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REVIEW ARTICLES

RESEARCH ARTICLES

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Review Article

Seventy five years of research and development in genetic resources of horticultural crops

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ABSTRACT

Horticulture Genetic Resources (HGR) include gene pool of fruits, vegetables, spices and condiments, medicinal and aromatic plants and several commercial crops and their wild and weedy relatives and well-adapted introduced crop plants from time to time. During last 75 years genetic resources management of horticultural crops has made unprecedented progress both in developing infrastructure for conservation in the field and laboratory. Several new field genebanks have been established by the crop-based institutes and State Agricultural Universities to conserve and utilize the germplasm. Several new in vitro and cryopreservation protocols have been developed to conserve indigenous horticultural crops through research and developmental efforts of scientists.

Keywords: Characterization, Conservation, Evaluation, Germplasm, Horticulture

INTRODUCTION

This horticulture diversity, including neglected and underutilized species, is the key to achieve food and nutritional security throughout the globe. Indian gene center is a store house for a number of wild and weedy relatives of horticultural crops. Horticultural food basket is enriched with a variety of crops for different climatic and edaphic conditions. Wild relatives are incredible genetic resources carrying several desirable attributes like resistance to biotic and abiotic stresses that are generally lacking in the cultivated allies. A total of 326 wild relatives in different crops including cereals and millets (51), legumes (31), fruits (109), vegetables (54), fiber plants (24), spices and condiments (27), miscellaneous crops (26) have been reported from India (Arora and Nayar, 1984). As far as fruits are concerned Southeast Asia is represented by more than 500 species of fruits (Arora and Ramanatha Rao, 1995), while the Hindustani region of diversity represents 344 species of fruits having vast potential for new crops (Arora, 1995). Fruits exhibit vast diversity in size, shape, colour, taste, quality and habitat. Many of these fruit species have been domesticated since time immemorial and now in vast commercial use providing nutritional and food security to vast populations of south Asia. Vast genetic diversity of major and minor fruits present in natural wild and in the farmers, field required protection for posterity and use for developing new varieties.

Plant genetic resources are the building blocks of any crop improvement programme and keeping this in mind major emphasis has been given to explore, characterize, evaluate and conserve the indigenous and exotic genetic resources to bring out superior genotypes and varieties to enhance production, productivity and quality of horticultural commodities. India is endowed with a rich genetic diversity of fruits and vegetables. 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 4.74 m ha out of the total area of 6.80 m ha under fruit crops and account for 81 percent of the total annual fruit production (DAC&FW website, 2021). Presently India is second largest producer of fruits and vegetables and expected to produce about 330 million tons of horticultural production in the year 2020-21 (DAC&FW, website, 2021). This has been possible due to the major initiatives taken by the Indian Council of Agricultural Research (ICAR) during last 75 years to establish various research institutes to undertake research and development activities in the area of germplasm management and crop improvement in diverse horticultural crops (Table 1). Most of the infrastructure in the form of research intuitions and crop-based germplasm management activities have been initiated during last 75 years which is incredible and brought India to the forefront as far as genetic resources management in concerned. During this period several field genebanks for major and minor fruits have been established and germplasm collections of vegetables and other horticultural commodities have been established as per the mandated crops mentioned in the Table 1.

Table 1: HGR in various organization/research centers

S.No.	Institution/ Research Centre	Established Year	Genetic resources
1.	Central Coffee Research Institute (CCRI), Balehonnur	1925	Coffee
2.	ICAR-National Bureau of Plant Genetics Resources, New Delhi	Plant Introduction and Exploration (1946) in Botany Division of IARI, Plant Introduction and Exploration Organization' in the Botany Division (1956), National Bureau of Plant Introduction (August 1976), NBPGR (January 1977).	Fruit and nuts, Vegetables, Spices and condiments, Medicinal and aromatic plants, Tuber crops, floriculture crops etc.
3.	ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur, Rajasthan	Desert Afforestation Station(1952) later expanded into Desert Afforestation and Soil Conservation Station (1957) upgraded to CAZRI (1959)	Bael, Karonda, Guava, Lemon, Pomegranate, Ber, Chilli, Cumin etc.
4.	ICAR-Central Potato Research Institute, Shimla	1956	Potato
5.	CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow	1959 .	Isabgol, Kalmegh, Palmarosa, Pyrethrum, Satawar, Senna, Tulsi, Ashwagandha, Stevia, Patchouli, Brahmi, Geranium etc
6.	ICAR- Indian Institute of Oil Palm Research, Pedavegi, West Godawari	OPRS (1960), CPCRI, Research Centre(1975), AICRP on Palm(1992), NRCOP(1995), Merge of CPCRI, and NRCOP(1999), Redesigned DOPR (2009), IIOP(2014)	Oil Palm
7.	ICAR-Central Tuber Crops Research Institute, Trivandrum	1963	Cassava, Sweet potato, Lesser yam, White Yam, Taro, Amorphophallus, Coleus etc.
8.	ICAR-Indian Institute of Horticultural Research, Bengaluru	1967	Mango, Citrus, Custard apple, Papaya, Guava, Chilli, Bottle gourd, Spine gourd, Coriander, Amaranth, Onion, Garden pea etc.
9.	ICAR-Central Plantation Crop Research Institute(CPCRI), Kasargod, Kerala	1970	Coconut, Cocoa, Arecanut, Oil palm etc.
10.	ICAR-Central Institute for Subtropical Horticulture (CISH), Lucknow, U.P.	CMRS(1972), CIH for North plains (1984), CISH(1995)	Mango, Guava, Jamun etc.
11.	ICAR-Indian Institute of Spices Research (IISR), Kozhikode, Kerala	1975	Black Pepper, Cardamom, Turmeric, Ginger, Clove, Nutmeg, Cinnamon, Kokum, tamarind etc.
12.	ICAR-Central Citrus Research Institute, Nagpur, Maharashtra	1985	Citrus
13.	ICAR-Directorate of Cashew Research, Puttur	1986	Cashew Nut
14.	Central Institute for Arid Horticulture, Bikaner (CIAH), Bikaner, Rajasthan	NRCAH(1990), CIAH(2000)	Ber, Custard apple, Aonla, Tamarind, Bael, Wood apple, arid vegetables etc.
15.	ICAR-Directorate of Medicinal and Aromatic Plants Research, Anand	1992	Ashwagandha, Brahmi, Chirayita, Giloe, Guggal, Kalmegh, Mentha, Sarpgandha, Safedmusli, Shatavari, Vativer etc.
16.	ICAR-National Research Centre for Banana, Trichy	1993	Banana
17.	ICAR-Central Institute for Temperate Horticulture, Srinagar	1994 at Lucknow now shifted to Srinagar (J&K) 1997	Apple, pear, peach, plum, apricot, almond, walnut, cherry, kiwifruit and olive
18.	ICAR-Directorate on Onion and Garlic Research, Pune	1994	Onion and Garlic
19.	ICAR-National Research Centre on Orchids, Pakyong, Sikkim	1996	Orchid
20.	ICAR-National Research Centre for Grape, Manjri , Pune, Maharashtra	1997	Grape
21.	ICAR-Indian Institute of Vegetable Research	1999	Tomato, Brinjal, Okra, Raddish, Carrot, Chilli, Cauliflower,

S.No.	Institution/ Research Centre	Established Year	Genetic resources
	(IIVR), Varanasi, U.P.		Cucurbits etc.
22.	ICAR-National Research Centre on Seed Spices, Ajmer	2000	Cumin, Ajwain, Coriander, Fennel, Dill, Celery, Aniseed, Fenugreek, Caraway, Nigella etc.
23.	ICAR-National Research Centre on Litchi, Mujaffarpur, Bihar	2001	Litchi, Citrus
24.	ICAR-National Research Centre on Pomegranate, Solapur	2005	Pomegranate
25.	ICAR-Directorate of Floricultural Research, Pune, Maharashtra	2009	Tuberose, Chrysanthemum, Gladiolus etc

History of PGR Management

The collection, conservation and utilization of economic plants has been of great interest to Indian/British scientists and explorers and this dates back to the early decades of twentieth century (Howard and Howard, 1910). Several botanical missions have been undertaken in the different parts of India and botanical flora of economic plants/ products had been recorded and published (Hooker, 1872-97; Watt, 1889-93). However, PGR management in pre-independent India was a small key affair. There was a meagre infrastructure and priority to manage indigenous/ exotic genetic resources. However, it was the vision of late Dr. B.P. Pal who really paid emphasis on the use of plant germplasm and existing genetic variability for the improvement of crop plants in India. His classical publication, "The search for new genes", showed the way for collection and use of genetic diversity (Pal, 1937; Pal and Singh, 1943). Due to the initiatives and vision of Dr Pal in 1946 Plant Exploration and Collection Unit was established in the Division of Botany at the Indian Agricultural Research Institute, New Delhi. This Unit elevated to the regular wing in 1956 and gained the status of a Division of Plant Introduction in 1961. The late Dr. Harbhajan Singh, Dr Hardas, Dr. M.S. Swaminathan and Dr. A.B. Joshi significantly contributed to strengthen the activities of plant genetic resources collection and utilization in India during this period. The Indian Council of Agricultural Research created a separate institute "National Bureau of Plant Genetic Resources (NBPGR)" in 1976 to manage and facilitate the need of germplasm for various breeders. Since then, ICAR-NBPGR is systematically managing the Indian PGR along with other ICAR institutes and State Agricultural Universities under the umbrella of Indian Plant Genetic Resources Management System (IN-PGRS). It is to mention here that PGR management activities in some of the horticultural crops like coconut, mango, citrus and other temperate fruits crops and vegetables were being undertaken by several State (Presidencies) Departments and institutions even before 1947. Since its inception in 1976, ICAR-NBPGR has actively undertaken genetic resources management activities of agri-horticultural crops which has benefited in bringing out various new cultivars and varieties. This led to the diversification of horticultural crops to even non-traditional areas greatly benefiting the Indian farmers and consumers.

Major emphasis of NBPGR during these years remained on germplasm exploration, introduction from indigenous and exotic sources, characterization and evaluation of germplasm, ex situ conservation and providing germplasm to breeders for crop improvement purposes.

PGR Management Activities Undertaken During last 75 years

During last 75 years tremendous progress has been made in each and every field of genetic resources management of horticultural crops in India. In the present review achievements made by ICAR-NBPGR and SAU's during this period have been briefly highlighted based on published ;literature and also the information available on websites of respective institutions.

Germplasm Exchange

In India ICAR-NBPGR being the nodal agency for germplasm exchange and quarantine, several important introductions of fruits, vegetables and other horticultural species have been made in India from different parts of the World. Since, 1976 more than four lakh samples have been supplied to researchers/users for utilization in various research programmes of National Agricultural Research System. Some of these introductions of fruits and vegetables have been directly popularized for large scale cultivation and gained significant importance in India. Introductions made in especially temperate fruits, Citrus, temperate vegetables and ornamentals have substantially benefited the farmers of some states and added to the diversification of horticulture and production of fruits and vegetables. Some specific examples in fruits like Red Delicious group of cultivars in apple, Barlett pear, Elberta peach, Santa Rosa plum, Loose Perlette and Thompson Seedless grapes, Red Blood Malta, Valenacia Orange, Jaffa and Kinnow mandarin are important introduction made by NBPGR (ICAR) which has largely benefited Indian farmers and increased substantial fruit production in India.

In vegetables prominent introductions like Copenhagen Market and Golden Acre cabbage, Erfut-Alfa and Snowball groups of cauliflower, Green sprouting broccoli, Early Grano of Onion, Sioux of tomato and Poinsette of cucumber, All Green spinach and Sugar Baby of water melon have gained large popularity among farmers. Many introductions in vegetables have been used as parents to improve and develop new varieties of Indian vegetables. Similarly, several rootstocks have been introduced from USA and other countries for improvement and developing biotic and abiotic resistance in fruits especially Citrus and temperate fruits. Several new introductions which contributed largely to Indian Horticulture directly or helped in development of varieties are presented in table (2) below:

Table 2: Germplasm Introductions from International Agriculture Research Centers (IARCs) and other Organizations

Crop Group	Varieties/Cultivars
Fruits	Kiwi fruit (Alison), Peach (Stanford, Flordasun), Pear (Flemish Beauty, Manning Elizabeth), Apple (Tropical Beauty), Pecan nut (Mahan), Seedless Pome granate (Anar Bedana), Seabuckthorn from Russia (EC468632), Japanese plum fruit (EC538999) from USA, buffalo gourd (USA), Bull oke (Australia), Prickly pear (Mexico & USA)
Vegetables	Guar (Naveen), Field pea (Harbhajan),Winged bean (AKWB-1), Vegetable Amaranth (Pusa Chaulai), French bean (Kentuky Wonder and Contender, Cowpea (Rituraj), Vegetable guar (Pusa Nav Bahar and Sharad Bahar), Onion (Pusa red and Pusa Ratnar), Pea (Bonneville), Tomato (Pusa Ruby and Pusa early Dwarf), Okra (Pusa Sawani), Spinach (Pusa Palak), Radish (Japanese White) and Sugarbeet. Important Varieties released as direct selections: Pea (Early Badger), Cowpea (Assem), Onion (Early Grano), Tomato (La Bonita, Sioux, Pusa Ruby, Pusa Early Dwarf, Fireball)
Other Commercial crops	Mint (EC 41911), Palmarosa (IW31245), Poppy (Trishna), Hops (Tardif-de-Bourgouge and Golden Cluster, Rose scented geranium

Exploration and Collection

India is rich in diversity of horticultural crops, large number of fruits, vegetable, spices, floricultural and medicinal and aromatic plant species are distributed in various phyto-geographical regions of India. NBPGR has taken up several explorations in different parts of India to collect the horticultural germplasm belonging to fruits, vegetables, medicinal and aromatic plants and spices from indigenous sources. Specific focus has been given during last two decade to collect indigenous germplasm of underutilized fruits and other major fruits with vast diversity in India such as Citrus in collaboration with horticultural institutes and State Agricultural Universities to strengthen the germplasm base, conservation and utilization in crop improvement programmes (Malik et al., 2010; 2012). Special emphasis has been given to collect the horticultural germplasm from remote areas in north-eastern, north-western Himalayan region and Western Ghats which were not explored for several rare germplasm existing in these hot-spots of biodiversity. ICAR-NBPGR have collected/ assembled more than 54000 accessions of vegetables, above 14,000 accessions of fruit crops and about 28000 accessions of medicinal and aromatic plants including spices and condiments (Anonymous, 2022). As far as underutilized fruits are concerned various horticultural institutions have collected the germplasm under the All India Coordinated Project on Tropical Fruits with 22 centres covering 11 SAUs and 2 ICAR Institutes and also under the All India Coordinated Project on Arid Fruits with 13 centres of which 10 are located in SAU (s) and 3 are located in ICAR institutes as per their mandated crops. Overall, more than 3000 accessions of underutilized fruits have been collected by various institutions in India and national identity (IC Numbers) have been assigned by the NBPGR since 1976. Similarly, germplasm of 24 mandated vegetables has been collected by crop-based institutes and SAU individually and under the All India Coordinated Project on Vegetables having 29 main centres operational throughout the India.

Characterization and Evaluation

Besides introduction vast indigenous germplasm of horticulture crops have been characterized and evaluated by NBPGR and several promising accessions have been identified which have been registered and utilized in crop improvement programmes. Major emphasis has been given to the indigenous vegetable crops like brinjal, okra and cowpea, tomato, taro, greater yam etc. in fruits banana, Citrus, Kokam, Malabar tamarind, jackfruit and several temperate fruits have been evaluated. Besides morpho-agronomic evaluation several accessions of fruits, vegetable and medicinal and aromatic plants have been evaluated for biochemical traits. Evaluation of germplasm at NBPGR headquarter and its Regional Stations has helped in identifying several promising germplasm accessions for different traits and these have been registered by NBPGR. Presently 63 accessions of vegetables, 32 accessions of fruits and nuts, 48 of medicinal and aromatic plants, 62 of commercial crops, 41 of ornamental plants and 23 of tuber crops have been registered for specific characters by the NBPGR (Table 3).

