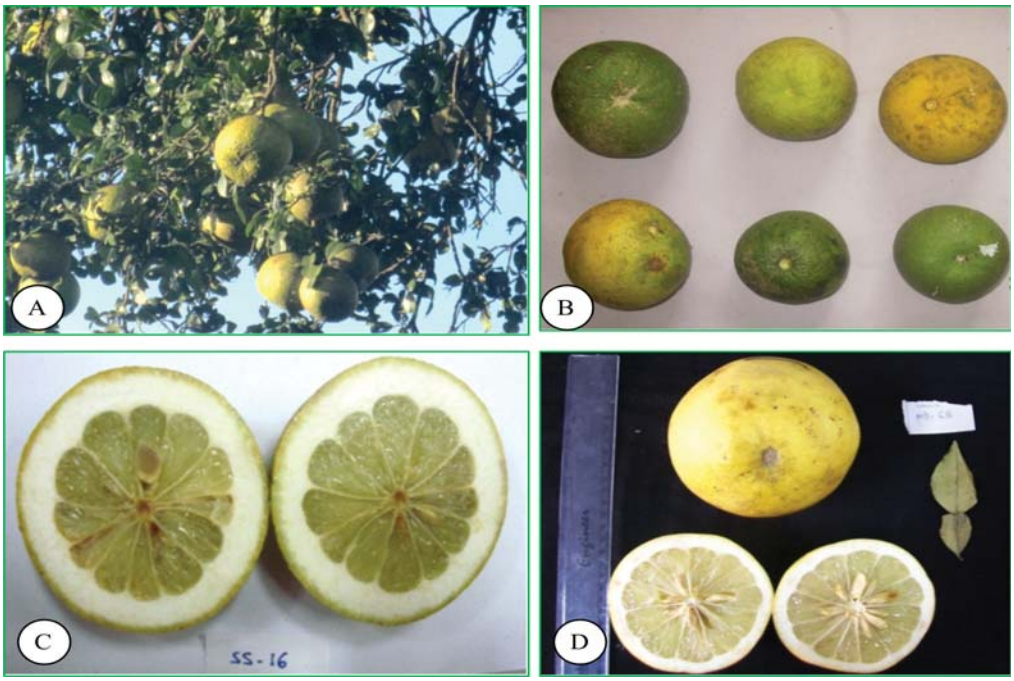

Fig. 7.4. *Citrus latipes* collected from Khasi Hills, Meghalaya, (A) MS-16, Twig bearing fruits, (B), Phenotypic diversity in mature fruits, (C) Internal structure of fruit; (D) MD-11/68, mature fruit leaf and its internal structure

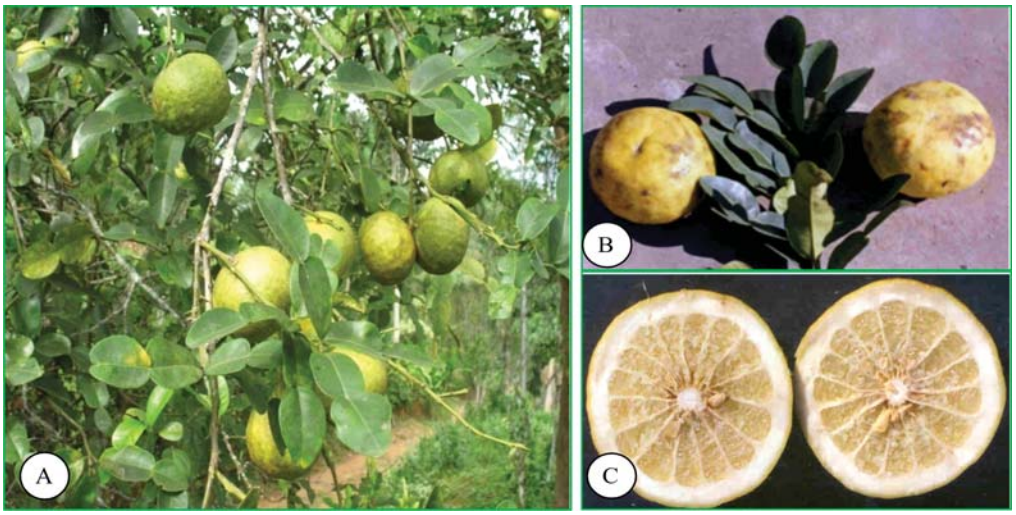

Fig. 7.5. *Citrus macroptera* collected from Mizoram, (A) Twig bearing mature fruits, (B) Phenotypic variability in mature fruits, (C) Internal structure of fruit showing segments and thick rind