Table 3: Promising Germplasm of Horticultural Crops Registered by NBPGR

Name of Crop	Trait for which registered
Black Pepper (INGR10065)	Oval shaped berries
Bottle guard (INGR 10064)	Spindle shaped fruit with hard durable rind
Brinjal (INGR 9122 and 9123)	Resistance to bacterial wilt
French Bean (INGR 10026)	Pole type habit, long pod and dual-purpose type
Galangal (INGR 9051)	High 1,8-cineole and alpha fenchyl acetate content
Babchi (INGR 8054)	High psoralen content
Chilli (INGR 8095, 8097)	Resistant to thrips and mites; Resistant to thrips and powdery mildew respectively
Cowpea (INGR 8083, 8084)	Bold seeded type, Resistant to black eye cowpea mosaic virus respectively
Greater Galangal (INGR 8107)	High 1,8-cineole content
Lime (INGR 08098)	Frost tolerant
Meetha Karela (INGR 6020)	Spineless large fruit
Pea (INGR 7048)	Bold seeded
Rose Geranium (INGR 7042)	Better aroma
Tomato (INGR 8094, 8096)	Resistant to root knot nematode
Yam (INGR 8061, 8062, 8063, 8064)	High diosgenin content/ yield
Geranium (INGR 3039)	High aroma
Kokum (Garcinia, INGR 4063)	High yield
Malabar Tamarind (INGR 4061, 4062)	Early bearing with superior yield
Soybean (INGR 1035)	Vegetable type

Conservation

ICAR-NBPGR have given special emphasis to the conservation of horticultural crops using both *ex situ* and *in situ* approaches. Citrus gene sanctuary was set up in the Garo hills of Meghalaya in 1981 to preserve the rare genetic diversity of various *Citrus* species including Indian Wild Orange (*Citrus indica*), which is a rare, endemic and endangered species (Singh, 1981). New chapter in the history of PGR management was written in the last two decades when state of the art National Genebank and a unique multi-crop facility to conserve difficult to store species of vegetative propagated crops and non-orthodox seeds using *ex situ* conservation was established at ICAR-NBPGR. National Gene Bank at ICAR-NBPGR is holding vast diversity of horticulture species germplasm especially vegetables (28,191 accessions), fruits (298 accessions), medicinal and aromatic plants (8645 accessions), spices (3482) and ornamental crops (687) in the form of seeds. As several horticultural species are vegetatively propagated and bear recalcitrant seeds, *in vitro* conservation and cryopreservation methods have been used at Tissue Culture and Cryopreservation Unit of NBPGR. In vitro germplasm accessions are being maintained as proliferating cultures under normal and slow growth conditions. For long term conservation various explants such as shoot apices, meristems, dormant buds, embryos and embryonic axes have been used to cryopreserve the germplasm of tropical and temperate fruits, tuber crops, bulbous crops, medicinal and aromatic plants, spices and industrial crops etc. (Table 4). Comprehensive base collection of indigenous diversity of underutilized fruits, nuts, vegetables, spices and major crops like Citrus and piper germplasm have been established in the Cryogenebank at NBPGR for long-term conservation and utilization (Table 5).

Besides this ICAR-NBPGR has been internationally recognized as the Centre of Excellence for human resources development by Bioversity International and during last two decades more than 500 national and international scientists have been trained in the area of in vitro conservation and cryopreservation.

Table. 4: Status of Horticultural Species Germplasm in *In Vitro* Genebank ICAR-NBPGR (as on Jan' 2022)

Crop Group	Genera (No.)	Species (No.)	Accessions (No.)
Tropical Fruits (banana, Garcinia sp.)	3	14	445
Temperate and Minor Fruits (apple, apricot, blackberry, kiwifruit, pear, strawberry)	9	41	375
Tuber Crops (sweet potato, yam, taro)	5	12	527
Bulbous and other Crops (*Allium* spp., Gladiolus)	4	11	171
Medicinal and Aromatic plants (species of *Rauvolfia*, *Tylophora*, *Picrorhiza*, *Valeriana*)	21	28	185
Spices and Industrial Crops (ginger, turmeric, pepper, cardamom, hops, jojoba)	7	27	227
Total	49	133	1,930

Table: 5: Status of Horticultural Species Germplasm in Cryogenebank ICAR-NBPGR (as on Jan' 2022)

Category	Total accessions
Non-orthodox Seeds	
Fruits and Nuts	3,763
Spices and Condiments	349
Plantation Crops	278
Industrial and Medicinal Plants	1,991
Vegetables	644
Dormant Buds of temperate fruits and mulberry	703
Pollen Grains of mango, litchi and citrus	650
Grand Total	8,378

Field genebanks

Ex situ conservation of fruits is important to safeguard the existing genetic wealth and to provide access to germplasm for the genetic improvement to develop desirable cultivars or varieties. Field gene banks have an important place in conservation and maintenance of clonally propagated species, tree species with long juvenile phase, species which do not produce true-to-type seed, or produce recalcitrant seeds where laboratory conservation technologies have not been standardized so far. Presently, several field gene banks for diverse horticultural plant species are operational throughout the world. In India most of the field gene banks of citrus, mango, banana, guava, mulberry, oil palm and several other fruit species have been established during the last 4-5 decades and are being maintained by the ICAR horticultural institutes, the State Agricultural Universities (SAUs) and by various State Horticulture Stations in different locations (Malik et al., 2016). Germplasm of three major fruits mango, banana and citrus is mainly being maintained at CISH, Lucknow, NRC Banana, Trichy and Central Institute of Citrus Research, Nagpur. For temperate fruits and vegetables CITH, Srinagar is maintaining large germplasm of various fruits representing indigenous and exotic cultivars in the field gene bank.

As far as minor fruits are concerned field gene bank conservation has been undertaken especially under the AICRP on Arid Fruits at various ICAR institutes namely Central Institute of Arid Horticulture, Bikaner, *Central Horticultural Experiment Station, Godhra,* Central Institute of Sub-tropical Horticulture, Lucknow, Central Arid Zone Research Institute, Jodhpur, NBPGR Regional Station, Jodhpur, Indian Institute of Horticulture Research, Bangalore and at State Agricultural Universities namely CCSHAU, Hisar and Regional Station, Bawal, Haryana; MPKV, Rahuri, Maharashtra; GAU, Sardar Krushinagar, Gujarat; SKN College of Agriculture, RAU, Jobner, Rajasthan; MPUAT, Udaipur, Rajasthan; ANDUAT, Faizabad, Uttar Pradesh; RAU, Bikaner, Rajasthan; and other state horticulture stations at Tamil Nadu and Andhra Pradesh and other states. Systematic effort under the "National Network Project on Underutilized Fruits" initiated by Indian Council of Agricultural Research from 2007 to 2011, where promising collections were made and elite germplasm accessions were identified, characterized, established and conserved in the field gene banks of CISH, Lucknow and Central Horticultural Experiment Station, Central Institute of Arid Horticulture, Godhra, Gujarat (Anonymous, 2010, Malik et al., 2010, 2017). Similarly, UNEP funded Tropical Fruits project on Mango, Citrus and Garcinias significantly contributed to the on-farm conservation and utilization of germplasm of indigenous local cultivars through farmers participation. However, there is still need for continued and concerted efforts through such network approaches to manage the vast genetic diversity of these fruits and vegetables in India at various levels. Table 6 provides the elaborated tentative list of germplasm collections existing in the field genebanks and collections made by the various centers during last 75 years.

Table. 6: Tentative status of germplasm of various fruits at various important centers in the FGBs which is established and maintained during last 75 years.

S.No	Institute/ Universities	No. of accessions
	Mango	
1.	CISH, Lucknow	775
2.	CIAH, Bikaner	01
3.	IIHR, Bengaluru	767
4.	CHES, Bhubaneshwar	04
5.	Dr. B.S. K. Krishi Vidyapeeth, Dapoli, Maharashtra, Centre- Vengurle	305
6.	Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal	24
7.	Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, M.P	235
8.	Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra	85
9.	Dr.Y.S.R. Horticultural University Venkataramannagudem-Andhra Pradesh, Centre- Sangareddy	437
10.	Navsari Agriculture University, Navsari-396450, Gujarat, Centre-paria	197
11.	Govind Ballabh Pant University of agriculture and Technology, Pantnagar	15
12.	Maharana Pratap Univ. of Agriculture & Technology, Udaipur, Rajasthan	6
	Total	**2851**
	Banana	
1.	IIHR, Bengaluru	20
2.	CISH, Lucknow	07
3.	NRCB, Trichy	481
4.	University of Horticultural Sciences, Navanagar, Bagalkot, Karnataka	69
5.	Orissa Univ. of Agriculture & Technology, Siripur, Bhubaneswar, Orissa	109
6.	Tamil Nadu Agricultural University, Coimbatore	206
7.	Assam Agricultural University, Jorhat, Assam, Centre- Jorhat	105
8.	Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal	150
9.	Kerala Agricultural University, Thrissur-, Kerala	220
10.	Mahatma Phule Krishi Vidyapeeth, Maharashtra, Centre- Jalgaon	87
11.	Dr. Y.S.R. Horticultural University Venkataramannagudem, Andhra Pradesh, Centre, Kovvur	118
12.	Navsari Agriculture University, Navsari, Gujarat, Centre- Gandevi	60
	Total	**1,632**
	Citrus	
1.	CCRI, Nagpur	645
2.	IIHR, Bengaluru	35
3.	Assam Agricultural University, Assam Centre- Tinsukia	139
4.	Rajasthan Agricultural University, Rajasthan	41
5.	Dr. Y.S.R. Horticultural University Venkataramannagudem, Andhra Pradesh, Centre- Tirupati	117
6.	Punjab agricultural university, Ludhiana	17
	Total	**994**

S.No	Institute/ Universities	No. of accessions
	Guava	
1.	CISH, Lucknow	152
2.	IIHR, Bengaluru	70
3.	CIAH, Bikaner	03
4.	Dr B.S.K Krishi Vidyapeeth, Dapoli, Maharashtra, Centre- Vengurle	24
5.	Tamil Nadu Agricultural University, Coimbatore, Tamil NaduCentre- Perriyakulam	19
6.	Jawaharlal Nehru Krishi Vishwavidyalaya, Krishi Nagar, Jabalpur, M.P.	42
7.	Maharana Pratap Univ. of Agriculture & Technology, Udaipur-, Rajasthan	33
8.	Dr. Y.S.R. Horticultural University Venkataramannagudem, Andhra Pradesh, Centre- Sangareddy	24
9.	Govind Ballabh Pant University of agriculture and Technology, Pantnagar	6
	Total	**373**
	Jackfruit	
1.	CISH, Lucknow	36
2.	IIHR, Bengaluru	197
3.	CHES, Bhubaneshwar	24
4.	Dr. B.S.K Krishi Vidyapeeth, Dapoli, Maharashtra Centre- Palghar	23
5.	Assam Agricultural University, Jorhat, Assam, Centre- Jorhat	19
6.	Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, Nadia, West Bengal	50
7.	Kerala Agricultural University, Kerala	31
8.	Dr. Y.S.R. Horticultural University Venkataramannagudem, Andhra Pradesh, Centre Kovur	27
	Total	**407**
	Pomegranate	
1.	CIAH, Bikaner	92
2.	IIHR, Bengaluru	298
	Total	**390**
	Grapes	
1.	CISH, Lucknow	14
2.	IIHR, Bengaluru	20
3.	NRCG, Pune	481 active field grape germplasm 32 active field grape rootstock germplasm
4.	Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra	11
5.	Rajmata VRS Agricultural University, Gwalior, Madhya Pradesh	54
6.	Dr. Y.S.R.Horticultural University Venkataramannagudem, Andhra Pradesh, Centre- Rajendranagar	58
7.	Punjab agricultural university, Ludhiana	18
	Total	**688**
	Papaya	
1.	IIHR, Bengaluru	41
2.	Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu	88
	Total	**129**
	Sapota	
1.	IIHR, Bengaluru	52
2.	University of Horticultural Sciences, Navanagar, Bagalkot, Karnataka	57
3.	Tamil Nadu Agricultural University, Coimbatore, Tamil NaduCentre- Perriyakulam	23
4.	Dr. Y.S.R. Horticultural University Venkataramannagudem, Andhra Pradesh Centre, Kovvur	40
	Total	**172**
	Litchi	
1.	NRC Litchi, Muzaffarpur, Bihar	72
2.	CISH, Lucknow	35
3.	Bidhan Chandra Krishi Vishwavidyalaya, P.O Krishi Vishwavidyalaya, Mohanpur, Nadia, West Bengal	10
4.	Bihar Agriculture University, Sabour, Bihar	40 Genotypes
	Total	**157**
	Bael	
1.	CISH, Lucknow	36
2.	CIAH, Bikaner	21
3.	IIHR, Bengaluru	119
4.	CHES, Bhubneshwer	103
	Total	**279**
	Jamun	
1.	CISH, Lucknow	35
2.	IIHR, Bengaluru	108
	Total	**143**

Temperate Fruits

1.	CITH, Srinagar(J&K)	Apple	90 Cultivars
		Apricot	54 Genotypes
		Cherry	23 Genotypes
		Kiwi	03 Cultivars
		Olives	18 Cultivars
		Plum	26 Genotypes
		Peach	25 Genotypes
		Strawberry	20 Genotypes
	Total		**259**

In vitro conservation and cryopreservation of dormant buds

Dormant buds are one of the best explants for cryobanking of true-to-type cultivars of temperate fruits. Due to cold acclimation the buds are dry and hardy and survive exposure to ultra low temperatures. Grafting of cryoretreived buds on the field plants obviates the need for in vitro recovery and the plants go into flowering without a lag phase. Micropropagation techniques have been applied with encouraging initial results to serve as a viability criterion for control and frozen explants. In mulberry 389 accessions belonging to *Morus indica, M. alba, M. latifolia, M cathayana, M laevigata, M.nigra, M. australis, M bombycis, M multicaulis* and *M rotundiloba* have been successfully cryostored as dormant buds and their recovery into plantlets checked for various periods (Choudhary *et al*., 2015).

In vitro conservation and cryopreservation of prioritized tropical and temperate crops is being carried out in multi-crop i*n vitro* Repository at NBPGR (Agrawal et al., 2019). Protocols for micropropagation and/ or *in vitro* conservation have been developed in species of *Aegle marmelos*, *Fragaria* spp., *Musa* spp., *Rubus* spp. NBPGR maintains about 444 accesssions of banana (*Musa* spp.) and 375 accessions of temperate and minor fruits (Anonymous, 2022) in *in vitro* repository. *In vitro* cryopreservation protocols are routinely applied for *Malus* spp., *Morus* spp., *Musa* spp., *Pyrus communis* and *Rubus* spp.

Pollen cryopreservation

In several clonally propagated crops, *in vitro* method is a successful complementary strategy of germplasm conservation. Pollen storage method has utility in gene pool conservation and in hybridization programs. Pollen of 621 accessions belonging to mango, litchi, citrus, Prunus and some of the important indigenous vegetables have been successfully cryopreserved in the National Cryogenebank. Pollen viability was tested after four years of cryostorage using *in vitro* germination, the flurochromatic reaction (FCR) method and by fruit set following field pollination (Chaudhury et al. 2010). Pollen of 64 accessions belonging to *C. limon, C. aurantifolia* and *P. trifoliata* has been cryopreserved at Indian Institute of Horticultural Research, Bangalore (Ganeshan and Rajasekharan 2000).

DNA Finger printing and molecular marker studies

NBPGR has developed and standardized molecular markers techniques for DNA finger printing, tagging of economically important genes and construction of molecular maps of several horticultural species especially indigenous vegetables, fruits and medicinal and aromatic plants. NBPGR has developed a technique for distinction among Citrus rootstocks namely Galgal, Jambhiri and Rangpur lime at seedling stage. The technique is benefiting Citrus growing farmers and nurseries in several districts of Maharashtra by supply of good quality planting material.

Table 7: DNA Fingerprinting Undertaken in Various Horticulture Crops

S.No.	Crop	No. of Cultivars	Techniques
1.	Frenchbean	74	AFLP, STMS
2.	Peas	38	AFLP
3.	Tomato	27	RAPD
4.	Chillies	42	ISSR, AFLP, STMS
5.	Brinjal	19	ISSR, RAPD
6.	Banana	243	AFLP, STMS, RFPL
7.	Mango	30	ISSR, AFLP, RAPD
8.	Citrus	34	AFLP, ISSR
9.	Cashew	140	ISSR, AFLP, RAPD
10.	Vetiver	24	AFLP, RAPD
11.	Saffron	13	AFLP
12.	Plantago	48	ISSR, AFLP, RAPD
13.	Palmarosa	34	ISSR, RAPD
14.	Chlorophytum	21	ISSR, RAPD

Source: http://www.nbpgr.ernet.in/Divisions_and_Units/Genomic_Resources.aspx

CONCLUSION

However, vast indigenous genetic diversity of horticultural crops existing in India still needs continuous and concerted efforts by institutions and scientific community to safe guard this valuable wealth. Survey, explorations and collection of germplasm from biodiversity hot spots (Western Ghats and Northeast India) especially in diversity rich areas of these fruits species and their wild relatives needs priority. Protected Areas, National Parks, Reserve forests and Sanctuaries are to be targeted for collection of wild species of fruits and vegetables. For efficient conservation of vast genetic diversity of fruits complementary approach using both *in situ* and *ex situ* methods need to be adopted. Participatory conservation with farmers' involvement would be highly beneficial for these species benefiting farmer's livelihood, natural evolution and providing ecosystem services. Immediate *ex situ* conservation (i.e. field genebanks, clonal repositories and cryobanking) may be adopted for safe conservation and utilization of germplasm, and facilitating farmers with good planting material helping diversification of horticulture and widening the fruit basket for consumers.

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Review Article

Fruit Breeding in India: Achievements and Way Forward

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ABSTRACT

Breeding of perennial fruit trees is quite different than breeding of annual crops. Besides, there are several constraints impeding fast testing and release of varieties. In addition, there are several inherent problems in some fruits crops such as structural differences in floral biology, apomixes, parthenocarpy, cross incompatibility, number of seeds per fruit and large acreage required for meaningful assessment. After independence of India fruit crop improvement got a fillip with the setting up of a network of Institutes/Project Directorates/ National Research Centres and Regional Station of Institutes in different regions of the country. The concerted efforts in research and development by different institutions led to the development of many superior varieties along with associated production technology which has resulted in the significant jump in production and productivity of many fruit crops.

Keywords: clonal selection, genetic resources,MAS, rootstock, varieties

INTRODUCTION

Fruit crop improvement is more than one hundred years old today. It was in 1905 that varietal improvement work was initiated in guava by late Dr. G.S. Cheema & Deshmukh and followed by Burns and Prayagon mango in 1921 at Ganesh Khind Fruit Experiment Station, Pune. As a result, L-49 guava (Sardar Guava) was developed through a selection from cv. Allahabad Safeda in 1927. These initiatives set the tone for emphasis on fruit crop improvement in India. After that, fruit crop improvement has been carried out in a number of crops through introduction, selection, hybridisation and mutation breeding.