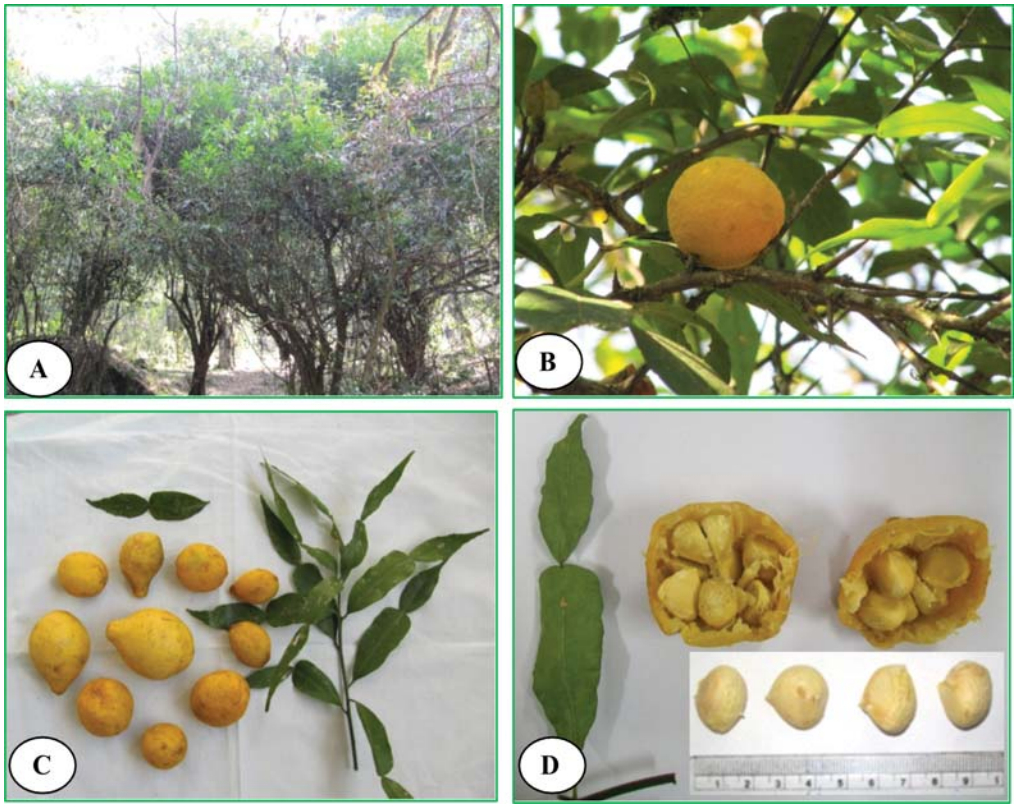

Fig. 7.6. *Citrus ichangensis* collected from Nagaland, (A) Old tree showing very long and stout spines in stem, (B) Twig bearing matured fruit, (C) Variability in mature fruits and leaf morphology, (D) Internal structure of fruit showing very large size seeds and no pulp

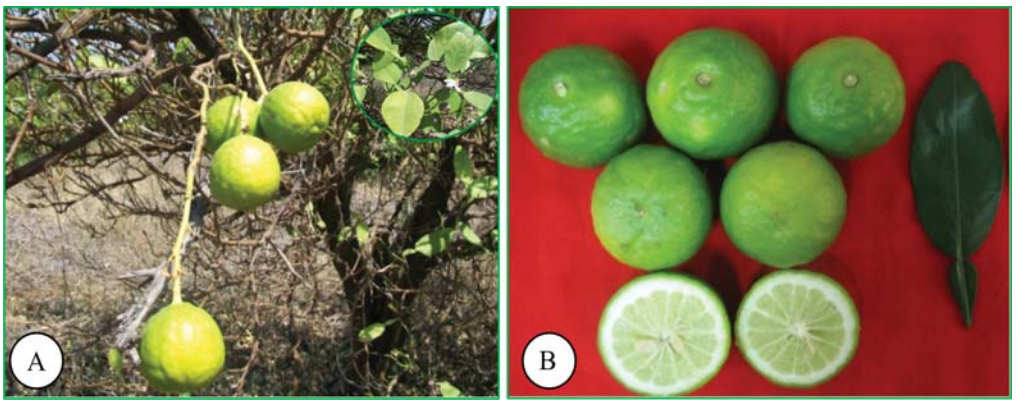

Fig. 7.7. *Citrus assamensis* (A) Mature tree bearing mature fruits, inset: twig with flowers, (B) Fruit and its internal structure

Table 7.2. Qualitative parameters of *Papeda* and other Citrus wild species group

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit shape	Shape of fruit apex	Fruit colour	Fruit surface texture	Adherence of albedo to pulp	Seed shape	Colour of coty-ledons	Chalazal spot colour
MD/07/104	558128	*C. indica*	Memang narang	Obloid	Truncate	Dark Orange	Smooth	Weak	Ovoid	Light green	Brown
MD/07/105	558129	*C. indica*	Memang narang	Spheroid	Truncate	Green yellow	Smooth	Weak	Ovoid	Light green	Brown
MD/07/106	558130	*C. indica*	Memang narang	Obloid	Truncate	Orange	Smooth	Medium	Ovoid	Light green	Brown
MD/07/107	558131	*C. indica*	Memang narang	Spheroid	Truncate	Light Orange	Smooth	Strong	Spheroid	Light green	Brown
MD/07/109	558133	*C. indica*	Memang narang	Obloid	Rounded	Orange	Smooth	Weak	Ovoid	Light green	Brown
MD/07/110	558134	*C. indica*	Memang narang	Obloid	Truncate	Orange	Smooth	Medium	Ovoid	Light green	Brown
MD/07/112	558136	*C.* x *indica*	Memang athur	Spheroid	Mammiform	Yellow	Smooth	Strong	Ovoid	Light green	Brown
MD/07/118	558142	*C. indica*	Memang narang	Obloid	Truncate	Dark Orange	Smooth	Weak	Ovoid	Light green	Brown
MD/07/146	558170	*C. indica*	Memang narang	Spheroid	Rounded	Yellow	Smooth	weak	Ovoid	Light green	Brown
MD/07/154	558178	*C. indica*	Memang narang	Obloid	Depressed	Yellow	Smooth	Strong	Ovoid	Light green	Brown
MD/07/155	558179	*C. indica*	Memang narang	Spheroid	Rounded	Light yellow	Smooth	Strong	Ovoid	Light green	Brown
MD/07/156	558180	*C. indica*	Memang narang	Obloid	Truncate	Yellow	Smooth	Strong	Semi-deltoid	Light green	Brown
MD/07/159	558183	*C. indica*	Memang narang	Obloid	Truncate	Green yellow	Smooth	Weak	Spheroid	Light green	Brown
MD/07/161	558185	*C. indica*	Memang narang	Obloid	Rounded	Green yellow	Smooth	Weak	Ovoid	Light green	Brown
MS-14	587027	*C. latipes*	Soh-kymphor	Spheroid	Truncate	Green orange	Pitted	Strong	Semi-deltoid	Cream	Dark brown
MS-17	587028	*C. latipes*	Soh-kymphor	Spheroid	Truncate	Green orange	Pitted	Strong	Semi-deltoid	Cream	Dark brown
MD-11/68	591427	*C. latipes*	Soh-kymphor	Spheroid	Round	Yellow	Pitted	Strong	Semi-spheroid	Cream	Dark brown
MD-11/70	591429	*C. latipes*	Soh-kymphor	Spheroid	Rounded	Dark yellow	Pitted	Strong	Ovoid	Cream	Dark brown
MDY-60	395391	*C. macroptera*	Satkara	Spheroid	Truncate	Yellow	Pitted	Strong	Semi-deltoid	Cream	Cream
MD/07/137	558161	*C. macroptera*	Chambal	Spheroid	Depressed	Green yellow	Smooth	Strong	Cuneiform	Cream	Brown
MD/07/160	558184	*C. macroptera*	Chambal	Spheroid	Truncate	Yellow	Smooth	Strong	Clavate	Cream	Brown
MD-11/101	591460	*C. ichangensis*	Ketsa chüpfü	Spheroid	Rounded	Yellow	Pitted	Weak	Semideltoid	Cream	Light brown
MD-11/102	591461	*C. ichangensis*	Ketsa chüpfü	Pyriform	Rounded	Yellow	Pitted	Weak	Semideltoid	Cream	Light brown

Table 7.3. Quantitative data of *Papeda* and other Citrus wild species

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit weight (gm)	Fruit diameter (mm)	Fruit length (mm)	Width of epicarp at equatorial area (mm)	Fruit rind thick-ness (mm)	No. of segments per fruit	TSS(^{0}B)	No. of seed/ fruit	10 Seed wt. (gm)
MD/07/104	558128	*C. indica*	Memang narang	65.00 ±2.89	38.20 ±0.72	43.10 ±0.06	1.18 ±0.15	2.19 ±0.45	11.33 ±1.20	6.17 ±0.17	3.00 ±0.08	0.60 ±0.10
MD/07/105	558129	*C. indica*	Memang narang	48.62 ±1.67	38.03 ±0.15	31.90 ±0.06	1.10 ±0.04	2.20 ±0.45	8.33 ±0.33	6.47 ±0.18	4.33 ±0.33	2.08 ±0.18
MD/07/106	558130	*C. indica*	Memang narang	56.63 ±1.67	41.10 ±0.10	39.97 ±0.09	1.13 ±0.03	2.10 ±0.12	10.33 ±0.33	5.23 ±0.03	7.67 ±1.45	0.60 ±0.10
MD/07/107	558131	*C. indica*	Memang narang	68.23 ±0.08	39.13 ±0.52	41.97 ±0.07	1.20 ±0.90	2.30 ±0.17	11.33 ±0.33	7.33 ±0.33	12.00 ±0.58	2.18 ±0.04
MD/07/109	558133	*C. indica*	Memang narang	63.67 ±1.56	41.93 ±1.55	40.37 ±0.15	2.00 ±0.58	2.50 ±0.78	10.33 ±0.33	9.03 ±1.13	10.00 ±0.58	4.84 ±2.58
MD/07/110	558134	*C. indica*	Memang narang	67.89 ±0.13	39.07 ±0.30	42.00 ±0.17	1.10 ±0.45	2.05 ±1.56	9.33 ±0.88	5.93 ±0.07	3.33 ±0.67	2.05 ±0.28
MD/07/112	558136	*C.* x *indica*	Memang athur	56.27 ±1.67	39.83 ±0.12	42.43 ±0.12	1.10 ±0.70	2.20 ±0.08	11.33 ±0.33	5.37 ±0.37	4.00 ±1.00	0.77 ±0.31
MD/07/118	558142	*C. indica*	Memang narang	57.96 ±1.26	41.43 ±0.15	42.23 ±0.12	1.19 ±0.78	2.24 ±0.48	11.67 ±0.33	6.27 ±0.27	6.00 ±0.08	1.29 ±0.02
MD/07/146	558170	*C. indica*	Memang narang	53.33 ±1.61	31.17 ±0.17	30.83 ±0.17	1.10 ±0.85	2.20 ±1.25	11.00 ±0.08	6.33 ±0.33	4.00 ±1.00	0.77 ±0.31
MD/07/154	558178	*C. indica*	Memang narang	63.33 ±5.50	41.47 ±0.57	44.77 ±0.09	1.17 ±0.03	2.40 ±0.48	12.67 ±0.67	5.30 ±0.20	24.00 ±7.51	2.25 ±0.07
MD/07/155	558179	*C. indica*	Memang narang	73.33 ±5.50	42.07 ±5.11	43.87 ±0.15	1.18 ±0.79	2.14 ±0.25	11.33 ±0.33	6.33 ±0.33	28.33 ±2.03	2.07 ±0.02

MD/07/156	558180	*C. indica*	Memang narang	56.67 ±9.28	35.43 ±1.20	43.87 ±0.09	1.20 ±0.78	2.29 ±0.45	10.67 ±0.33	6.37 ±0.37	43.00 ±7.23	2.08 ±0.18
MD/07/159	558183	*C. indica*	Memang narang	51.67 ±1.67	35.50 ±0.17	32.23 ±0.09	1.10 ±0.05	2.00 ±0.08	8.33 ±0.33	6.13 ±0.58	5.00 ±1.00	0.77 ±0.31
MD/07/161	558185	*C. indica*	Memang narang	60.34 ±1.03	37.57 ±0.23	33.60 ±0.06	1.10 ±0.09	2.10 ±0.86	9.33 ±0.33	6.40 ±0.20	5.67 ±2.67	2.07 ±2.07
MS-14	587027	*C. latipes*	Soh-kymphor	230.00 ±0.00	80.51 ±5.28	70.00 ±0.47	1.12 ±0.09	8.13 ±0.75	11.00 ±0.18	5.80 ±0.43	43.00 ±0.50	2.36 ±0.80
MS-17	587028	*C. latipes*	Soh-kymphor	233.33 ±3.33	82.01 ±1.50	70.00 ±0.23	1.12 ±0.07	8.09 ±0.04	11.00 ±0.37	5.87 ±0.07	45.67 ±2.67	2.31 ±0.05
MD-11/68	591427	*C. latipes*	Soh-kymphor	388.33 ±9.50	93.20 ±9.85	99.72 ±7.03	2.33 ±0.12	10.16 ±0.10	11.33 ±0.33	10.33 ±0.333	53.33 ±3.33	2.36 ±0.12
MD-11/70	591429	*C. latipes*	Soh-kymphor	336.67 ±7.50	89.77 ±2.75	86.34 ±3.13	1.77 ±0.14	9.25 ±0.39	10.00 ±0.00	6.83 ±0.44	38.67 ±5.50	4.12 ±0.33
MDY-60	395391	*C. macroptera*	Satkara	280.67 ±1.67	67.17 ±0.44	69.13 ±0.23	1.13 ±0.03	8.13 ±0.65	14.33 ±0.33	4.00 ±0.48	7.67 ±1.45	2.36 ±0.09
MD/07/137	558161	*C. macroptera*	Chambal	238.33 ±6.50	88.00 ±0.57	97.33 ±0.167	1.23 ±0.03	10.00 ±0.10	13.33 ±0.88	7.56 ±0.28	14.00 ±2.64	2.01 ±0.04
MD/07/160	558184	*C. macroptera*	Chambal	246.66 ±8.50	100.67 ±2.90	106.66 ±0.667	1.300 ±0.00	8.967 ±0.167	15.33 ±1.85	8.30 ±0.10	13.33 ±4.84	2.08 ±0.04
MD-11/101	591460	*C. ichangensis*	Ketsa chüpfü	73.33 ±3.33	48.20 ±0.93	69.27 ±3.08	2.19 ±0.06	4.22 ±0.12	5.33 ±0.33	6.07 ±0.07	12.67 ±2.91	23.33 ±1.67
MD-11/102	591461	*C. ichangensis*	Ketsa chüpfü	82.33 ±7.33	55.17 ±6.75	80.27 ±8.50	2.19 ±2.08	3.24 ±1.28	12.00 ±5.00	4.80 ±4.50	21.00 ±6.50	25.00 ±6.00