Similarly, the exotic germplasm was also introduced. These activities performed by local growers, often patronized by the then rulers and some enthusiastic horticulturist continued over the years and resulted in the development of several popular varieties in different fruits. After independence of India fruit crop improvement got a fillip with the setting up of a network of Institutes/Project Directorates/ National Research Centres and Regional Station of Institutes in different regions of the country. Today we have institutes devoted to Tropical Fruits (IIHR, Bengaluru), Sub-tropical Fruits (CISH, Lucknow), Temperate Fruits (CITH, Srinagar), Arid Fruits (CIAH, Bikaner) and Citrus (CCRI, Nagpur). Besides, there are Project Directorates/ NRCs for Banana (NRCB, Trichi), Grape (NRCG, Pune), Litchi(NRCL, Muzaffarpur), Pomegranate (NRCP, Solapur). Several Department of Horticulture/ Fruit crops in state Agri/ Horti Universities also took up crop improvement work on a number of crops, e.g., mango, guava, grape, aonla, pomegranate, etc. which has resulted in a number of superior varieties.

PROBLEMS IN FRUIT BREEDING

Fruit crop breeding is a long drawn and difficult process due to distinct floral biology, out crossing, high heterozygosity, sterility, parthenocarpy, apomixes, polyembryony, poor fruit set, excessive fruit drop. Low rate of sexual propagation with mostly one seed from one fruit, lack of selection procedures for isolation of desired hybrids and long pre-bearing age. Although the breeding methods are the same as for other group or crops, resulting off springs in fruit breeding require huge space for evaluation. There is also need to refine the selection procedure in different crops coming in the way of improvements as understanding of the geneticsand inheritance pattern of the quantitative traits in fruit crops has been extremely difficult. Hence, the selection of parents in a breeding programme based on the phenotype becomes difficult and progeny performance or manifestation of hybrid vigour becomes unpredictable. The progenies are also influenced to a great extent by environment. One of the advantages of the heterozygosity is that in the F_2 generation itself segregation is maximum and the desirable traits in the progenies can be fixed by vegetative propagation. However, a time has come to shift our emphasis from conventional breeding to modern methods of breeding based on biotechnological intervention.

CROP IMPROVEMENT THROUGH CONVENTIONAL METHODS

Plant genetics resources form basic raw material to meet current and future needs of crop improvement. Diversity comprises of native land races, selections, elite cultivars and wild relatives of plants. There is also lot of diversity due to seedling population and spontaneous mutations. In fact, unlike other crops where there isneed to create variability in fruit crops it is the management of diversity which is more challenging. Significant achievement made through the above method is discussed below:

Introduction, evaluation and conservation of gene pool

India is an important centre of diversity and has rich variability of several fruits. There is a large diversity of several native but underutilized fruits namely aonla, bael, jackfruit, jamun, karonda and phalsa. Simultaneously; exotic introduction of new fruit species and varieties have been made in several fruits adding to the existing variability. As a result, a rich reservoir of species and cultivars of several fruit crops has been built up at various research centres (table 1) listed below:

Table 1: National Active Germplasm sites for tropical fruits in India

S.No	Crop	No. of accession	Total accessions across India	NAGS
1	Banana	375+	1213	NRCB, Trichy
2	Citrus	430+	435	CCRI. Nagpur
3	Grapes	299+	458	NRCG, Pune
4	Guava	120+	287	CISH, Lucknow
5	Jackfruit	100+	281	IIHR, Bengaluru
6	Litchi	40+	40	NRCL, Muzaffarpur
7	Mango	750+	1382	IIHR, Bengaluru, CISH, Lucknow
8	Papaya	89+	89 (30+)	TNAU/IIHR
9	Sapota	57+	57	Arabhavi, Karnataka
		Total	4242	

Source: https://aicrp.icar.gov.in/fruits/achievements/plant-genetic-resources/nc

Table 2: Fruit genetic resources available under IIHR, Bengaluru

Crops	IIHR, Bangalore	CHES, Bhubaneshwar	CHES, Chettalli	CHES, Hirehalli	Total
Mango	767	105	0	0	872
Papaya	38	0	0	0	38
Guava	62	0	0	0	62
Sapota	41	0	0	0	41
Pomegranate	271	0	0	0	271

S.No Crop	No. of accession	Total accessions across India		NAGS	
Jackfruit	67	27	0	25	119
Custard apple	27	4	0	0	31
Grapes 72	0	0	0	72	
Strawberry	123	0	0	0	123
Jamun 131	0	41	0	172	
Pummello	27	0	65	0	92
Minor fruits	47	35	0	13	95
Bael 0	11	0	0	11	
Mangosteen	0	0	17	0	17
Rambutan	0	0	200	0	200
Avocado	6	0	50	16	72
Malabar tamarind *(Garcinia gummigutta)*	0	0	85	0	85
Yellow mangosteen *(Garcinia xanthochymus)*	0	0	106	0	106
Total					2479

Conservation, evaluation & utilisation of biodiversity, which is an important genetic wealth is very important. Many species & varieties in different fruits are rapidly being lost. There are several methods of conservation, which include pollen storage, conservation at haploid stage (accomplished through pollen) and *in situ* conservation, while evaluation of these collections have resulted in identification of several vs suited to different agro-climatic regions of the country much remains to be done in respect of evaluation & utilization of large varietal wealth in India (Table 2). Some of the prominent exotic introductions are listed below:

Apple: One of the most significant contributions in the temperate fruits was made by Mr. Samuel Evan Stokes, a resident of Philara, USA who settled in Kotgarh and introduced Delicious group of apples in 1916. It is from these first few samplings that the sweet Delicious group of apple e.g. the Golden Delicious, Red Delicious, were introduced in the area. A large number of new apple cultivars namely Fuji, Oregon Spur. Neil Chief, Red Gold, Red Spur, Royal Gala, Scarlett Gala, Staking Delicious, Top Red andVance Delicious were introduced from Denmark, Japan, Yugoslavia, West Germany, Europe and USA keeping in view our preference for red coloured, spur bearing and apple scab tolerant varieties.

Banana: Some of the prominent introduction in banana include varieties like Lady Finger having resistance to bunchy top virus from Australia; Grand Naine from France and Valery from West Indies. Of these varieties, Grand tone is now extremely popular and is grown commercially all over the country. Some accessions introduced in India and released as Kaveri Saba, Kaveri Kalki and Kaveri Kanya (NRCB, Trichy).

Citrus: Several varieties and rootstocks of citrus have been introduced from USA and Japan. These include hybrids due Kinnow, Blood Red and Washington, Naval oranges, grapefruits, Marsh Seedless, Foster, Duncan,Starking Ruby, Red Blush and lemon, Lisbon and Eureka.

Grape: A large number of varieties have been introduced in grape from different countries. Some of the notable introductions are Thompson Seedless, Perlette, Beauty Seedless, Delight, Himrod cultivars from USA and Kismish Chorni and Kismish Beli cultivars from erstwhile USSR. Other commercial grape cultivars introduced are Red Globe, Crimsom Seedless, Ruby Seedless, Riesling, Centennial Seedless, Flame Seedless, FantasySeedless, Rose, Pinot Noir, Shiraz, Chenin Blanc, Cabernet Sauvignon, Chardonnay, Merlot, Sauvignon, Blanc,and Cabernet Blanc from USA and European countries. Many of these varieties are now under commercial cultivation for table, raisin and wine purposes.

Mango: Many exotic cultivars of mango such as Tommy Atkins, Haden, Sensation, Keitt, Zill, Carabao and Julie have been introduced from Florida (USA) and Peru. Sensation and Tommy Atkins have been used in hybridisation programme for imparting red peel colour to indigenous varieties.

Papaya: In papaya Solo, Sunrise, Sunset varieties have been introduced.

Pineapple: Almost all commercial varieties of pineapple grown in India, e.g. Kew, Giant Kew, Queen, Mauritius, and Spanish are exotic introduction.

Arid Zone Fruits: While a large number of arid zone fruits are indigenous to India, several cultivars were introduced in date palm, from Sultanate of Oman, Saudi Arabia and Egypt, fig from USA and Iran and mulberry varieties, Black English, California Giant, Large Black, and Wellington etc. have been introduced.

Temperate Fruits: A number of varieties were also introduced in other temperate fruits. These include William's Bartlett, Conference, Keiffer, Baggugosha, Chinese sand pear in pear, New Castle, Royal, Kaisha,Charamgz in apricot; Early Rivers, July Elberta, JH Hale in peach and Allison, Bruno, Abbott, Hayward,Monty etc. in kiwifruit. Besides, a number of low chilling peach varieties namely Flordasun, Floradred,SunRed and 16-33 were introduced from USA in subtropical regions by PAU Ludhiana. In olive, varieties like Cortina, Apression, Pendotino, and Lessino introduced in Jammu & Kashmir and UP hills produced good quality oil yield (Table 3).

Table 3: Temperate fruits genetic resources conserved at CITH, Srinagar

S.No.	Germplasm	Germplasm Status in 2014-15	Present Status
1.	Fruits	1010	1323
	Pome	321	445
	Stone	162	246
	Nuts	359	398
	others	168	224
	Total		2636

Selection of Seedling & Elite Clones

Clonal selection is an important tool in fruit crop improvement. While the exact basis of clonal variants is still not known, seedlings resulting from spontaneous mutations may be the reason for such variants. India is an important centre of diversity of crop plants and has rich variability in several fruits. This gene pool has provided cvs of several fruits grown commercially. Lot of emphasis has been laid on variety improvementin fruit crops through selection of superior chance seedlings and elite clones and their use through vegetativepropagation. Clonal selections from commercial varieties are of great value as they differ from the parental material only in few important characteristics. Superior clones have been selected in a number of almost two dozen fruit crops and many of them are now being grown commercially. Some of the seedling and clonal selections which have become commercial in different crops are listed below:

Table 4: Clonal selections in different fruit crops

Aonla	Krishna Kanchan (Faizabad); Goma Aishwarya (Godhra)
Bael	Banarasi and Kagzi (UP); Pant Shivani (Pant Nagar)
Banana	Udayam, NRC-7, Bhat manohar, Kaveri Harita (Trichy)
Ber	Goma Kirti (Godhra), Thar Bhubharaj (Bikaner)
Citrus Acid lime	Vikram, Pramalini (Parbhani), Sai Sarbati (Rahuri), Jai Devi (Tamil Nadu), Tenali (AP), Pusa Udit, Pusa Abhinav (IARI, New Delhi)
Lemon	Pant Lemon-1 (Pantnagar)
Mandarin	Mudkhed Seedless (Maharashtra)
Pummelo	Arka Ananta, Arka Chandra (Bengaluru)
Sweet orange	Yuvraj Blood Red (Ludhiana), Pusa Sharad, Pusa Round (IARI, New Delhi)
Custard Apple	NKM-1&2 (Maharashtra), Arka Neelachal Vikram (Bengaluru)
Grape	Dilkhush (Andhra Pradesh), Manjari Kishmish,(Pune) Manjari Naveen (Pune), Sharad Seedless, Cheema Sahebi (Maharashtra); Pusa Seedless (New Delhi), Tas-e-Ganesh, Manik Chaman,Sonaka (Maharashtra)
Jackfruit	Palur-1 Jack, Siddu, Shankara (Bengaluru), Swarna Chandra, Swarna Halasu (UAS, Bengaluru, Karnataka)
Jamun	Konkan Bhadoli (Vengurle), CISH-J42 (Lucknow), Narendra Jamun (Faizabad)and Goma Priyanka (Gujarat)
Karonda	Pant Manohar, Pant Sudarshan,Pant Suvarna (Pantnagar)

(Contd.)

Mango	Niranjan, off season bearing (Parbhani);Sunderraja, a red blushed selection (Rewa), Dashehari-51, regular bearing and high yielding (Lucknow);Cardoz Mankhurd, (Goa); Paiyur-1, a clonal selection (Paiyur); Maneka (Sabour)Arka Neelachal Kesari clonal selection from Gulabkhas (CHES, Bhubaneshwar)
Pomegranate	G-137 , Ganesh (Pune) and Jyothi (Bengaluru)
Rambhutan	Arka Coorg Arun, Arka Coorg Peetab (Karnataka)
Sapota	PKM-1 (Periyakulum); CO-1,2 & 3 (Coimbatore)
Strawberry	Shimla delicious, Jutogh Special (CITH- Srinagar), Pusa early dwarf, Pusa Pride, Pusa sweet (IARI, Shimla)
Tamarind	Goma Prateek (CIAH, Bikaner)
Walnut	Series of clones selected CITH, Pusa Khor (IARI, Shimla)

One of the drawbacks in clonal selection is that if the mother clone is susceptible, the selection is also susceptible. However, some clonal selections can be used as pre-breeding lines for traits different than their mother clones.

Mutation

Gandevi, tall mutant of Dwarf Cavendish (FRS, Gujarat)

Pusa Seedless Pummelo-1, India's first seedless white fleshed pummelo mutant having juice recovery of 41.13% (IARI, New Delhi, annual report 2020)

Pusa Arun, a natural mutant from IARI, New Delhi.

Fruit Breeding

Developments of fruit varieties through hybridisation has also been underway in some fruit crops at different centres under National Agriculture Research system in the country and have resulted in several varieties ofwhich many are grown commercially. Some of these are as follows:

A**pple:** Breeding work has been in progress at Regional Horticultural Research Station, Mashobra, Shimla; Fruit Research Station, Shalimar, Kashmir, and Horticultural Experiment and Training Centre, Chaubatia, Uttarakhand with the objectives of developing varieties with better shelf-life, early maturity, high dessert quality and resistance to scab. Hybridization work initiated at Kashmir during 1956 resulted in the release of two hybrids namely Lal Ambri and Sunehari. Similar work started at Mashobra, Himachal Pradesh in1960 resulted in four hybrids, namely, Ambstarking, Ambroyal, Ambred and Ambrich. To evolve low chillingvarieties having coloured and sweet fruits with good keeping quality, work was initiated at Chaubatia in 1970.As a result Chaubatia Princess, Chaubatia Agrim, Chaubatia Swarnima and Chaubatia Anupam were released for cultivation. Further, systematic breeding aimed at development of scab resistant apple varieties at SKUAST, Srinagar resulted in the release of Firdaus and Shireen varieties. IARI, regional station Shimla has released two hybrids namely Pusa Gold (Golden Delicious X Tydeman early Worcester) and Pusa Amartara Pride (Royal Delicious x Prima) which are resistant to Powdery mildew and apple scab (Verma.M.K.,2014)

Almond hybridization programme aimed at developing low chilling varieties resulted in development of Hybrid-15, Hybrid A-258 and H-98 with high productivity and quality at PAU, Ludhiana.

Apricot: The major objective in apricot improvement has been climatic adaptation to help it escape spring frost.As a result, work at RFRS, Chaubatia (Uttarakhand) taken up in 1969 resulted in the release of three varieties namely, Chaubatia Madhu (early ripening and highly productive), Chaubatia Kesri (Mid-season variety), and Chaubatia Alankar (low chilling and early ripening).

Ber: Thar Sevika (Seb X Katha) (CIAH, Bikaner)

Custard Apple: A variety of custard apple, Arka Sahan (Gem x Mammoth) has been released from IIHR,Bengaluru and has gained popularity throughout the country and now in the production chain.

Grape: Hybridization work in grape was taken up by IIHR, Bengaluru and IARI, New Delhi. eleven hybrids namely Arkavati, Arka Kanchan, Arka Shyam and Arka Hans were released from IIHR, which have fruitful basal buds and could be trained on head system. Subsequently, seven more grape hybrids namely Arka Neelmani, Arka Sweta, Arka Majestic, Arka Chitra, Arka Soma, Arka Trishna and Arka Krishna have been developed fortable, juice and wine purposes. At IARI, New Delhi, three promising hybrids namely Pusa Urvashi and Pusa Navrang (tenturier) have been released during mid-nineties while, two more hybrids (Pusa Aditi, Pusa Trissar and Pusa Swarnika) have also been identified for release in 2014. Recently Pusa Purple Seedless, a cross of Pearl of Casaba and Beauty seedless was obtained through embryo rescue technique (IARI, New Delhi, 2020 annual report). In 2017, NRC on grape, Pune has developed Manjari Medika (Pusa Navrang* Flame Sedless) (NRC grapes, Pune) Some of these hybrids namely Arkavati from IIHR, Bengaluru and Pusa Navrang from IARI, New Delhi have given good performance and are under adoption bygrape growers in certain states.

Guava: improvement through hybridization has been undertaken at various centres has resulted in the development and release of soft seeded and large fruited varieties Safed Jam and Kohir Safed (Sangareddy,A.P.), soft seeded white fleshed Arka Amulya, Arka Poorna and soft seeded red blushed Hybrid, Arka Kiran, Arka Rashmi, Hybrid 16-1 (IIHR, Bengaluru); Hisar Safeda and red dotted peel and pink fleshed Hisar Surkha (CCS HAU, Hisar),besides a dwarfing rootstock Pusa Srijan from IARI, New Delhi.Lalit, Shweta, Dhawal and Lalima are the promising selections of guava from CISH, Luknow.

Mango: Systematic hybridization work in India started at Sabour in Bihar and resulted in two hybrids Mahmood Bahar and Prabha Shankar by crossing Bombai and Kalapady varieites. Subsequently, work at Ananthrajupet,Andhra Pradesh resulted in the release of four mango hybrids namely Neeleshan, Neelgoa, Neeludin and Swarnjehangir. Subsequently mango hybridization was taken up at New Delhi (IARI), Vengurla (MPKV) and Bengaluru (IIHR). Major emphasis has been given to development of regular and precocious bearing, dwarf,and large fruited varieties with red blush, good keeping quality and freedom from spongy tissue disorder. More than 30 hybrid cultivars have been released by various institutes which include:

Andhra Pradesh:	AU Rumai (Sangareddy)
Bihar:	Sundar Langra, Alfazli, Sabori and Jawahar (BAU, Sabour);
Gujarat:	Neelphanso, Neeleshan and Neeleshwari from Paria;
Karnataka:	Arka Arun and Arka Puneet, (spongy tissue disorder free) Arka Anmol (having good quality) and Arka Neelkiran (attractive red blush) (IIHR, Bengaluru)Arka Udaya and Arka Suprabath are the double cross hybrids of same parent, Early and Bunch bearing habit;
Maharashtra:	Ratna (free from spongy tissue disorder), Sindhu (seedless) and Konkan Ruchi fromKKV, Dapoli; Sai Sugandh from Rahuri, Ratna released from Vengurla,
New Delhi:	Mallika, (High TSS, regular bearing, semi-vigorous with wider adaptability); Amrapali, (regular bearing variety, suitable for HDP); Pusa Arunima (red coloured peel andexcellent shelf life), PusaShresth, Pusa Lalima, Pusa Pratibha and Pusa Peetamber(IARI, New Delhi)Pusa Manohari (Amrapali X Lal sundari) and Pusa Deepshika (Amrapali X Sensation) regular bearer,
Tamil Nadu:	PKM-1 and PKM-2 (Periyakulum);
Uttar Pradesh:	Ambika and Arunika from CISH, Lucknow

Papaya: Systematic work on breeding of papaya varieties with high yield and good quality for wider adaptability was taken up at IARI, Regional Station, Pusa, Bihar in 1966. Among the collections Ranchi variety was found to be most promising. As a result of inbreeding and selection for eight generations during 1966-82, uniform gyno-dioceious lines Pusa Delicious, Pusa Dwarf, Pusa Giant and Pusa Majesty with desirable attributes weredeveloped. Development of papaya cultivars with good quality and high papain content was also taken up at TNAU, Coimbatore resulting in release of CO-1 to CO-7 series through inbred selection and hybridization. Papaya improvement work carried out at IIHR, Bengaluru has resulted in the development of two hybrids IIHR-39 named as Surya and IIHR-54 which have superior fruit quality. Another promising hybrid HPSC-3 has been developed at ICAR Research Complex, Tripura for high yield potential and resistance to mosaic virus.

Passion Fruit: Kaveri, a hybrid passion fruit bred at IIHR, Chethalli by crossing green and purple varietiescan endure rains and has better keeping quality. It is now extensively cultivated in the N.E. regions.

Peach: In peach, hybridization work at Saharanpur resulted in release of Saharanpur Prabhat, while that at CITH, Srinagar of variety CITH P-1 and Pant Peach at Pantnagar (Uttarakhand).

Pomegranate: Hybridization work in pomegranate in Karnataka and Maharashtra has resulted in the development of a number of new varieties. This includes selections No. 61 namely, Mridula from Rahuri, Maharashtra and Ruby-dark red non sticky arils with soft seeds from IIHR, Bengaluru from F2 populations.

Ploidy Breeding

A fascinating phenomenon in fruit plant has provided an important pathway for evolution and speciation. Innature, somatic mutations, union of unreduced gametes, irregularities of mitosis or meiosis produce polyploids. Attempts have been made to exploit polyploidy in fruit crop improvement through use of physical and chemical mutagenesis. Using colchicines or Oryzalin, fusion of protoplast upto different species or genera to form hybrids. Somatic hybridisation is an important tool or polyploidy manipulation resulting in allotetraploids and autotetraploids.

Polyploidy is important in conferring desirable characteristic in fruit crops e.g.seedlessness and increased fruitsize in guava, pear, apple and has provided advantages ovular fertility in banana. Similarly tetraploid grapes produce distinctly large berries e.g. Mawal Seedless, Perle, Case, Early Niabel, etc. Difference in ploidy levelsof parents of some species adversely affect desirable crosses. Such crosses lead to development of abnormal endosperm; poor pollen tube growth and embryo abortion at different development stages. Manipulating ploidy level of one of the parent may help to overcome these barriers in hybridisation. Treatments with colchicine have helped to some extent in such situations.

In cases where inter specific or inter genric hybridisation is to be carried out studies dealing with somatic chromosome number determination (cytogenetic) and its ploidy level are of fundamental consideration. Success of such crosses depends on genomic relatedness particularly chromosome structural similarity, meiotichomology, genetic compatibility and recombination. Thus, comparative genetic and Karyotopic characterisation of such taxa is an important step towards perspective in gene introgassion.

SCION *VS.* ROOTSTOCK BREEDING

The important point which has been evading attention of fruit breeders in India is the recognition of the fact that in most fruit crops there are two parts requiring improvement i.e., scion and rootstock. The objectives in both cases are different. The objectives in scion breeding include attractive colour and high yield; Dwarfing for amicability to high density planting; Precocity & regularity in bearing; Seedlessness, soft seeds and better pulp quality; richness in nutrients. Much of the work on fruit crop breeding carried out so far has been related to these objectives.

On the other hand, rootstock in fruit crops is primarily used either because of their capability to impart dwarfness or their ability to utilise nutrients from soil and water efficiently or their resistance for abiotic andbiotic stresses. They can be used either directly or in breeding programmes in their vital role in production and productivity. Selecting or breeding rootstocks is more difficult than selecting a scion variety. Evaluation of rootstocks for desirable characters and stionic effects on candidate fruit crops also requires much time.

REDEFINING TRAIT PRIORITIES

Exploitation of wild species

Wild species can play an important role in developing genetically superior varieties particularly as donor for vigour and of disease pest resistance. Unfortunately, most wild species have neither been systematically collected nor evaluated either by morphological or molecular means. Some wild species of mango are already in danger of extinction while many others grow wild even to-day e.g.*M.sylvatica* (NE) and *M.andaminica* (Andaman group of Islands). Hybrid population of *Carica papaya* cv. Arka Surya X*Vasconcealla cauliflora* have found tolerant to papaya ring spot viral disease (Jimenz and Horovitz, 1967; Veena and Dinesh, 2014). In case of guava, the wilt resitant hybrid population were obtained by crossing the *Psidium molle* x *P. guajava* (Rajan and Negi, 2005).

Incidentally wild species have been extensively used for breeding scions and rootstocks in citrus, banana,grape, papaya, blueberries and raspberries in other countries. We have not even taken full advantage of information generated from this work by foreign institutions or introduced promising materials requiring priority in different crops.Exploitation of wild species and incorporating their desirable genes in cultivated species however is different task as quantitative traits are harder to transfer. Also, resultant hybrids are sterile with low yield and poor quality. Further mechanical isolation, chromosomal aberration and genetic & cytoplasmic incompatibilities hinder hybridization between wild and cultivated species.

Some of the recently identified Banana wild species are *Musa indoandamanesis* (Singh 2014)*, M paramjitiana* (Singh 2017, Bohra 2019)*, M arunachalensis* (Sreejith *et. al.,* 2015), *M nanensis* (Swangpol *et. al.,*2015).

Breeding of Scion Varieties

Yield & Quality Improvement: Some of the traits of commercial importance in scion varieties include fruit size, colour, yield and quality components. Efforts have been made to improve these in a number of crops e.g. mango, guava, papaya, grape, pomegranate through conventional breeding. However, polyploidy breeding is a potential tool for improving yield and quality, which are critical commercial traits. Even large fruit size is an important trait to fetch premium price in certain fruits like grape, kiwifruit, etc. besides size, novel colour and nutrient content adds value to the crop variety. While tetraploid varieties resulting in larger berries and early ripening have been developed in grape, certain defects like poor growth habit, irregular flower setting and reduced yield prevent their commercial acceptability. Many fruit crops play an important role in nutritional security, being important sources of vitamins, mineraland antioxidants compounds like anthocyanims, flavonoids and procyanadins. Some wild species of *Vitis* (grape), strawberry and *Rubus* and cultivated varieties of apple, grape, kiwi, orange, peach, pear and *Rubus*are rich in antioxidants. These genes can be introduced through hybridisation. Source of some antioxidant sreported elsewhere are listed below:

Anthocyanins	Grape	*V.vinifera x V. labrusca; V.labrusca x V. riperia*
	Raspberry	*R.innominates*
Anti-oxidants	Strawberry	Wild spp. *F.virginiana, spp. glaca*
	Grape	*V. amurensis*
	Raspberry	Red & black raspberries of genus *Rubus*
Total Phenolics	Raspberry	*R.caucasicus*
Ascorbic Acid	Raspberry	*R.idaus*

Seedlessness: Seedlessness is an important trait in commercial fruit crops. It can be induced through mutation and polyploidy breeding by crossing tetraploids x diploids. Autopolyploids play a crucial role in developmentof triploids. Triploids are generally mere vigorous than diploids and sterile which features helps in producing seedless cultivars. Triploidy has been commercially exploited in citrus, banana, grape & guava. Some seedless varieties produced through Mutation/ Hybridisation are listed below:

Fruit	Hybridisation	Mutation
Grape	Pearlette, Seedless, Pusa purple seedless	Beauty
Grapefruit		Duncan, Star Ruby, Ray Ruby, Flame and Nel Ruby (Vuuren and Vyver 2000)
Lemon		Eureka
Mandarin	Gold Nugget, Pixie, Winola	Shiyueju
Orange	Clara, Tacle	Hongju 418, 420, Pineapple
Pummelo x Grapefruit	Oroblanco, Melogold	

Breeding of Rootstocks

Tree Architecture: Rootstocks have the ability to modify the vegetative growth and affect scion vigour resulting in dramatic change in planting systems of fruit crops by their ability in tree size control making itpossible to go for high density planting system leading to meadow orchards. Emphasis therefore needs to belaid on selection of dwarf trees/ rootstocks for close spacing. Spacing distance will however, vary based on scion vigour i.e. high, medium & dwarf; fertility status and water holding capacity of the soil. Some work in this regard has been carried out successfully in UK in apple, where a number of dwarfing, semi-dwarfing and standard rootstocks have been developed and are being successfully exploited commercially are listed below:

Dwarfing Rootstocks	Semi-Dwarfing Rootstocks	Standard Size Rootstocks
B.9, B.10, B146, B49, Bemani, G.16, G.41, G.65, G.214, G.935, M.9, M.27, Mark, MAC39, Ottawa 3, P.2, P.22, Supporter 1, Supporter 4, V.3	B.118, B.490, G.11, G.30, G.202,G.210, G.890, G.969, J-TE-H, M.26, M.27, M.4, M.7EMLA, M.9 (interstem)/ MM.106rootstock, MM.106rootstock, M.27,M.9(interstem) /MM.111 rootstock, MM.106 EMLA, V.1	Antonovka 313, MM.111EMLA, P.18, Seedling

Breeding for Abiotic stress tolerance

As climate changes become more severe, several abiotic stresses e.g. high temperature, drought, cold and salinity limit plant growth, yield and fruit quality. Losses are often inter-related and hinder normal,physiological, biochemical and molecular processes in plants. There is also severe cellular damage impairingplant development and fruit set. Work done in breeding of varieties for abiotic stress tolerance is briefly given below:

Drought Tolerance: Water scarcity is becoming a key limiting factor in fruit crop production. It is being caused due to decline in rainfall pattern and increase in number of warmer days. Drought plays an important role in scion growth and yield during water scarcity period. With the drought incidence becoming frequent in the country, it has become important to identify drought tolerant varieties and species and developing drought tolerant hybrids has assumed significant importance. The mechanism involved in drought tolerance include,drought escape, dehydration, avoidance, drought tolerance, recovery and resistance besides increasing water uptake and reducing water loss. Blueberry, a fruit not grown commercially in India is highly susceptible to drought. A number of drought tolerance species/ hybrids have been identified in different crops. These include *C. reshni, C. aurantium, C. limonia, C. jambhiri and P. trifoliata* of Citrus and *V. arboretum, V. dorrowi*of Raspberry. Some highly, moderately drought tolerant species/ hybrids are listed below:

Reaction to drought	Crop	Rootstock
Highly tolerant	Citrus	Flying Sunki
	Grape	110 R, Ramsey, 1103 Paulsen, 140 Ruggeri, Kober 5BB
Moderately tolerant	Apple	M 9, M 26, M 111
	Citrus	Carrizo Citrange, Swingle Citrumelo
	Grape	Teleki 5C, SO4
Moderately tolerant to drought	Peach	4247T1
Tolerant	Citrus	SSW 1

Thus, breeding of rootstocks adapted to different drought conditions in important fruit crops is the best optionavailable to manage drought.

Cold Tolerance: Cold stress is a major limiting factor that affects productivity of many fruit crops. While severe cold restricts growth, freezing temperatures injure plants and kill trees. Many commercial fruits namely apple, citrus, guava, grape, papaya, blueberry and pear are susceptible to cold and freezing temperature. Low temperatures often affect plant growth and crop productivity. Plants differ in tolerance to chilling (0-15°C) andfreezing (0°C) temperatures. Continuous effort is required to breed *cvs*, which is cold hardy and escape severe cold climate. However, resistance to cold is complex, quantitatively inherited and controlled by polygene infruit crops. Vast germplasm is available in different fruit crops possessing genes for cold hardness as below:

Apple: On the basis of evaluation, the following cold tolerant rootstocks have been identified:

Temperature	Rootstocks
-16°C to -19°C	G 935
-12°C to -14°C	G 11, G 30, G 41, B 9, P 2 and M 26, B 9, Ottawa 3, P.2
-08°C to -11°C	-M 26, MM 106, MM 111, and M 7, Jork 9, Alnarp 2, M 26
-06°C to -08°C	M.7, MM 106

Grape: American grape species such as *V. labrusca, V. aestivalis*, and *V. riparia* are potential sources of coldhardiness. *V. riparia* species have been reported to with stand up to -40°C. Rootstocks like *V. riparia, Glorie,St. George,* and 1103P are tolerant to cold injury. Even though resistant sources are available, selection of cold hardy progenies from hybrid populations by lengthy screening and evaluation makes breeding difficult. Further the study of cold hardiness and inheritance pattern is challenging. Such studies are also few. Inheritance pattern of cold tolerance has been studied in a few crops is given below:

Crop	Trait	Heritability
Blueberry	Bud freezing tolerance	High
Apple	Winter survival	Mid – high
Peach	Dormant flower buds	Mid – high
	Cambium, xylem and bud injury	0.65 – 0.96
Plum	Winter survival	>0.0

Salt tolerance: Salinity is one of the most serious environmental factors that affect the crop productivity worldwide. Most crops are sensitive to high salt concentrations in the soil. Sodium and chloride ions in thesoils are the dominating factors in adversely affecting yield of fruit crops. More than 800 million hectares of land are affected by soil salinity throughout the world. Fruit crops like citrus, grape, apple, pear, peach, cherry, apricot, strawberry, plum, etc. are susceptible to soil salinity. There is thus need to give priority to breeding salt tolerant rootstocks. The level of susceptiblity to salinity has been worked out in some fruit crops and the threshold levels are given below:

Crop	Threshold level (dS/m)
Grape fruit	1.2
Sweet orange	1.3
Almond, Apple, Black berry, Grape, Lemon, Mandarin	1.5
Apricot, Avocado	1.6
Peach	1.7
Plum	2.6

There are three types of salinity tolerance mechanism in crops e.g.; tolerance to osmotic stress, salt exclusion,tissue tolerance. Citrus is one of the most sensitive crops for salinity. A large number of citrus orchards in India is getting affected by salinity every year. The ability of citrus trees to tolerate root zone salinity is mainly dependent on rootstocks. Citrus rootstocks vary in their degree of tolerance for salinity. The Cl- excluding ability of Rangpur lime and Na+ excluding ability of *P. trifoliata* can be transferred to their hybrid derivatives.Work done in Australia, Canada, Spain & USA has resulted in development of several hybrids, namely Swingle, Citrumelo, Troyer, Risk and Carrizo Citranges besides US-897 and X637. Evaluation of different Citrus species, relatives and hybrid rootstocks for salinity tolerance has indicated that Cleopatra mandarinis salt tolerant and Sour orange is susceptible. The rootstocks US-897 and X639 have also been shown to behighly salt tolerant than Cleopatra mandarin. Some of the salt tolerant citrus rootstocks are listed below:

Rootstock	Remarks
Swingle Citrumelo	Moderately tolerant to salinity
Troyer Citrange	Tolerant to salinity
Rusk Citrange	Tolerant to salinity
Us-897	Highly tolerant to salinity
X 639	Highly tolerant to salinity
Carrizo Citrange	Moderately tolerant to salinity

Salinity is a serious concern in grape production also because of its moderate sensitiveness in saline soils. *Vitis vinifera*, the commonly cultivated grape is a poor Cl- excluder and rapidly absorbs and accumulates salts in theplant system leading to poor vegetative growth, burning of leaves and low yields in contrast to *Vitis* species like *V. rupestris, V. cinerea, V. champini* and *V. berlandieri* which are good chloride ion excluders. Results of different rootstocks have revealed that Salt Creek and Freedom have high level of tolerance to salinity. Someof the commonly used grape rootstocks tolerant to salinity are listed below:

Rootstock	Parents
Salt Creek	*V. champinii*
Freedom	Complex hybrid of *V. champinii, V. riparia, V. labrusca, V. vinifera, V. solonis*
140Ru	*V. berlandieri*x *V. rupestris*
1103P	*V. berlandieri*x *V. rupestris*
SO4	*V. berlandieri*x *V. riparia*
41B	*V. vinefera*x *V. berlandieri*

Salinity causes yield loss in citrus, mango, avocado, stone fruits etc. The mango rootstock Gomera-1 is reported to be was a Cl- excluder. Similarly, 13-1, Olour and Kurukan are also reported for salt tolerance. Theinter specific *Prunus* rootstocks like HS-314 and GF-677 have proved to be good source of salinity resistance. The extent of salinity has been on the increase in India rendering several suitable areas unfit for fruit cultivation particularly for lack of salt tolerant rootstocks. It therefore calls for priority attention to this aspect.