8. Related Genera of *Citrus*

8.1 Genetic Resources

***Fortunella japonica* (Thunb.) Swingle**

Common name: Kumquat, Candy fruit

Description

The plant is an evergreen shrub or small tree, up to 12 ft tall. Branches have numerous branchlets that are thornless or have thorns of lengths varying from under 1 to 5 cm. Leaves are alternate, lanceolate, and small, 3.2-8.6 cm long, acute or rounded at the base, veins evident above, scarcely showing beneath, lower surface pale green, densely glandular-dotted; petioles narrowly winged or margined, articulation present, sometimes not articulated with the leaf blade. Flowers are fragrant and white, solitary or in clusters of up to 4 in the axils. Fruits vary from round to oval or egg-shaped, oval-oblong or round, 1 to 3.5 cm diameter, with a thin peel that ripens to yellow, golden, or reddish-orange, segments 3-7; pulp-vesicles small, fusiform or subglobose, stalked, containing an acid juice; seeds ovate, smooth; cotyledon light green, chalazal cap brown, polyembroynic.

***Poncirus trifoliata* (Lin.) Raf.**

Common name: Trifoliate orange

Description

A small tree profusely branched, spine very sharp, leaves palmately 3-foliolate; terminal leaflet 2.5-5.6 X 1.6-2.5 cm, shallowly crenulate, cuneate at the base, lateral leaflets sessile, petioles 1-2.5 cm, wing 2-3 mm at broadest part, tapering to the base; flowers solitary, sessile, stamens 20 or more (up to 60); filaments free, unequal in length, slender, tapering gradually towards the tips; ovary subglobose, 2 mm diam., pubescent, fruits almost sessile, globose, ovoid or slightly pyriform, 3-5 cm diam., slightly rough surface dull lemon-colored and fragrant when ripe, finely and densely pubescent, peel 6-10 mm thick, with numerous oil glands, seeds ovoid, plump, numerous, light yellowish cotyledons, chalazal cap reddish, polyembryonic.

Citranges [*Poncirus trifoliata* X *Citrus sinensis*]

These are intergeneric hybrids between trifoliate orange (*P. trifoliata*) and sweet orange (*C. sinensis*). The first adequately safeguarded hybrids of *Poncirus* and *Citrus* were made by Swingle in 1897. Some of the Citrange cultivars are troyer, savage, carrizo, etc.

Citrumelos [*Poncirus trifoliata* X *Citrus paradisi*]

Citrumelos are inter-generic hybrids between trifoliate orange (*P. trifoliata*) and grapefruit (*C. paradisi*) and are very similar to citranges. Important cultivar of Citrumelo is scaton.

8.2 Exploration and Collection

Fortunella japonica is cultivated throughout India for their ornamental appeal and rootstock purposes. *P. trifoliata* and its hybrids are found to grow in various field genebanks in different parts of India including Northeastern states. Two accessions of *F. japonica* (Oval kumquat) and 3 accessions of *P. trifoliata* (cultivars: Rubidoux and Pomeroy) were collected from Punjab, Sikkim, Assam and Arunachal Pradesh. Inter-generic hybrids between *Poncirus* and *Citrus*, viz. Citrange, Citrumelo and Citremone were also collected from Citrus field genebanks in Punjab, Rajasthan and Arunachal Pradesh. Passport details of all the collected accession are given in Table 8.1.

8.3 Characterization

Fortunella japonica

Fruits shape varied from oval to spheroid with rounded or truncate apex (Fig. 8.1 A,B; 8.2 A,B). Fruits were orange and yellowish in colour with smooth texture. Seeds were ovoid in shape with green cotyledons and brown chalazal spot. Fruit weight varied from 55.00 to 56.33 gm. TSS value ranged from 7.67 to 9.00 ^{o}B. Seed weight varied from 0.87 to 1.52 gm. Detailed characterization data of qualitative and quantitative traits is given in Table 8.2 and 8.3.

Poncirus trifoliata

Fruit shape varied from pyriform to spheroid with truncate or rounded apex (Fig. 8.2 F). Fruits were yellowish or orange in colour with pitted rough or smooth surface. Seed shape varied from ovoid to spheroid, with yellowish creamish or greenish cotyledons and reddish brown or purple chalazal spot colour. Fruit weight varied from 57.19 to 62.67 gm. TSS value ranged from 10.50 to

Table 8.1. Passport data of other related genus of Citrus (*Fortunella japonica*, *Poncirus trifoliata* and its hybrids) collected from different parts of India

S. No.	Collector Number	IC No.	Botanical Name	Common/Vern. /Cult. Name	Biological status	District	State	Lati-tude	Longi-tude
1	MDY-75	395403	*Fortunella japonica*	Kumquat	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
2	KARHMD-10/41	586989	*Fortunella japonica*	Kumquat	Cultivated	East Sikkim	Sikkim	27.34	88.62
3	MDY-73	311345	*Poncirus trifoliata*	Pomeroy	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
4	MDY-74	395402	*Poncirus trifoliata*	Rubidoux	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
5	MD-09-13	583256	*Poncirus trifoliata*	Trifoliate Orange	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
6	MD-11/44	591402	*Poncirus trifoliata*	Rubidoux	Cultivated	Tinsukia	Assam	27.31	95.21
7	MDY-55	395386	*P. trifoliata x C. sinensis*	Troyer citrange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
8	MDY-56	395387	*P. trifoliata x C. sinensis*	Savage citrange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
9	MDY-66	395396	*P. trifoliata x C. sinensis*	Yamma citrange	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
10	MDY-69	395398	*P. trifoliata x C. sinensis*	Citrumelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
11	MD-433	470348	*P. trifoliata x C. sinensis*	Carizo citrange	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
12	MD-451	470364	*P. trifoliata x C. sinensis*	Carizzo Citrange	Cultivated	Sri Ganganagar	Rajasthan	29.91	73.87
13	MD-11/42	591400	*P. trifoliata x C. sinensis*	Troyer citrange	Cultivated	Tinsukia	Assam	27.31	95.21
14	MD-11/43	591401	*P. trifoliata x C. sinensis*	Troyer citrange	Cultivated	Tinsukia	Assam	27.31	95.21
15	MD-09-11	583254	*P. trifoliata x C. sinensis*	Citrange	Cultivated	Upper Subansiri	Arunachal Pradesh	27.56	94.20
16	MDY-51	395382	*P. trifoliata x C. paradisi*	Scaton citrumelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
17	MDY-59	395390	*P. trifoliata x C. paradisi*	Citrumelo	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22
18	MD-434	470349	*P. trifoliata x C. paradisi*	Citrumelo	Cultivated	Sri Ganganagar	Rajasthan	29.93	73.86
19	MDY-70	395399	*P. trifoliata x C. limon*	Citrimone	Cultivated	Abohar (Ferozpur)	Punjab	30.21	74.22