Breeding for Biotic Stress Tolerance

Resistance to biotic stresses is a major objective in any crop breeding programme world over. Resistance is the ability of host plant to reduce the infestation or damage or both by an insect or disease or any of the external force. Resistance level may vary from only slight plant tolerance to stress or total immunity. It can be result of one or more mechanism. Both vertical and horizontal mechanisms have been used by breeders for development of new varieties. Building desirable resistance is the only permanent solution to control pest incidence. Further, with call for organic farming and making food safer a priority, resistance breeding has assumed great importance. In this regard, development of rootstocks for certain biotic and abiotic stress is extremely important in fruit crops.

5.5.1. Pest Resistance

A number of pests adversely affects the productivity & quality of different crops. Important pest which has attracted attention of breeders worldwide include the following:

Economically important pests in some fruit crops.

Crop	Pests
Apple	Wooly Apple Aphids
Banana	Corm Borer, Pseudostem Weevil
Citrus	Aphids, Citrus Butterfly, Leaf Miner, Psyllids, Stem Borer, Thrips, Whitefly
Grape	Phylloxera
Guava	Fruit Fly
Mango	Fruit Fly, Hopper, Stone Weevil
Papaya	Papaya Mealy Bug, White Fly
Pomegranate	Anar Butterfly

Besides nematodes (in citrus, banana & grape) and borers in certain fruit crops cause huge economic losses.Since chemical control of these pests can be a major hazard to the environment, breeding of pest resistantrootstocks becomes important. Several wild species have been identified as sources of resistance as discussedbelow:

Apple: The woolly apple aphid (WAA), (*Eriosoma lanigerum*, Hausmann) is the primary pest of apple worldwide. It affects roots and aerial parts of the plant. It causes more damage by feeding the roots. The control of this pest when feeding of roots under soil is very difficult either chemically or culturally. As a result,rootstock breeding programmes were started globally and Northern Spy was used as a source of resistance along with Malling series. The Malling-Merton rootstock series e.g. MM 104 (M2 x Northern Spy), MM 106(M1 x Northern Spy), and MM 111 (Merton 793 x Northern Spy) derived from Northern Spy were resistantto WAA. However, they were not immune. The immunity to WAA was identified in *M. robusta*accessionRobusta 5 which has *Er*2 resistant gene.

A breeding programme aimed at Cornell University, Geneva campus for combining multiple resistance andtree size control using different Merton series, *M. domestica* and *M. robusta* has resulted in release of several rootstocks with multiple level of tolerance and varying degree of tree size control listed below:

Sl.No	Rootstock	Tree Vigour	Resistance to	Tolerant
1	G 41	Dwarf	WAA and fire blight	
2	G 214	Dwarfing	WAA, fire blight, and crown rot.	
3	G 202	Semi dwarf	WAA and fire blight, replant disease and crown rot	
4	G 222	Semi dwarf, precocious	WAA and fire blight, replant disease andcrown rot	
5	G 210	Semi dwarf	WAA and fire blight,	cold hardy
6	G 890	Semi dwarf,	WAA and fire blight precocious	cold hardy
7	G 969	Semi dwarf,	WAA, fire blight and precocious crown rot	cold hardy
8	G 4210	Semi dwarf	WAA and fire blight	

Grape: In grapes, Phylloxera, (Fitch) is the most devastating pest of grape and itinvaded Europe during the late 1860s and caused severe economic losses in grape vine industries. Intensivegrape breeding programme was initiated by several breeders resulting in development of hybrid rootstocks like SO4, 5BB and 5C derived from *Vitis berlandieri*Planch. X *V. riparia* Michx. resistant to phylloxera. However, this pest is fortunately not available in India.

Nematodes: Nematodes constitute one of the major limiting factors in fruit crop production. They cause extensive root necrosis resulting in serious economic consequences that drastically reduce the yield. The roots damaged by nematodes are easy prey to fungi which invade the roots and accelerate root decay. Important nematode species which threaten the global fruit industry and cause huge economic losses are listed below:

- root-knot nematodes (*Meloidogyne incognita* and *M. arenaria*),

- burrowing nematode (*Radopholus similis*),

- citrus nematode (*Tylenchulus semipentrans*),

- dagger nematode (*Xiphinema index*) and lesion nematodes (*Pratylenchus* spp.) are the major nematode pests that infest commercial fruit crops in general

Work on breeding of nematode resistant rootstocks in citrus, grape & banana has resulted in the development of following rootstocks elsewhere:

Rootstocks resistant to nematodes

Grape	Degree of Resistance to Root knot Nematodeand Dagger Nematode
O39-16	Highly resistant to Dagger
Schwarzmann, Freedom, Boerner	Highly resistant to both
1616C	Highly resistant & Moderately resistant respectively
Ramsey	Highly resistant
101-14 Mgt	Moderately resistant to both
Fercal	Moderately resistant
Banana	
H 21, H 59, H 65, H 74, H 84, H 95, H 109 and H 201 (Triploids)	Burrowing nematode
NARITA-1 (Triploid)	*Helicotylenchus multicinctus*
H 212, H-02-19, H-02-21, H-02-22, H-02-23, H-02-36;FHIA 01 (Tetraploid)	*R. Similis*
H 61, H 74 and H 95, BRS 1 andBRS 2 (Triploids)	Other nematodes

The Citrus nematode (*Tylenchulus semipenetrans*) is a worldwide problem that leads to poor growth of young plants and is responsible for poor performance of mature trees. The important source of resistance is *Ponciru strifoliata* and its derivatives. Although *P. trifoliata* is resistant to citrus nematode, its performance is very poorin alkaline and calcareous soils. It has been reported that the hybrid rootstocks of *C. reshni*x *P. trifoliata* and*C. volkameriana*x *P. trifoliata* are highly resistant to citrus nematodes. Further, some hybrid rootstocks of *C.reshni*x *P. trifoliata,* King mandarin x *P. trifoliata,* and *C. volkameriana* x *P. trifoliata* also showed very little incidence of nematodes and are moderately resistant**.**

5.5.2. Disease resistance

A number of bacteria, fungi, virus, and mycoplasma like organisms affect fruit crop production severely. Themajor diseases which affect production and quality of fruits drastically are listed below:

Fruit	Diseases
Apple	Scab, crowned rot, fireblight and powdery mildew
Banana	Fusarium wilt, sigatoka and leaf spot
Grape	Powdery & downy mildew
Guava	Wilt
Mango	Anthracnose, Powdery Mildew
Papaya	Mosaic, ring spot, phytopthora
Strawberry	Crinkle virus, mottle virus and red steel virus

Identification and utilisation of source of resistance is a basic requisite for incorporating disease resistancethrough breeding programmes. It requires screening and evaluation of germplasm to determine the magnitudeof genetic variation of resistance. Several sources of resistance to major diseases have been identified indifferent fruit crops. These are as under

Resistant wild species used as rootstocks in different fruit crops

Crop	Diseases	Resistant wild species rootstocks
Apple	Fire blight	*Malus robusta*
	Scab	*M. floribunda* (vf resistant gene)
Banana	Black sigatoka	*M. acumita*
	Fusarium Wilt (Race 1,2,4)	*M. acumita, spp. malaccensis*
Citrus	Phytophthora	*Trifoliate orange, swingle citrumello, Bento cintrange (hybrid)*
	Tristeza virus	*Rangpur lime, rough lemon, Cleopatra mandarin, Trifoliate orange*
Grape	Downy mildew	*V. Muscadinia, V. rotendifobia, V. amorensis*
Guava	Wilt	*Psidium friedricsthalianum*
Papaya	Ring spot	*Vasconcillecauliflora, Quercifolia pubscence*
Pear	Fire blight	*Pyrus communis*

A number of efforts have been made in different fruit crops to develop disease resistant/tolerant hybrids aslisted below:

Fruit	Hybrids	Resistance
Apple	Borovinka, Hagloe Crab, TitaZetei, Braburn, Britegold,Delicious, Empire Red, Enterprise, Fuji, Goldstar,Jonafree, Nittany and wealthy red,Pusa Gold, Pusaamartara pride	Powdery mildewScab
	Prima, Primula, Sir Prize, Jonafree, Dayton	Scab
Banana	Diploids- SH2095, H109 andTriploid- NARITA-1Tetraploids - FHIA 01, 07 & 23	Fusarium wilt Resistant to Sigatoka Sigatoka Race 4
	FHIA 01, 17 & 18 & PITA 17	Sigatoka
Guava	Peipa, TS-G1, TS-G2	Wilt
	TS-G3	Wilt
Mango	Hybrid progenies, CISH-2035 and 1734	
Papaya	Cinta L 41, L 90	Moderately

6. STRATEGIES FOR FRUIT BREEDING

6.1. Haploids and double haploids

In fruit crops, high heterozygosity, long generation cycle with long juvenile period and often self-incompatibility do not allow the haploid development easily through the conventional methods. The haploids and double haploids can make a significant contribution in shortening the time taken for fruit breeding. Using DH technology,completely homozygous plants can be established in one generation thus saving several generations of selfing required in conventional methods. Development of homozygous lines through gametic embryogenesis resultsin single step improvement of the crop.

In a conventional breeding programme, a pure line is developed after several generations of selfing. However, in fruit crops, there is no way of obtaining homozygous lines through conventional methods. Hence, fixation by doubling the chromosome complement presents a possibility of using haploids. In many of the importantfruit crops mango, citrus, banana, grape, papaya, sapota, pomegranate, custard apple, apple, peach, pear, plum,apricot, kiwi fruit etc. it can be a very handy tool in the improvement.

Role of bio-technology in fruit breeding

Marker assisted breeding (MAB): Fruit crops being perennial and heterozygous remain juvenile for a long period, when propagated through seeds. Since seed production is indispensable in a breeding programme,shortening of juvenile period or finding alternate ways to induce early fruiting in seedlings is very importantto achieve early assessment at seedling stage and avoiding evaluation of unwanted seedlings. A number of methods like top working, induction of flowering by chemicals, shortening of juvenile phase by grafting have been employed. Using a combination of above techniques, a number of superior varieties have been developed.

These include:

- Blood red guava
- Pink pulped papaya
- Early maturing seedless grape
- Seedless mango
- Vitamin rich peach & plum
- Regular bearing mango hybrids

Assessment of genetic diversity of fruit crops is an important step in breeding. A diverse range of plant material including land races, modern cultivars, wild relatives and other wild species are available as the starting material. Conservation of germplasm is of little importance without characterisation and further utilization of concerned plant material. To intensify these activities DNA finger printing has been implemented in the characterisation of germplasm. The molecular markers are being used for maintenance of core collection for the assessment of genetic diversity and finger printing. However, phenotyping is still advantageous to validate performance.Development of molecular markers for different traits should continue to receive priority attention. A large number of molecular markers have been developed and applied for analysis of genetic diversity and relatednessand all markers have their strengths and weaknesses. In general, two main groups of molecular markers havebeen utilised for PGR characterisation:

- Markers for identification of accessions detection of structure of genetic reserves collection & Relatedness of available plant material.

- Gene specific markers, applicable for Marked assisted selections (MAS).

The last two decades have witnessed initiatives to a transition from traditional phenotype to genotype assisted breeding. This has become possible due to availability of wide array of molecular markers, transcriptome and whole genome sequence data in many woody fruit plants.

A marker is a tag of identification of any trait of an organism which can be identified with confidence and relative ease and can be followed in a mapping population. DNA marker is a small region of DNA that shows sequence polymorphism among genotypes. Such DNA/ molecular markers have contributed numerously in breeding of many crops due to their reliability and tight linkage to the trait of interest. Mapping and tagging ofgenes controlling important agronomic traits have been facilitated by an array of molecular markers. Marker assisted breeding in fruit crops is given considerable importance as it would improve the breeding efficiency in fruit crops.

A few genes and markers identified in fruit crops linked to various traits are given below:

Crop	Trait	Gene	Marker
Apple	Fruit colour	*Rf*	BC226
	Fruit acidity	*Ma*	OPT16-1000
	Mildew	*Pl-1, Pl-2, Pl-w, Pl-d,*	LAP – 2
	resistance	*Pl-m*	
	Scab	*Hcrvf2, Rvi6*	*nptII* (Belfanti *et al.,* 2004)
	Fire blight resistance	*FB_MR5*	SCAR/SSR
Citrus	Fruit acidity	Ac	RFZ20
	Seedless fruit	Fs	OPMO6r
	Citrus leprosis virus r esistance		AFLP and RAPD

(Contd.)

Crop	Trait	Gene	Marker
Peach	Flesh adhesion	*F/f*	OPB5a
Pear	Incompatibility		AFLP/SSR
Banana	Sugar content		RFLP
Grapes	Seedlessness, berry size, andripening date		AFLP, SSR RAPDs, ISSR and SCAR
	Fungal disease resistance	*vvtl-1*	22-kDa (Jayashankar*et al.,* 2003)
Straw	Day neutrality		AFLP
berry	Anthracnose Fruit rot resistance	*FaRCa1*	SNP and SCAR (Salinas *et al.,* 2019)
Apricot	Plum Pox virus		SSR

Genomics in Fruit Crops: Genomics are the next generation sequencing technologies being used to generate whole genome sequences for a wide range of crop species. It helps to understand genome structures, to make use of quantum of data produced and to describe their function and interactions. With the significant advancement in sequencing technologies in recent years, efforts have been made to release whole genome sequences of many fruit crops. Many more whole genome sequencing projects of fruit crops are also in progress. The biggest challenge in genomics of perennial fruit trees is the development of bio-informatic tools to manage huge volume of data generated by next generation sequencing technologies. There is a need to create genomere source platforms for the benefit of academician and researchers. A few crops whose genomes have been sequenced are discussed below:

Apple: Genes have been identified for scab, fire blight fungal disease resistance, and induction of anthocyanin accumulation.

Grape: Genome sequence (size 457 Mbp) has been studied in variety Pinot Noir which was bred close to fullhomozygosity.

Mango: A draft genome based on transcriptome and whole genome sequence data of Dashehari, Neelum andAmrapalli (403) (Singh *et al.,* 2021) cultivars has been reported.

Musa: A global Musa genomic consortium, an international network with 40 institutions in 24 countries has worked for sequencing the banana genome. All available markers have been used to study phylogenetic relationships, diversity, evaluation, parentage analysis differentiation of A&B genomes and to develop traitspecific markers.

Papaya: Papaya with a small genome size (372Mbp), is having only a few disease resistant genes besides fruit ripening skin colour change and sugar accumulation genes. The transgenic female *Sun Up* variety was chosen for sequencing genes.

The genome size of different fruit species is given below:

S.No.	Fruit Crop	Scientific name	Genome size (Mbp)
	Almond	*Prunus amygdalus*	238 (Alioto *et. al.,*2020)
1.	Apple	*Malus domestica*	742.3
2.	Banana	*Musa acuminataspmalacensis*	523.0
	Date	*Phoenix dactylifera*	605.4 (Sharma *et al.,* 2016)
3.	Grape	*Vitis vinifera*	487.0
	Guava	*Psidium guajava*	443.8 (www.ncbi.nlm.nih.gov.in)
4.	Kiwifruit	*Actinidia chinensis*	616.1
5.	Mango	*Mangifera indica*	439.0
6.	Papaya	*Carica papaya*	372.0
7.	Peach	*Prunus persica*	265.0
8.	Pear	*Pyrus bretschneideri*Rehd	600.0
	Pineapple	*Ananas comosus*	381.9 (www.ncbi.nlm.nih.gov.in)
9.	Sweet Orange	*Citrus sinensis*	452.0
10.	Wild Banana	*Musa balbisiana*	438.0
11.	Woodland Strawberry	*Fragaria vesca*	240.0

7. CONCLUSION

A lot of genetic variability has been collected and maintained in a number of fruit crops, major emphasis in fruit breeding has so far been laid only on developing varieties with high yield and superior fruit quality. Time has come tohave a fresh look on breeding priorities and strategies to harness the full potential of fruit breeding. Following recommendations are made to achieve the desired objectives: While a lot of genetic variability has been collected and maintained in a number of fruit crops, major emphasis in fruit breeding should be given for systematic evaluation of germplasm of fruit crops. Collection of wild germplasm, endangered species and other gene sources should be taken on priority and their descriptive evaluation is of utmost importance. There is urgent need to do basic research on inheritance of characters which will ease the choice of parents in hybridization programmes. There is need to clearly define objectives and priorities of breeding of fruit crops for different regions. Furthermore, the work should be assigned to different centres on the basis of their human resource capabilities and available facilities. Rootstock breeding of commercial fruits like mango, citrus, grape, pomegranate etc; indigenous fruits like Bael, jamun should be taken at priority. In view of climate change, breeding work should be taken at priority for developing climate resilient varieties and rootstocks. There should be integrated breeding approaches involving traditional and modern molecular methods for the improvement of fruit crops. Marker aided selection and enriching the genome resources of fruit crops should be taken on priority. There is dearth of manpower for fruit breeding programmes keeping in view the number of crops and aspects requiring attention.