11.00 °B and seed weight varied from 1.81 to 2.42 gm. Detailed characterization data of qualitative and quantitative traits is given in Table 8.2 and 8.3, and Natural habit of the trifoliate orange trees are shown in Fig. 8.1 C-F).

Citrange (*P. trifoliata* x *C. sinensis*)

Fruit shape varied from ellipsoid to spheroid with rounded and truncate apex (Fig. 8.2 C,D). Fruits were green, yellow and orange in colour with pitted, rough and smooth texture. Seeds were clavate to ovoid in shape with white, creamish and yellowish cotyledons and brown, creamish and reddish chalazal spot. Fruit weight varied from 53.33 (IC591401) to 246.66 gm (IC395396). TSS value ranged from 6.60 to 12.33 °B. Seed weight varied from 1.28 to 2.81 gm. Detailed characterization data of qualitative and quantitative traits are given in Table 8.2 and 8.3.

Citrumelo (*P. trifoliata* x *C. paradisi*)

Fruits were pyriform to spheroid in shape with rounded apex (Fig. 8.2E). Fruits were yellow and orange in colour with smooth surface texture. Seeds were semi-deltoid to ovoid in shape with light greenish to light yellow cotyledon and purple or reddish chalazal spot. Fruit weight varied from 36.92 (IC395382) to 117.86 gm (IC395398). TSS value ranged from 3.00 to 7.87 °B. Seed weight varied from 1.27 to 2.43 gm. Detailed characterization data of qualitative and quantitative traits are given in Table 8.2 and 8.3.

Citremone (*P. trifoliata* x *C. limon*)

Fruits were spheroid in shape with mammiform apex, deep yellowish in colour and smooth texture. Seeds were clavate in shape with light green cotyledons and purple chalazal spot. Fruit weight was 190.60 gm with 7.63°B TSS value and seeds weight was recorded as 8.53 gm. Detailed characterization data of qualitative and quantitative traits are given in Table 8.2 and 8.3.

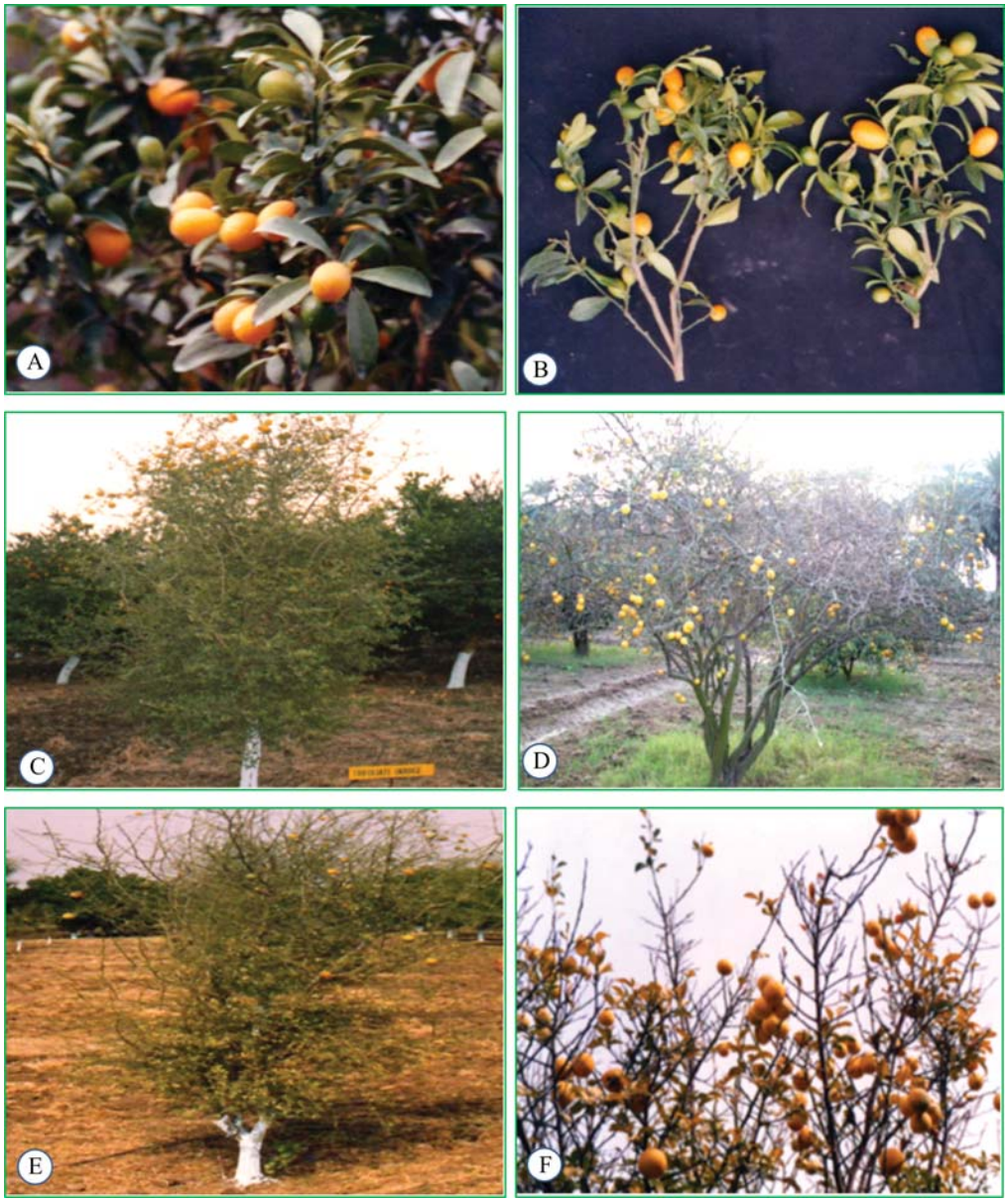

Fig. 8.1. Phenotypic variability in indigenous and exotic cultivars of *Fortunella japonica* and *Poncirus trifoliata* collected from different parts of India, (A, B) *F. japonica* (Oval Kumquat) from Sikkim, (C) *P. trifoliata* (Trifoliate orange) from NRCC, Nagpur, Maharashtra; (D) Pomeroy from PAU, RS, Abohar, Punjab; (E, F) Trifoliate orange from NRCC, Nagpur, Maharashtra