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Review Article

Seventy five Years of research and development in arid fruit crops

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ABSTRACT

The green revolution has by pass the arid regions, which constitute 12 per cent country's cultivated area. Despite the introduction of many new technologies the productivity in arid region remained low might be due to very poor soil fertility, scanty moisture and uncertain climatic factors. However, these conditions greatly favour development of high quality production in number of fruits such as date palm, ber, pomegranate, citrus, aonla, bael, ker, lasoda, karonda, fig, pilu, cactus pear etc. For arid environment, the crop either having xerophytes adaptation or its varieties are resistant to biotic and abiotic stresses for sustainable production. Systematic work on arid fruit crops initiated by Indian Council of Agricultural Research on arid zone fruits (AZF) start functioning from 1987 with objective to develop fruit growing technologies for the arid regions of the country. Main work was on conservation, characterization and sustainable utilization of germplasm on traits of interest in the view to build up viable commercial cultivation in the arid region of the country to improve economic conditions, health and nutrition of the people. In arid zone, farmers are resource poor and undertake subsistence farming. Food, fodder, fuel, timber etc. are the primary requirements of the farmers. Therefore, mono cropping is highly risk prone in this area; hence to mitigate the effect of total crop risk failures, fruit based multistory cropping system has been developed with research, which is able to meet these requirements, depending upon the land and water resources. Successful fruit based models like aonla-ber-brinjal-moth bean, ber-drumstick-senna-moth bean-cumin can be profitably adopted by the farmers of arid region for better cash flow, nutritional, environmental security and sustainable livelihood. Besides, survey, collection of genetic diversity and established in field repository released improved varieties of arid fruit crops with standardized *in-situ* orchard establishment technique, vegetative propagation, plant canopy architecture management, integrated nutrient -water management, plant protection schedule, postharvest management and value addition etc. for arid regions on the country. Research and development work in progress on new crops and novel varieties identification, biochemical and molecular understanding of the mechanisms of adaptive behavior, micro propagation and nutraceutical compounds etc. Market focused diversification in arid fruit crops definitely will capture new opportunities in domestic as well as export markets.

Keywords: Arid fruits, fruit based cropping system, arid zone fruits, ICAR-CIAH research

INTRODUCTION

In India, arid region is spread over 39.54 million ha including 31.71 million hectare as hot arid region mainly in the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab and Haryana and 7.83 million hectare as cold arid region in the states of Jammu and Kashmir and Himachal Pradesh (Saroj and Dhandar, 2004). The Western Rajasthan consist of the districts of Bikaner, Hanumangarh, Jaisalmer, Barmer, Ganganagar, Churu, Jhunjhunu, Sikar, Nagaur, Jodhpur, Pali and Jalore covering an area of nearly 1,43,842 sq.km. The Indian arid zone is characterized by high temperature, very poor in soil fertility, low and variable precipitation which limit the scope for high horticultural productivity. Next to moisture regimes, radiation, thermal and wind status during crop growing period also important as they influence crop productivity significantly. The irrigation water resources in the region are seasonal rivers and rivulets, surface wells and some runoff water storage devices *(e.g., nadi, tanka*, *khadins*) and canal irrigation in arid region. Thus, the water resources in arid region are limited and can irrigate hardly 4 per cent of the area. Apart from this, in western parts of arid region, occurrence of frost is also common features during winter season which affects vegetative growth of plants as well as productivity and quality of produce especially in *ber*, lasoda and aonla. However, these conditions favour physiological adaptive horticultural crops and their varieties of date palm, ber, pomegranate, citrus, aonla, bael, and in vegetables such as cucurbitaceous crops, spices and some medicinal plants.

As far as the arid fruit crops have developed and/or modified their organs to perform certain vital physiological functions such as strong deep root system (ber, bael, aonla, wood apple, jamun, *etc*.), synchronize their flowering and fruit development with the season of moisture availability (ker, lasora, aonla, pilu, *etc*.) and other xerophytic characters *i.e*. leaf shedding in summer (ber), scanty foliage (ker), mucilaginous sap in plant part (ker, gonda, pilu, bael, *etc*.), sunken stomata and fur/ hairiness and waxy coating on the leaf surface (phalsa, ber, lasoda, fig, etc.) thorny nature, and selective or reduced absorption of cation (Na^+) and anions (Cl^-, SO_4^{--}) for survival under adverse arid conditions. Therefore, cultivation of suitable species of fruits with strategic site management approaches (windbreaks, shelterbelt) in the arid areas will increase the sustenance of the inhabitants and provide the alternate sources of income through development of nurseries, small scale industries and exports. Rao *et al*. (1983) reported that a reduction of evaporative demand by 8-10 per cent can be achieved in leeward side of the tree shelterbelt between distances of 2 to 5 times the height of plants. Further, Gupta and Gupta (1981) reported a reduction in soil loss of 49 per cent in sheltered areas. Strength of this region are availability of vast area (12% of land), surplus family labour, ample sun shine so great opportunity to exploitation of native flora, multilayer receptor crop cultivation, introduction of new crops, high value product development etc. Researchable issues in such a challenging area for production enhancement are genotype improvement, propagation protocol development, planting system management, canopy architecture engineering, crop diversification, protected cultivation, organic cultivation, ICT based technology, geo-spatial technology, postharvest management including value addition, integrated nutrient, water, weed, diseases-insect management etc.

PRESENT STATUS – WORLD VS INDIA

World produced total fruit production around 800 million tonnes and India produced near to 100 mt that is 12.5 per cent of the world production. In India, the area under fruit cultivation is about 6.9 m ha with production of 103.03 mt (that was 28.63 mt at the time of independence). The area expansion and yield of arid horticultural crops has been increased gradually because of development of new varieties and advancement in agro-techniques. At present area and production of arid fruit crops are around 5.2 mha and 60 mt, respectively. As far as new crop introduction as date palm, olive, jojoba etc area under cultivation is increasing due to involvement of technology driven policies and subside support of government through different schemes. For instances date palm in Bikaner district alone, more than 1100 ha area owing to supply of tissue culture plants, skill development on pollination and processing awareness through capacity building programmes and joint R &D efforts under public privet partnership (PPP) mode research.

In arid region, considerable area has come up under fruits like ber, pomegranate, bael, fig, aonla, custard apple, date palm, karonda, lasoda, tamarind, wood apple, manila tamarind, phalsa in different parts of the country, which had negligible spread in the recent past. Ber has spread from northern states to the western and southern India from a mere 12000 ha in 1978 to nearly 86,000 ha in 2004-2005 with a production of about 0.90 million tonnes. Similarly, the area under pomegranate has also leaped to over 1.25 lakh ha. Likewise aonla, presently cultivated on 50,000 ha with the production of 2, 50, 000 tonnes. This has become possible as a result of the research and developmental efforts. There is need to develop large orchards of under-utilized fruits like jamun, mahua, chironji, khirni, wood apple, fig, karonda, lasoda, manila tamarind *etc*. for commercial exploitation both for internal consumption and export as these fruits are of high nutritive value and are rich in anti-oxidants for health conscious populace of modern world (CSIR, 2003).

Table 1: Area and production of arid fruit crops.

Crops	1993-94		2016-17		2030	
	Area (ha)	Production (MT)	Area (ha)	Production (MT)	Area (ha)	Production (MT)
Ber	41,256	3,30,048	85,500	8,95,000	1,10,000	12,10,000
Pomegranate	4,500	45,000	2,02,050	26,68,950	3,50,000	50,00,000
Aonla	26,000	2,86,000	75,000	8,25,000	1,00,000	13,00,000
Date palm	5,000	41,000	25,000	2,00,000	40,000	3,75,000
Sapota	49,000	6,44,000	80,000	9,13,000	1,10,000	12,80,000
Tamarind	10,500	52,500	15,280	82,300	20,000	1,20,000
Others (Custard apple, Fig & Phalsa)	6,600	30,450	15,700	1,31,700	35,000	3,50,000
Total	1,42,856	14,28,998	4,98,530	57,15,950	7,65,000	96,35,000

CHANGING DEMAND IN DOMESTIC MARKET

Socio economic and demographic characteristics play in determining what food households purchase and consume, nor on its nutritional content. Socio economic factors associated with suboptimal food consumption including low income and education levels and prevalence of fast food restaurants. We know that diet has been played significant health impact for quality life and economic welfare of the society. Basic need is food that should be required sufficient quantity, nutrition rich and protective against various health ailments.

Sparse population (around 20 million) and low density (61 persons square km) habitat in arid region. Large holding size, more labour availability and canal source of irrigation facilities are blessed strength in this area may help in provide bundles of opportunities towards promotion of cultivation practices of underutilized fruits owing to high in nutritional value and diverse fruit basket. Domestic demand increased due to shifting of food habit of people and availability enhancement. Availability of fruits near 100 g, which is very less comparison to United State of America and European country (Switzerland) i.e., 223 and 419 g, respectively. A recent past research study on consumption habit among mass population of cities and rural showed an interesting trend, city population cereals consumption decreasing and horticultural crops consumption increasing and vice versa trends was observed in rural population. We know that demand and supply directly affect the market because of that the horticultural crops production surpassed over total cereal production (Fig-1). India witnessed the shift in area from food grain towards horticulture crops over more than a decades (2012-13 onwards), but less

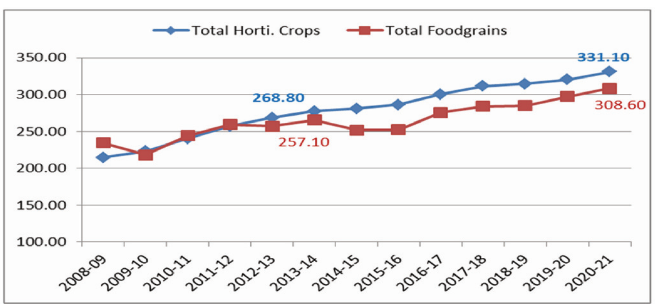

Fig.1: Production of Horticulture vis a vis Food grains

known fruits as such consumption is very limited, require awareness and health benefits promotions and preparation of acceptable value added products for fetching market of domestic to foreign as well.

Nutritional requirement in developing countries like India not so good position and in arid region situation is very much alarming. For instances

- 70% Indian population consume < 50% of recommended dietary allowances of micronutrients
- 50% children are below 5 years age are under weight and 20% of them severely malnourished.
- 57% women and children suffer vitamin A deficiency
- Global hunger index out of 116 country India's position is 101 (http/www/GHI)

Arid region fruit crops are comparatively heat/ drought tolerant and low load of biotic complexes and underutilized crops very much rich in nutritional and medicinal properties. In folk, yunani, ayurvedic formulations (eg. Triphala, chyawanprash, joshanda, etc) had been used in treatment of diseases and disorder by remedial methods (Table-2)

Marketing of arid fruits produce is a major constraint in the production and disposal system and has a major role to play in making the industry viable. The high capital cost involved in establishing orchards or rejuvenation of existing old unproductive plantation poses serious constraint in area expansion. The situation becomes further difficult in view of the large number of small holdings devoted to these crops which are essentially owned by weaker section, who have limited resource to invest, also cannot afford burden

Table 2: Therapeutic uses of arid fruits

S.No.	Common Name	Botanical Name	Therapeutic use
1	Bael	*Aegle marmalos* Corr.	Appetizer, stomachic, cooling, restore vitality
2	Date palm	*Phoenix dactylefera* L.	Antibacterial, antifungal and anti-proliferative properties good for teeth due to florin rich
3	Ker	*Capparis deciduas* Edgew	Biliousness, asthama, inflammations, fever, laxative, cough, cure stomach pain, vomiting, arthritis, diabetes and hypertension
4	Kaith	*Feronia limonia* L.	Stomachic, stimulant, carminative, tonic for digestive disorders and antiscorbutic.
5	Jamun	*Syzygium cumini* L.	Stomachic, anemia, improves hemoglobin in blood, diabetes.
6	Tamarind	*Tamarindus indica*	Useful in heart care and against stone formation in urinary system
7	Pomegranate	*Punica granatum*	Super food ageist melignated cells, improve hemoglobin , anti-anemia
8	Lasoda	*Cordia dichotoma*	Anticlimactic, diuretic, expectorant
9	Karonda	*Carissa carandas*	Anti-scorbutic, anemia
10	Phalsa	Grewia *subinaequalis* D.C.	Blood purification, anemia
11	Ber	*Ziziphus nummularia*	Helps in blood purification and improves digestion
12	Fig	*Ficus carica* L	Diuretic, laxative expectorant and antispasmodic treatment of leucoderma as the presence of furocoumarin a chemical
13	Aonla	*Phyllanthus officinalis*	Anti-anemic, boost immunity, liver functioning, healthier skin, cardiovascular health
14	Pilu	*Salvadora persica*	Rbeumatism pains, cure piles, cough and purgative, root bark is vesicant, fruit is useful in enlarge spleen and low fever with skin diseases, etc.

Source- Goyal and sharma, 2009; Pareek et. al. 1999; Gopalan et al., 2004;CSIR, 2003 of credit, even if available. High cost of inputs and lack of enough incentives for production of quality varieties / species, product diversification, value addition, etc. also hinder crops development in such resource poor area.

RESEARCH AND DEVELOPMENT IN ARID FRUIT CROPS

Major research and development in arid fruit crops was initiated by the ICAR in 1976 as *ad-hoc* basis under AP Cess Fund Scheme. Research work taken up on ber, pomegranate, bael, custard apple, date palm, fig and minor fruit crops (tamarind, jamun, karonda, phalsa etc) at 10 centres namely Lahaul – HPKVV, Bhojka – RAU , Chandan-Bikaner, Hisar – CCSHAU, Yercaud – TNAU, Udaipur - SKRAU. Anantapur-APHU, Dantiwada-SDAU, Faizabad-NDUAT and Lucknow. Considering the potential and performance merged adhoc scheme with ICAR-AICRP on Arid Zone Fruits (AZF) and started functioning from 1987. At present, 18 centres, 14 under SAUs in 10 States and 4 under ICAR Institutes in four States are functioning. The Project Coordination Unit, initially established at Hisar was shifted in 1993 to Bikaner (Rajasthan). The mandate of this project is to develop fruit growing technologies for the arid regions of the country with particular reference to fruits such as ber, pomegranate, bael, custard apple, date palm, fig and other minor fruit crops with a view to build up viable commercial cultivation in the arid region of the country to improve economic conditions, health and nutrition of the people. The project has been successful in expeditious dissemination of varieties, technologies and information which has resulted into converting minor fruits like aonla, pomegranate into viable commercial crops of the country. Apart from this project ICAR-CIAH, Bikaner, ICAR-CAZRI, Jodhpur, SAUs (SK RAU-Bikaner, SK DAU-Gujarat,MPKV-Rahuri etc.) are working together in different research activities for benefit of the farming communities. Different recommendation/ scientific informations generated in the area of commercial cultivation of arid fruit crops are as under-

General R&D activities for orchard establishment: The planting system adopted in arid region depends upon largely on topography of land, kind of fruit crop and its variety and soil type. Planting is generally done in plain area in square or rectangular system, but in sloppy land terraces made across the slop. Micro catchment areas require and where runoff accumulates plants should be planted. Pit bottom and side placed a clay or pond silt barrier 2-3 cm thick for reducing percolation loss of the water in light textured soil. Polythene mulch cover help in substantial evaporation loss of water and young plants should be covered for protection from high radiation and wind action. Double walled pitcher of 3-5 litre or more capacity with bottom painted use alongside of each tree with periodically filled with water helping in establishing orchard in arid region (Pareek, 1987 & Gupta *et al.*, 1987).

Mass multiplication of quality planting material: To boost the horticulture production quality planting material availability play a major role. Standardization of propagation techniques for commercial orchard establishment of desired variety require planting material so that should be raised as per standard protocol in this direction constant research and development efforts require. Institute central institute for arid horticulture has been working since 1993 and reproducing and distributing quality planting material to the stakeholders under different R & D activities (Sarolia *et al*., 2018). Details of protocol standardized for propagation of the fruit crops are given as under-

Water and nutrient management: Orchard soil moisture and water management greatly affect the productivity of the crops. Under dry land situations both should be judiciously managed and maintain at optimum level for getting maximum efficiency. Water use efficiencies may be enhanced by use of water harvesting, mulching, weed management simultaneously approaches. Sharma et al. (1982-86) have reported that microcatchment slopes greater than 5 per cent did not significantly affect run off at Jodhpur and that yielded maximum when 0.5 per cent and 5 per cent slopes had 8.5 m and 7 m length and 72 m^2 and 54 m^2 catchment area per tree, respectively. Mulching with organic material have multiple benefits in reduction of moisture loss, suppress weed growth, prevent erosion and add organic mater to the soil (Gupta, 1995). In arid part black polythene mulch is very effective in ber orchard (Anonymous, 1989). Use of antitranspirant 4-6 % kaolin, 0.5-1.0 % liquid paraffin gave better result (Pareek ans Sharma, 1991). Shelterbelt and wind breaks can reduce evapotranspiration by reducing the wind velocity and stabilize micro-climate (Muthana *et al*., 1984). Achievements in water management aspects under AICRP-AZF is in-*situ* planting of aonla in sunken basin with 5% slope plus with black polythene mulch (600 gauges) registered the highest soil moisture, morphological characters, fruit yield, chlorophyll stability index and relative water content (Aruppukottai and SK Nagar centres), fig, 40% wetting zone with 900:250:275 g NPK/ tree applied through drip irrigation gave significantly higher fruit yield (Rahuri) and maximum marketable fruit yield of pomegranate was recorded with 20% wetting zone and 625:250:250 g NPK/tree in drip fertigation (Rahuri).