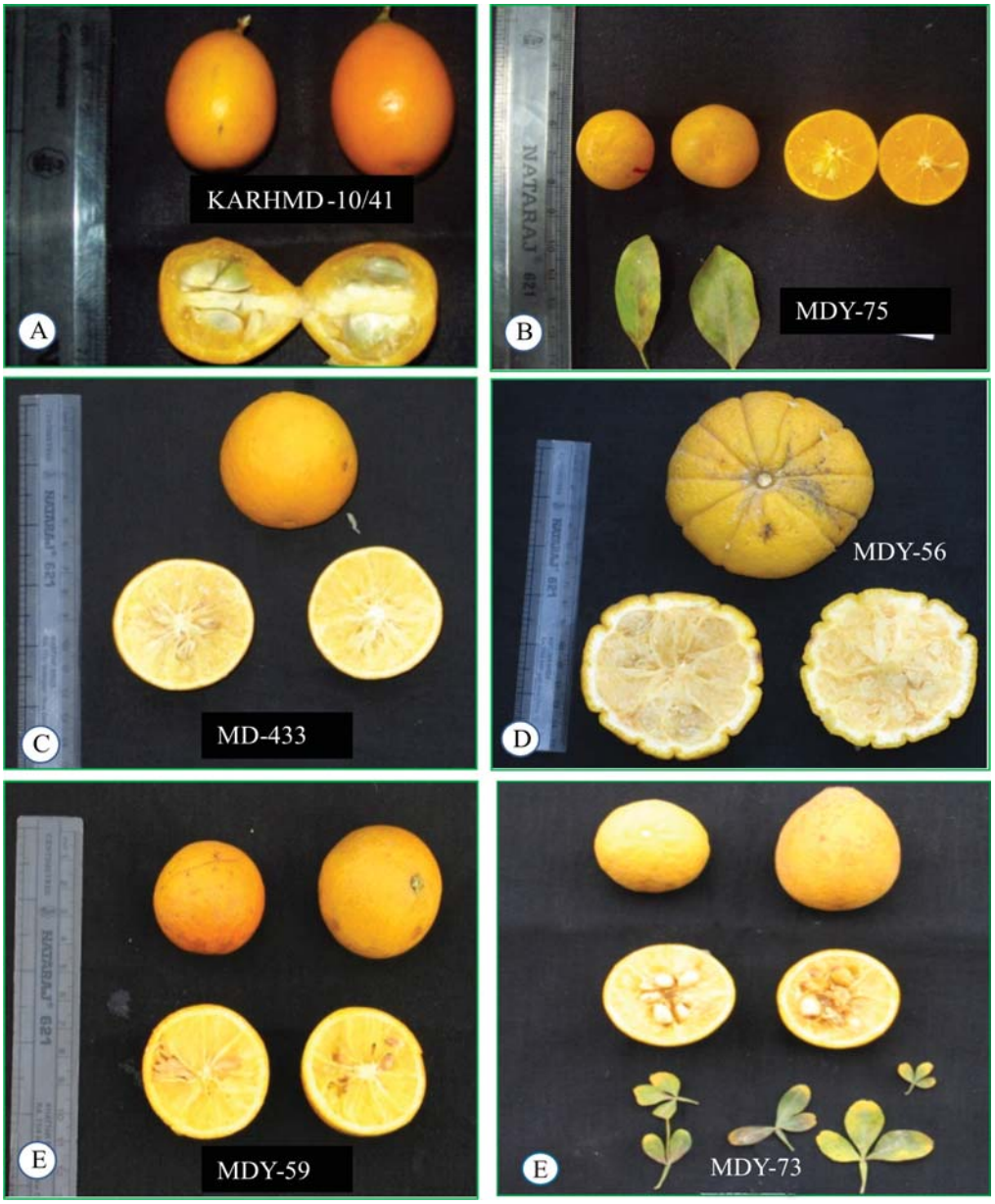

Fig. 8.2. Phenotypic variability in indigenous and exotic cultivars of *Fortunella japonica, Poncirus trifoliata* and its hybrids collected from different parts of India, (A) KARHMD-10/41, Oval Kumquat from Sikkim; (B) MDY-75, Kumquat from Punjab; (C) MD-433, Carrizo citrange from collected from Rajasthan; (D) MDY-56, Savage citrange collected from Punjab; (E) MDY-59, Citrumelo from Punjab; (F) MDY-73, Pomeroy from Punjab

Table 8.2. Qualitative parameters of *Fortunella japonica, Poncirus trifoliata* and its hybrids