The soil of the arid region is nutritionally very poor in organic carbon and nitrogen content as well as the availability of other nutrients. Regular application of organic matter not

Table 3: Methods of propagation in arid fruit crops

S.N.	Name of fruit	Methods of propagation Standardized	Commercial	Reference
1	Acid lime	Seed, budding, Air layering	Seed	Anon., 2011
2	Aonla	Budding	T-budding/ Patch budding	Anon., 2011
3	Bael	Root cutting, budding, layering	Patch budding	
4	Ber	Budding (T, I, ring and forkert)	*In-situ* budding (T-budding) / Polytube budding method	Nath *et al*., 1998
5	Custard apple	Seed, Soft wood grafting (SWG), budding	T-budding/ inarching	Anon., 2011
6	Date palm	Seed, offshoots, Tissue culture	Off shoot (suckers), Tissue culture	
7	Fig	Cutting, budding and air layering	Hard wood cutting	
8	Jamun	Seed and budding	Shield & patch budding	Singh and Singh,2006
9	Ker	Seed and suckers	Suckers/ seed	Anon., 2013
10	*Khejri*	Seed and patch budding	*In-situ* Patch budding	Purohit *et al.,* 2003
11	Karonda	Seeds	Seeds/ hard wood cutting	Bhardawaj and Sarolia, 2011
12	Lasoda	Seed	Patch budding	Krishna and Singh, 2013 and Singh *et al*., 2003
13	Mandarin	Seed and budding	T/shield budding	Anon., 2011
14	Mulberry	Cutting and budding	Stem cutting/ shield budding and cutting	
15	Phalsa	Seed and cutting	Seed	
16	Pilu	Suckers	Root suckers/layers	
17	Pomegranate	Budding (chip, patch and forkert), layering (air, ground and pot),	Hard wood cutting , air layering and tissue culture	Saroj *et al*., 2008
18	Tamarind	Seed and soft wood grafting	*In-situ* soft wood grafting	*Awasthi et al., 2005*
19	Wood apple	Root cutting, budding and seed	Seed/*In-situ* budding	Singh and Singh, 2015

only increases its content but also improved the soil condition and makes available the various nutrients to the plant. Recommended doses required at appropriate time according to age of the plant is essential. Nitrogenous fertilizers should be applied in 2-3 split doses at critical stages. In ber orchard every year require 15-20 kg FYM with 100-50-50 g NPK, respectively.

Plant architecture and canopy management: The canopy of plant plays a vital role to increase quality production of fruit trees. Plant architecture can be maintained through proper training and pruning of fruit plants. Training at initial stages of growth gives proper shape and strong frame to the trees. The bushy pomegranate should be trained keeping 3-5 stems from the ground level while in other fruits (ber, aonla, jamun, citrus, bael, lasoda etc); single stem training keeping 3-4 main branches is adopted. For regulation of shape, flowering and fruiting judiciously removal of wood is required. The response of

Table 4: Arid fruit crops and recommended dose of manure and fertilizers

Crop	FYM (kg)	NPK $g^{-1}plant^{-1}$ N	P	K	Recommendation & Reference
Ber	50	500	250	250	AICRP-AZF, Hisar
Aonla	150	500	250	125	AICRP-AZF, Bangaluru
Pomegranate	50	625	225	225	AICRP-AZF, Rahuri (MS)
Date palm	60	600	100	70	Nath and Singh, 2003
Bael	80	500	250	250	Singh & Mishra, 2000
Fig	40	900	250	250	AICRP-AZF, Rahuri (MS)
Custard apple	25	250	125	125	Anon., 1983
Phalsa	15	100	40	25	Pundir and Pathak, 1981
Jamun	50	1000	500	500	Nath *et al*., 2008
Karonda	10	50	100	150	Pandey and Reddy, 1989
Mulberry	30	300	150	200	Srivastava, 1984
Lasoda	25	500	250	250	Singh *et al*., 1996

Foliar feeding of nutrients such as nitrogen (0.5 to 2 % urea), zinc (0.05 to 1.0 %) and boron (0.01 to 0.05%) has given beneficial results in these area (Pareek and Sharma, 1991).

Table 5: Pruning time and level under different Arid fruit crops

S.No.	Fruit crop	Pruning time	Pruning level	New Approaches	Reference
1	Ber	End of May in North India	The main shoots of the previous season are cut back retaining 15-25 nodes	Under different training systems (T, Y, Espalier) pruned by hedging and topping techniques in established plant	Pareek & Nath, 1996Saroj *et al*., 2019
2	Phalsa	January in North India	Hard pruned at 20-30 cm height from ground	Trained as shrub require light pruning (25-50 % of previous year growth)	Singh and Sharma, 1961
3	Lasoda	December-January	Light pruning with maintain shape	Defoliation chemicals can be used	Chundawat, 1990
4	Mulberry	December-January	Medium level and for silk worm rearing hard twice a year require	Bottom pruning (0-15 cm height) for maximum leaf harvest	Nath *et al*., 2008
5	Fig	Just after harvest the crop	Light to hard (2-4 bud leave previous season growth level)	Old (October flowering) and new (Spring flowering) growth bear	Pareek and Nath, 2006
6	Custard apple	Light pruning spring	25 % top branches in March-April	Bear new and old branches	Nath *et al*., 2008
7	Pilu	Alternate year winter pruning	Light to 50 % once in three years	Bear one year old shoot	Nath *et al*., 2008

pruning depends on kind of fruit crops its varieties, location, age and vigour of tree. Under plant architecture engineering advance training system can be tried for enhancing productivity many fold eg. Ber and bael crop successfully can be trained under Y shape and espalier, respectively for quality crop harvest and promote HDP system in these fruits (Anon., 2019 & 2020).

Fruit based cropping systems: Monoculture in arid zone is highly risk prone due to crop failures, hence a suitable tree crop combinations is essential for alleviating the risk, generation of income, improvement productivity per unit area/volume as a result of efficient use of natural resources and inputs, and ameliorate and improve adverse agro-climate. Agri-horticultural combinations with legume intercrops and horti-pastoral system is beneficial with the system (Subbulakshmi *et al*.,2016) could have combinations such as *khejri (Prosopis cineraria)*+ber+dhaman *(Cenchrus ciliaris, C. setigerus) or* sewan *(Laisurus sindicus)*. Multi-storey combinations incorporating large trees, small trees and ground crops can be used based on edephoclimatic and rainfall pattern eg., In low rainfall (300-500 mm) zone-combinations such as *khejri* or ber + ber or drumstick + vegetables (legumes and cucurbits); in 500-700 mm rainfall zone-combination of mango or ber or aonla or guava + pomegranate or sour lime or lemon or drumstick + solanaceous or leguminous or cucurbitaceous vegetables; and in 700-1000 mm rainfall zone-combination of mahua or palmyrah palm or tamarind or guava + sour lime or pomegranate or aonla + vegetables can be adopted.

Some popularly adopted systems are described below (Pareek and Awasthi, 2008):

1. **Indian Jujube (*Ziziphus mauritiana*) based cropping system:** The Indian jujube is one of the important cultivated fruit trees of north India. Maximum benefit: cost ratio of 3.48:1 when crops were grown under combination of aonla + ber + karonda + moth bean + mustard. Among the perennial components, higher benefit: cost ratio (2.22:1) was found under ber. In this cropping system, the flow of cash was for almost nine months of the year under arid condition of Rajasthan (Krishna et al., 2018). Under hot arid condition, ber cultivar Gola as over storey component and cluster bean, mustard and Indian aloe can be integrated into the system as compatible ground storey component as compared to groundnut, wheat which has dominated rotation under irrigated hot arid condition (Saroj *et al*., 2003).

2. **Indian Gooseberry (*Emblica officinalis*) based system:** In arid climate, highest net profit was obtained in aonla based cropping system intercropped with moth bean-cumin system followed by moth bean-chickpea cropping system (Saroj and Krishna, 2017). The tree canopy of aonla allows filtered light and permit intercropping even after it has made full growth. Among the two models developed at ICAR-CIAH, Bikaner highest gross return was obtained under aonla – *Prosopis* – sehjana –moth bean – mustard model (Awasthi et al., 2005).

3. ***Khejri* (*Prosopis cineraria*) based system:** *Khejri* is an important component of farming system in hot arid region. This tree grows well in all sorts of climatic constraints which is evidenced by the fact that new foliar growth, flowering and fruiting occur during severe dry months (March-June) when most other trees of the desert remain leafless or dormant. In *khejri* based cropping system ber, *lasoda, pilu* and *ker* can be grown as filler crops (Kaushik and Kumar, 2003).

Agromet database management and Remote sensing techniques: With the advancement in computer based ICT technologies agro meteorological data/ information dissemination with rapid rate and utilize in management deals with both weather and crop data. GIS based techniques are useful in understanding both temporal and spatial variation of climatic parameters over a region. Agroclimatic/ agro ecological characterization of the land of the region through remote sensing is new tool and helping manifolds in the sector of soil moisture status, perfect mapping of farm, estimation of losses due to calamities, GIS techniques helping in crop simulation modeling that will enable the farmers to take weather based decision in horticulture for efficient utilization of the positive influence of weather resources and to minimize the adverse weather effects on crop productivity (Bhargava *et al*., 2014). Such advance techniques will pay the way to bring about stability and sustainability and help to achieve the future productivity targets of the crops.

IMPROVEMENT IN ARID FRUIT CROPS IN INDIA AND ITS VARIETAL IMPORTANCE

The Indian Council of Agricultural Research is engaged in harnessing modern scientific knowledge to develop high-yielding, open-pollinated varieties and hybrids that are resistant/ tolerant to major biotic and abiotic stress factors, efficient in input use, and adapted to different agro-climates, suited for irrigated and rainfed areas. Varieties and hybrids have also been tailored with ideal maturity and plant architecture for intensification and diversification of cropping systems.

While selection of fruit crops for arid region, one of the basic requirements is that those crops who complete their vegetative growth and reproductive phase during the period of maximum moisture availability. The fruit such as ber, pomegranate, custard apple, aonla and sour lime, conform to this prerequisite. In these crops also, there is need to select the most drought hardy cultivars for rainfed production. Early ripening cultivars seem to escape stress conditions caused by the receding soil moisture stored in the soil profile during the monsoon. For instances, ber cultivars Gola, Seb and Mundia for extremely dry areas, Banarasi Kadaka, Kaithli, Umran and Maharwali for dry regions, and Sanaur-2, Umran and Mehrun for comparatively humid regions have been recommended (Chadha, 2019). Apart from morphological parameters, plants should also have physiological parameters for endurance to drought for commercial cultivation in this region. Some physiological parameters identified in ber are no-mid-day depression in photosynthetic rate, low rate of transpiration, maintenance of leaf water balance, growth, canopy development, dry matter allocation, high water use efficiency, etc. It has been demonstrated that plant having capacity for drought endurance are able to maintain turgor, dry matter allocation, leaf and fruit growth even under low soil moisture level.

The important fruit crops and cultivars (More *et al*., 2008) which can be grown successfully in hot arid region are presented in table 6.

Table 6: Promising recommended fruit crops and their cultivars

Fruit Crops	Cultivar
Ber	Gola, Kaithali, Goma Kirti, Thar Sevika, Thar Bhubhraj, Thar Malti
Bael	NB-5, NB-9, Goma Yashi, Thar Divya, Thar Neelkanth, Thar Srishthi
Aonla	NA-7,Chakkaiya, Krishna, Balwant, NA-6,Goma Aishwarya , NA-10
Date palm	Halawy, Barhee, Medzool, Khuneizi, Khalas
Pomegranate	Bhagawa, Super Bhagwa, Solapur Lal, Mridula, Jalore Seedless, Goma Khatta (anardana type)
Fig	Poona Fig, Conadria, Diana, Excel, Black Ischia, Phule Purandar
Custard apple	Balanagar, Mammoth, Island Gem, Arka Sahan, Phule Janki
Tamarind	PKM -1, Pratisthan, Yogeshwari, Goma Prateek, Anant Rudhira
Sweet orange	Malta Blood Red, Mosambi, Satgudi, Pusa Round
Lime	Kagzi, Vikaram, Sai Sharbati, Pusa Abhinav, Pusa Udit
Karonda	Thar Kamal, Pant Sudharshan, Pant Manohar, Pant Suvarna
Khirni	Thar Rituraj

The ICAR- Central Institute for Arid Horticulture, Bikaner (Rajasthan) has National Field Repository of germplasm of arid fruits (Anon., 2013-14) and did work on characterization, evaluation and utilization of germplasm for different horticultural traits. The Institute has released 48 varieties of different arid horticultural crops, out of which 24 related to fruit crops (CIAH,2016). The released varieties brief details are as given below (Table-7).

Apart from this AICRP on AZF have been developed varieties of Pomegranate (Bhagwa and Super Bhagwa), Custard Apple (Arka Sahan, APK (Ca-1) and Phule Janaki, Ber (Narendra Ber selection 1 and 2), Aonla (ND/AH-16, NA-17), Lasora (JL-7 as Karan Lasoda), Jamun (CISH J-1 & 2), *Bael* (CISH B-1 & B-2) for higher quality production of different fruit crops (AICRP-AZF at a glance).

Table 7: Improved fruits varieties developed at ICAR-CIAH, Bikaner

S.No.	Crop	Variety	Salient characteristics
1	Aonla	Goma Aishwariya	It is an early and drought tolerant variety
2	Ber	Thar Sevika	It is an early maturing hybrid (Seb x Katha) variety
3	Ber	Thar Bhubharaj	It is very juicy, sweet and medium maturity variety
4	Ber	Thar Malti	Mid maturing group variety with high yield and soft pulp texture, no throat itching at raw stage eating
5	Ber	Goma Kirti	Late maturing variety but comes 10-15 days earlier than Umran and higher yielder
6	Bael	Goma Yashi	It is semi dwarf stature, low thorn, precocious and good yielder with smooth pericarp and suitable for commercial orcharding under dry land areas.
7	Bael	Thar Divya	Drought tolerant, early in maturity (second fortnight of February), precocious bearer and highly suitable for growing under dryland /rainfed hot semi-arid ecosystem.
8	Bael	Thar Neelkanth	Drought tolerant, lustrous growth and higher fruit yield having attractive fruit appearance under aberrant agro-climatic conditions.
9	Bael	Thar Shrishthi	Medium stature of the tree, locule centric variety contain high pulp and easy in processing
10	Bael	Thar Prikriti	Medium stature, rich in TSS and antioxidants
11	Bael	Thar Shivangi	Compact canopy and dwarf stature suitable for HDP and low incidence of scald
12	Jamun	Goma Priyanka	Medium vigorous growth habit, precocious, response to pruning and good yielder in rainfed conditions
13	Jamun	Thar Kranti	Early ripening (last week of May) and drought tolerant
14	Pomegranate	Goma Khatta	Anardana type and seed hardness is medium
15	Tamarind	Goma Prateek	This variety has long pod and high yield in rainfed conditions
16	Lasoda	Thar Bold	A prolific and early bearing lasoda variety
17	Chironji	Thar Priya	It is comparatively dwarf, precocious bearer and suitable for high density planting.
18	Khirni	Thar Rituraj	It is semi-dwarf, precocious bearer, dwarf and suitable for high density planting.
19	Karonda	Thar Kamal	It is comparatively dwarf, early, precocious bearer and suitable for high density planting and suitable for candy and jelly making.
20	Mahua	Thar Madhu	It is comparatively dwarf, precocious bearer and suitable for high density planting.
21	Mulberry	Thar Lohit	Low (frost) and high temperature tolerant colorant variety
22	Mulberry	Thar Harit	It is mid-season, precocious bearer, high yielding variety
23	Phalsa	Thar Pragti	It is dwarf, early precocious bearer (bearing in 3rd year) and drought tolerant and suitable for high density planting.
24	Wood apple	Thar Gaurav	Compact canopy, fruits rich in pectin and protein content and early maturing (1st week of November).

VARIETAL SITUATION PRODUCTION CONSTRAINTS – BIOTIC AND ABIOTIC STRESS

One side development of improved varieties of different horticultural crops from varios organizations and entry of these in suitable seed chain is very important for boosting the production. Mass multiplication of quality planting material at reasonable price as per standard is jumbo requirement of stakeholders. Planting standards are very much prerequisites for getting desired success in such edapho-climatic situations.

Gaps in prevailing system

- Lack of disease free seed/planting material.
- Presence of weeds and diseased and off type plants in farmer’s field/fruit orchard.
- Lack of awareness regarding crop rotation/sequence.
- Lack of awareness about uses of proper doses of agrochemicals in orchard mostly growers as higher/ lower doses may lead to resistance in insect/fungal races.
- Lack of provision of information, training, instruction and supervision to workers
- Lack of broad spectrum label claim agrochemicals with mode of action.
- Lack of development of forecasting systems against major diseases of horticultural crops.