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit shape	Shape of fruit apex	Fruit colour	Fruit surface texture	Adherence of albedo to pulp	Seed shape	Colour of coty-ledons	Chalazal spot colour
MDY-75	395403	*F. japonica*	Kumquat	Spheroid	Truncate	Orange	Smooth	Weak	Ovoid	Green	Brown
KARHMD-10/41	586989	*F. japonica*	Kumquat	Ellipsoid	Truncate	Yellow	Smooth	Weak	Ovoid	Green	Light brown
MDY-74	395402	*P. trifoliata*	Rubidoux	Spheroid	Truncate	Yellow	Pitted	Medium	Ovoid	Yellow	Reddish
MD-11/44	591402	*P. trifoliata*	Rubidoux	Spheroid	Round	Orange	Rough	Strong	Spheroid	Cream	Brown
MDY-73	311345	*P. trifoliata*	Pomeroy	Pyriform	Rounded	Dark yellow	Rough	Strong	Spheroid	Yellow	Purple
MDY-55	395386	*P. trifoliata* x *C. sinensis*	Troyer citrange	Spheroid	Rounded	Dark orange	Smooth	Medium	Ovoid	White	Brown
MDY-56	395387	*P. trifoliata* x *C. sinensis*	Savage citrange	Spheroid	Truncate	Green	Pitted	Medium	Ovoid	Light yellow	Reddish
MDY-66	395396	*P. trifoliata* x *C. sinensis*	Yamma citrange	Ellipsoid	Rounded	Yellow	Smooth	Strong	Ovoid	Light yellow	Cream
MD-433	470348	*P. trifoliata* x *C. sinensis*	Carizo citrange	Spheroid	Rounded	Orange	Smooth	Strong	Ovoid	White	Reddish
MD-11/42	591400	*P. trifoliata* x *C. sinensis*	Troyer citrange	Spheroid	Round	Orange	Rough	Strong	Clavate	Cream	Light brown
MD-11/43	591401	*P. trifoliata* x *C. sinensis*	Troyer citrange	Spheroid	Round	Yellow	Rough	Medium	Ovoid	White	Brown
MDY-69	395398	*P. trifoliata* x *C. sinensis*	Citrange	Spheroid	Rounded	Orange yellow	Smooth	Strong	Ovoid	Light green	Raddish
MDY-51	395382	*P. trifoliata* x *C. paradisi*	Scaton citrumelo	Pyriform	Rounded	Yellow	Smooth	Strong	Ovoid	Light yellow	Purple
MDY-59	395390	*P. trifoliata* x *C. paradisi*	Citrumelo	Pyriform	Rounded	Dark yellow	Smooth	Medium	Ovoid	Light yellow	Cream
MD-434	470349	*P. trifoliata* x	Citrumelo	Spheroid	Rounded	Dark yellow	Smooth	Strong	Semi-deltoid	Light yellow	Reddish
MDY-70	395399	*P. trifoliata* x *C. limon*	Citremone	Spheroid	Mammiform	Deep yellow	Smooth	Strong	Clavate	Light green	Purple

Table 8.3. Quantitative parameters of *Fortunella japonica, Poncirus trifoliata* and its hybrids

Coll. No.	IC No.	Species Name	Common/Vern. /Cult. Name	Fruit weight (gm)	Fruit diameter (mm)	Fruit length (mm)	Width of epicarp at equatorial area (mm)	Fruit rind thick-ness (mm)	No. of segments per fruit	TSS (°B)	No. of seed/ fruit	10 Seed wt. (gm)
MDY-75	395403	*F. japonica*	Kumquat	55.00 ±4.08	36.47 ±1.73	32.65 ±1.35	1.57 ±0.03	1.20 ±0.00	8.00 ±0.00	9.00 ±0.00	3.67 ±0.33	0.87 ±0.00
KARHMD-10/41	586989	*F. japonica*	Kumquat	56.33 ±0.88	33.58 ±0.39	36.27 ±0.46	1.70 ±0.06	3.02 ±0.75	5.00 ±0.00	7.67 ±0.33	11.33 ±0.67	1.52 ±0.00
MDY-74	395402	*Poncirus trifoliata*	Rubidoux	57.19 ±3.84	43.97 ±0.18	44.10 ±0.32	1.07 ±0.12	1.23 ±0.15	7.33 ±0.33	10.87 ±0.07	11.00 ±7.51	2.16 ±0.01
MD-11/44	591402	*Poncirus trifoliata*	Rubidoux	62.67 ±1.67	47.97 ±0.02	49.47 ±0.72	1.94 ±0.06	4.70 ±0.02	6.00 ±0.00	10.50 ±0.29	22.33 ±2.33	1.81 ±0.20
MDY-73	311345	*Poncirus trifoliata*	Pomeroy	61.67 ±1.67	43.51 ±0.45	45.29 ±0.53	1.00 ±0.00	1.53 ±0.03	6.00 ±0.00	11.00 ±0.00	8.33 ±0.67	2.42 ±0.00
MDY-55	395386	*P. trifoliata* x *C. sinensis*	Troyer citrange	105.47 ±6.65	58.01 ±1.21	58.46 ±0.80	1.47 ±0.18	2.41 ±0.22	9.33 ±0.33	8.13 ±0.07	9.00 ±1.73	1.56 ±0.16
MDY-56	395387	*P. trifoliata* x *C. sinensis*	Savage citrange	222.83 ±5.50	83.57 ±2.67	72.00 ±1.52	2.39 ±0.14	3.23 ±0.31	11.00 ±0.58	6.60 ±0.31	11.67 ±3.48	2.81 ±0.13
MDY-66	395396	*P. trifoliata* x *C. sinensis*	Yamma citrange	246.66 ±7.50	57.50 ±0.24	62.50 ±0.20	1.66 ±0.33	3.66 ±0.33	9.50 ±0.40	9.93 ±0.13	4.33 ±1.45	1.28 ±0.02
MD-433	470348	*P. trifoliata* x *C. sinensis*	Carizo citrange	80.47 ±9.92	53.09 ±2.20	54.53 ±1.39	1.77 ±0.12	2.60 ±0.54	7.67 ±0.33	9.93 ±0.13	4.33 ±1.45	1.68 ±0.03
MD-11/42	591400	*P. trifoliata* x *C. sinensis*	Troyer citrange	113.33 ±5.50	76.82 ±5.23	77.23 ±5.23	1.54 ±0.10	4.81 ±0.08	10.00 ±0.00	9.00 ±0.00	14.00 ±1.53	2.06 ±0.03
MD-11/43	591401	*P. trifoliata* x *C. sinensis*	Troyer citrange	53.33 ±3.33	44.83 ±0.50	44.95 ±1.62	1.08 ±0.02	2.83 ±0.09	6.00 ±0.00	12.33 ±0.17	0.00 ±0.00	2.14 ±0.29
MDY-69	395398	*P. trifoliata* x *C. sinensis*	Citrange	117.86 ±6.75	71.67 ±0.41	76.67 ±0.384	2.00 ±0.00	3.67 ±0.33	9.33 ±0.33	3.00 ±0.00	8.67 ±0.67	2.43 ±0.05

MDY-51	395382	*P. trifoliata* x *C. paradisi*	Scaton citrumelo	36.92 ±6.12	48.87 ±0.23	52.13 ±0.09	1.10 ±0.06	2.47 ±0.25	8.67 ±0.33	3.00 ±0.00	10.00 ±1.15	2.10 ±0.07
MDY-59	395390	*P. trifoliata* x *C. paradisi*	Citrumelo	97.57 ±3.72	62.00 ±0.00	67.00 ±0.00	2.00 ±0.00	3.67 ±0.33	8.00 ±0.00	4.00 ±0.00	8.67 ±0.67	1.27 ±0.05
MD-434	470349	*P. trifoliata* x *C. paradisi*	Citrumelo	113.24 ±6.65	57.27 ±0.78	59.68 ±2.08	1.12 ±0.03	1.76 ±0.04	9.00 ±0.58	7.87 ±0.07	8.67 ±0.67	1.77 ±0.08
MDY-70	395399	*P. trifoliata* x *C. limon*	Citremone	190.60 ±6.50	72.60 ±1.78	66.50 ±0.58	2.27 ±0.03	3.47 ±0.03	13.33 ±0.33	7.83 ±0.60	14.00 ±6.24	8.53 ±7.74

9. Future Perspective

Erosion of genetic resources of *Citrus* due to various biotic and abiotic factors has resulted in loss of gene pools from nature and as well as from different centers of collections in India and abroad. Northeast India, rich in Citrus genetic diversity, represents several natural wild species namely *Citrus indica*, *C. macroptera*, *C. ichangensis, C. latipes*, *C. megaloxycarpa* and *C. assamensis* and commercially cultivated species. These species indicate interesting domestication trends leading to "*in situ*" and "*in situ* on-farm" conservation due to their cultural and economic significance. These species have great potential in improvement of Indian Citrus industry being a source of genes for biotic and abiotic stresses. However, alarming loss of diversity from its natural habitat of Northeastern India and other areas due to large scale deforestation, urbanization, developmental activities and practice of Jhum cultivation or shifting cultivation especially in Northeastern India which is socio-economically neglected area till now, needs attention for rectification.

Management of genetic resources of vast and diverse genus like *Citrus* need appropriate planning for genetic resources management and complementarities of conservation approaches. All the activities related to genetic resources management viz. collection of germplasm, appropriate characterization of collected germplasm, conservation and utilization are required to be undertaken as a mission mode programme for Indian Citrus germplasm. Collection of germplasm of diverse species and local cultivars from various natural habitats/ sites, farmers' orchards and field genebanks need to be undertaken and characterized. Various conservation approaches presently being used for Citrus genetic resources discussed in detail in earlier chapters need to be strengthened. As far as conservation of genetic diversity of citrus is concerned, both *in situ* and *ex situ* approaches should be used in complementarity. The pattern of market value led domestication by stakeholders greatly helping the valuable plant species (*C. indica* and *C. macroptera*) to be protected or restored and eventually being conserved in dynamic *in situ* "on farm" conservation mode in their respective habitats, while species (*C. megaloxycarpa* and *C. ichangensis*) with no socio-economic value are slowly diminishing from its natural habitat and ecosystem.

Future Perspective

Till the appropriate steps and planning for *in situ* conservation are taken, the field genebank conservation and cryopreservation of seeds, embryo, embryonic axes of germplasm in the cryogenebank are the best options. Presence of high degree of polyembryony in many *Citrus* species provides the opportunity of conserving germplasm in the form of seeds without any risk of genetic instability. However, seeds of many *Citrus* species display recalcitrant or intermediate storage behaviour and, therefore, cannot be stored using conventional –20^{O}C storage methods. Cryopreservation has been extensively used for long-term conservation of such species using a range of explants like zygotic embryo, embryonic axis, shoot apex, cell suspension and somatic embryo. Appropriate designing of cryoprotocols for applying these techniques on large scale are required to be taken up.

Ex situ conservation of Citrus in the field genebanks need immediate infrastructure requirement and diversification as all the old field genebanks established during last 6-7 decades have already declined or are at the verge of decline. Several important collections have totally vanished from several sites and some need immediate rejuvenation. Citrus plants suffering from the problems of several insect pests, fungal, bacterial and viral diseases necessitates establishment of an alternate field conservation sites in a diverse country like India to ensure duplicate collections at 'off sites'. Field collections are to be replicated in Regional Field Genebanks to be established in the different edapho-climatic zones with all modern facilities and sufficient man power which is presently lacking in existing Citrus field genebanks. At least four Regional Field Repositories of Citrus need to be established spreading in Northeast, Northwest, Central and Southern parts of India. Northwest zone is the best suited for the field genebank conservation as proved by the performance of existing field genebank at Regional Research Station, Abohar where Citrus germplasm has been safer in comparison to other parts of India as far as disease symptoms and dieback of plants is concerned.

Establishment of gene sanctuaries and on-farm conservation are the suitable approaches for *in situ* conservation while for *ex situ* conservation suitable approaches are field genebank and cryogenebank. To protect these invaluable genetic resources of citrus, citrus gene sanctuary established in 1981 in the Garo hills of Meghalaya was a unique commendable effort. This unique citrus gene sanctuary, probably first of its kind in the World for fruits, is endowed with highly specified microclimate with a combination of tropical and mild temperate seasons and experiencing very high humidity and rainfall. Gene sanctuary is a

part of buffer zone of Nokrek Biosphere Reserve and spreads over the east, west and south Garo hills of Meghalaya. *Citrus* species growing inside the gene sanctuary are still safe, however, the slow regeneration of these species and increasing human intervention around the gene sanctuary area are the causes of serious concern. This Citrus gene sanctuary needs to be further strengthened by taking appropriate steps at ground level by designating that area as "Heritage Site" and also establishing a "Citrus Gene Park" near to this area. It is highly essential as due to lot of interventions and developmental activities, human interference and increased tourism activities in this natural forest area damage to the plant species naturalized in this area is inevitable. Such a trend has been recently exemplified in a comprehensive data set generated for 60 protected areas of the World studied, in which 3 sites were chosen from India (Laurance *et al*., 2012).

Various conservation strategies presently being used for plant genetic resources and specifically for Citrus genetic diversity are both *in situ* and *ex situ* approaches. In the present scenario most appropriate strategy for Citrus germplasm conservation is to adopt immediate *ex situ* conservation (i.e. field genebank and cryogenebanking) complemented with *in situ* conservation (*In situ* on-farm conservation, gene sanctuary and National Parks) for wild and semi-wild species of *Citrus*. Bioprospecting for confirmation of medicinal and nutritional traits in these Citrus genotypes would aid in their utilization in citrus industry leading to economic gains. Use of modern biotechnological tools would further enhance the possibilities of utilizing rare genes to mitigate the challenges of climate change and all biotic and abiotic stresses associated with it. Taxonomic studies based on molecular tools have advanced and have resolved controversies in Citrus classification. Several Citrus hybrids observed in authors studies once subjected to molecular techniques would generate more scientific data and add to our knowledge on current genetic diversity available for use in India.

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WILD AND SEMI-WILD SPECIES OF CITRUS IN INDIA

C. medica

C. indica

C. assamensis

C. ichangensis

C. macroptera

C. latipes

C. megaloxycarpa