Gap of planting material production need to be intensify on priority with establishment of mother plants of new varieties in nurseries for commercial level multiplication. Nursery infrastructure strengthen and promote good practices for raising of saplings as use of poly tube for rootstock raising, plug tray/ root trainers use for minimizing the constraints and follow standard protocol of production as well as *in situ* budding approach for orchard establishment in arid region.

Abiotic constraints are very much prominent (drought, frost, heat, hail, storms, salinity etc) in arid context and creating major hindrance in mass level production and orchard establishment. Strategic and apply integration of research and development techniques for orchard establishment of new climate resilient varieties in this area.

The arid region less load of biotic stress so, insect-diseases complex less prominent, but due to increase vegetation and cropping intensity some major biotic stress are causing loss of horticultural crops in this region are

Insect-pest	Termites, fruit fly (ber), fruit borer (ber), pomegranate butterfly, scale insect (date palm), stone weevil (ber), blue butterfly (ber), bark eating caterpillar, lemon butterfly (citrus), gall midge mites pomegranate, date palm), etc
Diseases	Powdery mildew, (ber *etc*.), wilt (citrus and bael), fungal leaf spot (bael, date palm, ber, *etc*.), bacterial leaf spot & fruit spot (pomegranate and bael), anthracnose (aonla and pomegranate), blight (pomegranate), mosaic and leaf curl viruses.

Integrated pest and disease management strategies to be required to control the insect –pest and diseases below economic threshold level (ETL). General field sanitation, deep summer ploughing, hoeing-weeding, destroy infested fruits *etc*. automatically will reduce the major insect-pest and disease load from the field and other crop specific good cultural activities. Growing the crop with non-host crop and removal of infected crop debris, periodical removal of webs around affected portion at the time of pruning (ber, aonla, anar) against fruit borer and bark eating caterpillar, bagging of fruits (pomegranate) for fruit fly and cue-lure traps (date palm) with growing available resistant genotypes. Use various label claim formulations Dimethoate (0.1%),Thiamethaxam-25%WG (0.05%), Indoxicarb (0.07%) or Imidacloprid (3-5 ml/10 lit. of water) used for controlling the same. Apart from insecticides under organic module can be used bio-pesticides namely, neem seed kernal extract (NSKE @ 2.5-5%), neem oil, tumba fruit extract (TFE 5% or Thar Jevik) on various crops effective in controlling aphid, thrips, jassids, butter flies, fruit flies, moths, *etc.* in pomegranate, citrus, aonla, *etc*. Similarly, different fungicides can be used for controlling different diseases like powdery mildew can be controlled by wettable sulphur (0.25%) and kerathane (0.1%). Anthracnose by Spraying of Carbendazim (0.1%) or Difolatan (0.2%), Leaf spot by two fungicidal sprays of mancozeb or copper oxychloride @ 0.2% at 15 days interval, bacterial leaf spot by spraying of 200 ppm streptocycline can be controlled followed by Pausamycin (0.05%) + Copper oxychloride (0.2%) with 3 sprays at fortnightly intervals. In organic way through botanicals based on *Trichoderma*, *Aspergillus*, *Pseudomonads, etc.* isolates and some herbal extracts of *Aloe vera*, turmeric, black pepper, neem kernel extract can be used effectively against the pathogens (Anon.,2019).

Post-harvest management

The post harvest handling accounts for 20 to 40 per cent of the losses at different stages of grading, packing, storage, transport and finally marketing of both fresh and processed products. The horticultural produce suffers heavy post-harvest losses in the absence of adequate post-harvest and marketing infrastructure *viz*; pre-cooling units, packing and grading sheds, short and long term cold storage facilities, refrigerated containers, storage and phyto-sanitary facilities at airports. In arid region, intense solar radiation is available during major part of the year; therefore, sun drying is very common and easy method. For sun drying in open, produce is spread in single layer on *pucca* floor or bamboo structure, or wooden crates or metal trays depending upon availability, convenience in handling, kind of fruits and the product type. Various fruits like ber, date palm, aonla, fig, pomegranate and *ker* etc. are being dried in sun. Presently, the technologies of mechanical dehydration like solar, osmotic, freeze, fluidized bed drying, *etc*. have been developed and attained sophistication. Pre-drying treatments like blanching or brining or sulphitation improves the quality of dehydrated products. The rate of drying depends on the temperature during the drying season. It is slower during winter (20-25°C) than summer (35-40°C). The air circulating type electric dehydrators have precise temperature control system inside the chamber, which yields desired quality product without spoilage.

Value addition of perishable commodities is needed to achieve better price of produce in the market. Arid fruits widely can be used for making various value added products (table-8) through drying, syruping, brining, pickling, beverage making, preserve making, *etc*. Proper packaging is an essential prerequisite to reduce losses of produce and attract the consumers.

Table 8: Value addition of arid fruit crop

Crops	Value added products
Fig	Dehydrated dry slices, confectionary products, nuggets, jam
Tamarind	Jam, jelly, syrup, pulp powder, candy, seed kernel powder
Wood apple	Chutney, pickle, frozen puree, sauce
Custard apple	Puree, jam, RTS, juice, frozen pulp
Jamun	Jam, juice, RTS, vinegar, preserve, frozen pulp
Ber	Candy, syrup, churan, bar, toffee
Pilu	Beverage drinks, RTS, squash
Date palm	Pind, chhuhara, biscuit, wine, jaggery
Pomegranate	Juice, squash, RTS, RTE (aril ready to eat), anardana
Aonla	Candy, preserve, toffee, juice, supari, powder, pickle, shreds
Bael	Nectar squash, leather, slab, powder, candy

Source: Goyal and Sharma, 2009

TECHNOLOGICAL CHANGES WHICH HAVE EXCEL ARID FRUIT PRODUCTION IN INDIA

The optimized technologies and inputs could increase the existing low productivity. It is now realized that there is a limited scope for quantum jump in fruit production in the traditional production areas. The recent aware-ness regarding the potential of these ecologically fragile lands for production of quality horticultural produce has not only opened up scope for providing economic subsistence for the people of this region, but also for bringing new areas to increase production through horticulture.

One of the major problems in development of horticulture scenario in arid region is lack of sufficient quality planting materials. Others constraints related to production system management and post-harvest management of both fresh and processed products. Lack of proper storage facility and knowledge and equipment for grading and packaging of fruits is also constraint for the growers of hot arid region.

Technological changes against major constraints dealing are as

- **Quality production of Planting-material**: Planting material, comprising all forms of propagules, acts as a catalyst and a starting point for realising potential of all other inputs. Thus, production of quality seed material and their supply to farmers will boost up the arid horticultural crops production. Developed protocol for mass level production of genuine, disease free saplings of arid fruits.
- **Production System Management**: Crops grown in risky location require some strategic site management approaches to ameliorate the surroundings or modified the micro climate in arid region. HPCPSMA (Horticulture Based Crop Production Site Management Approach) an improved practices and techniques to create such micro climate surrounding the grown crops and facilitate better establishment to production of crop with less influences of abiotic stress (temperature, hot winds, drought, frost etc) on main crops (Samadia,2016). Out come in form of package and practices (PoP) helped in boosting / dissemination of technologies to the farmers field with native and new introduced crops. High density planting, training system, canopy management, use of PGRs and crop regulation technologies involvement boosting the arid fruit production.
- **Value Chain Management**: Arid region in particular, has greater significance of dehydration technologies of fruits in order to dough-tail the amount of spoilage caused due to gluts and inappropriate post harvest handling methods. In arid region, intense solar radiation is available in major part of the year, therefore, sun drying is very common and easy method. Various fruits like ber, date palm, aonla, fig and ker *etc*. are being dried in sun. Presently, the technologies of mechanical dehydration like solar, osmotic, freeze, fluidized bed drying, *etc*. have been developed and attained sophistication. For instances date palm harvested at doka stage blanched 10-25 minutes was required for making dry dates (*chhuhara*). For making soft dates, curing for much shorter period i.e. for 20-25 seconds followed by dehydration at 30-40^{0}C was required (Chandra *et al*., 1994). Dipping of ker fruits in 4-6 per cent salt solution or 0.2 per cent NaOH solution for about a week improves the quality of dehydrated product. Date biscuits prepared by adding 10 and 20 per cent date pulp powder were found nutritive in terms of protein and sugars (Singh *et al,* 2013).
- **Capacity building of extension personals and Growers**: For large scale of diffusion and adoption of GAP, the capacity building of extension personnel may be increased through organizing training activities and reactive, diagnostic and perspective. Extension personnel should be trained as per need of the farmers. Practical work should be included on actual field conditions. There is a need to carry out extension activities for technological interventions for arid horticultural development like front line demonstrations of improved arid horticultural technologies at farmers fields, farmers trainings (on/off campus) or farmers school, farmers meetings-interaction-visits, method demonstrations, practical exposure of techniques to clients-farmers, farmers group organization, activities for empowerment of farm women, *etc.* to encourage the technological intervention for arid horticulture promotions.
- **Improved orchard mechanization**: Quick field operation in direction of conserving maximum rainwater and its effective use. Timeliness and precision in orchard operation is the key of success of arid region that not possible manually alone. Like other fruit crop production arid fruit nursery raising (plug tray filling and seeding machine, small tractor with accessories for mother orchard care), intercultural operation (harrow, power tiller, cultivator, disc plough), training-pruning (automatic secateurs, pruner, chain saw, brush cutter), crop harvesting (harvester), grader, waxing machine, shrink wrapper, refrigerated van and value addition (fruit mill,

juicers, pulper, extractor) are available for different fruit crops, however there is need to be commercialized and popularized.

EMERGING CHALLENGES AND APPROACHES

After massive research work on arid fruits, a large number of varieties have been released by different organizations which are recommended for commercial cultivation in arid region of the country. Even though constraints persist and challenges emerge in the context of arid fruit crop production. Native or adaptable fruit crops might be a better option in this direction by standardizing agro-techniques for commercial crop production and reducing the post-harvest losses in underutilized crops like bael, jamun, karonda, mulberry, phalsa, lasoda, pilu, wood apple, manila tamarind, ker, khirni, cactus pear etc. are not exploited well yet. Such fruit trees are not only hardy but have high nutritional and nutraceutical values which need proper attention.

In climate change scenario more focus on climate resilient genetic improvement and varietal development will definitely open the new avenues. Approaches for that strengthen farmers' participatory breeding to use high throughput technology such as CRISPR/CAS9 the genome editing emphasized for genetic improvement of arid fruits for desired traits. Specialty commodities such as off-season varieties and production systems, new crops and novel varieties should be identified to capture new opportunities offers great scope in domestic as well as export markets. Work on physiological, biochemical and molecular understanding of the mechanisms of adaptive behavior of arid flora in extreme hot and dry environment is the future thrust area in arid biodiversity research.

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Review Article

Papaya research and development in India- a review

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ABSTRACT

Papaya is one of the fruit crops that is grown both commercially as well as a backyard crop due to its delicious taste and high nutritive value. Among fruit crops it has highest productivity (42.85 MT/ha). Its production in India is 6.01 million tons from 0.142 million hectares, which is around 6 per cent share in total fruit production. Dramatic change in the production of papaya, from 0.805 million tons in 1991 to about 6.01 million tons currently is attributed to technological changes and improvement in value chain management. Systematic cultivation of new gynodioecious and dioecious cultivars coupled with adoption of improved agro-techniques have resulted increased yield, which was quite low (13 to 26 t/acre) during the seventies. Studies on the inheritance pattern has helped in identifying the parents as gene donors for several characters. Exploitation of heterosis is feasible as these characters are controlled by non-additive effects to a greater extent. In recent times crop improvement is being carried out with the objective of developing cultivars resistant to 'PRSV' coupled with desirable fruit traits. Intergeneric hybrids are being developed using wild genera *Vasconcellea* for imparting tolerance to 'PRSV'. The paper presents various facets and milestone of innovations, which has led to the transformation in papaya production of the country.

Keywords: Papaya, crop improvement, cultivars, nutrition, value addition.

INTRODUCTION

Papaya is one of the fruit crops that is grown both commercially as well as a backyard crop and can be grown in both the tropical as well in the subtropical regions of India. It has emerged as an important commercial fruit crop in recent years because of its high nutritive value (Vitamin A: 2020 IU, Vitamin B1: 40 mg, Vitamin C: 46mg, protein: 0.5% and mineral matters: 0.4%) and its availability at moderate prices. Being a highly cross-pollinated crop and since seed propagated it has resulted in considerable variation for size, shape, taste and pulp colour in the present-day varieties. The diversity coupled with varying agro-climatic conditions, especially with respect to duration allows the round year availability of fruits. Although, it is cultivated globally, India has emerged as the largest producer contributing 44.04 per cent to total world production with 6.05 million tonnes from an area of 0.149 million hectares (FAO, 2020). It is widely grown in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, West Bengal, Tamil Nadu, Bihar, Assam, Odisha, Manipur and some parts of Kerala. This has been made possible through dedicated research and development strategies leading to technological changes and adoption coupled with initiatives of Government and private sectors. The increasing demand and technological changes have revolutionized its production in India, which will continue with growing demand from domestic market as well as for export. The increasing population of country is a driving force for increasing demand. With growing health-conscious population, consumers must be ensured that the practices adopted for production of papaya is not likely to affect the health. Therefore, adoption of the Good Agricultural Practices (GAP) is becoming essential to ensure the quality However, full exploitation of papaya for yield has not been realized in an expected manner due to polygamous nature of crop that has resulted in large variability within a variety, highly sensitive to climatic conditions resulting in unstable varieties with high hermaphrodite sterility and all the varieties of *Carica* genus are susceptible to 'Papaya Ringspot Virus' (PRSV), which is a devastating disease world- wide as it has got several strains.

The objective of this article is to bring the attention of the reader on the development of papaya industry in India, which is unprecedented since independence. This is attributed largely to technological changes. Therefore, the focus is to describe the technological changes which have been adopted for improving production and productivity of papaya in India.

DEMAND IN DOMESTIC MARKET

Composition and volume of fruit production has changed with enhanced expandable income and growth in health-conscious population, which is driving force for increasing demand. This has resulted in expansion of papaya cultivation even under non-traditional areas. With growing health consciousness, consumers have to be ensured that the practices adopted for production of papaya is not likely to affect the health. Therefore, adoption of the Good Agricultural Practices (GAP) is becoming essential to ensure the quality. Now a days technologies were standardized for preparation of various processed products (concentrated fruit beverages, RTS, fruit bar, OD products and minimally processed products) which are having good demand in the market and may encourage several processing units even in rural areas. Thus, there is great demand for both fresh and processed products.

PRESENT STATUS OF PAPAYA PRODUCTION IN INDIA

India is the major producer of papaya in the world. During seventies, the production of papaya in India was quite low (13 to 26 t/acre) but in the current years the productivity (42.85 MT/ha) has increased mainly due to the constant efforts made in research and development. The production of Papaya in India during 1991 was at about 0.805 million MT but it has shown a steady increase and has reached production of 6.01 million MT in 2020 (NHB, 2020, Figure 1 and 2). This was possible partly due to the development of several superior cultivars from various organizations (both ICAR and SAUs) suiting to different agro climatic zones of the country.

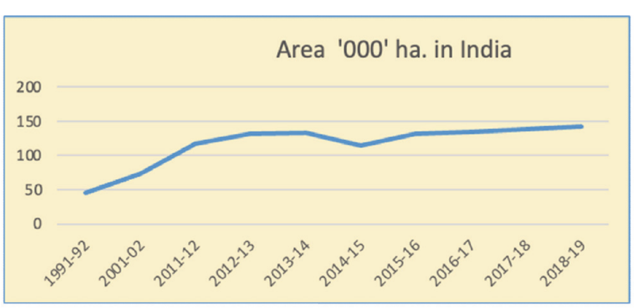

Fig. 1: Increase in area ('000' ha) for papaya production (NHB, 2020)

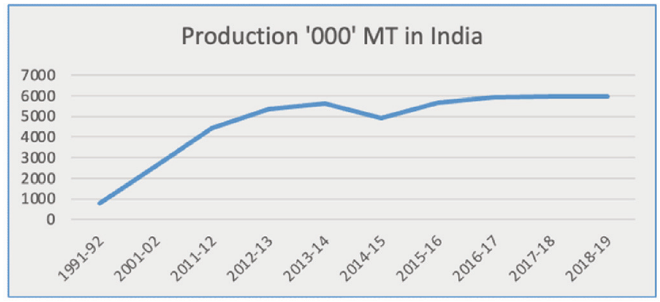

Fig. 2: Increase in production ('000' MT/ha) of papaya (NHB, 2020)

RESEARCH AND IMPROVEMENT IN PAPAYA IN INDIA

Introduction of varieties has played an important role in the development of papaya cultivation. Several attempts were made by papaya workers for improvement through various breeding approaches. Improvement of papaya by selection and sib mating has been the most successful method. Also, hybridization and selection to achieve homozygosity for the traits has given considerable success. Though, ploidy manipulation was attempted not much progress has been made (Singh 1953, 1963). In the early years, development of new varieties was taken up with the main objective of achieving the higher yield. Papaya breeding work in India could be broadly classified into three phases depending on the breeding objectives *viz.,* high yield and quality, development of medium sized gynodioecious varieties and in recent years the focus has been shifted to development of cultivars with 'Papaya Ring Spot Virus' (PRSV) disease resistance.

The earliest papaya breeding work was started at TNAU in 1965 and at Pusa in 1966. At ICAR-IIHR, regional station, Chettalli, one promising selection was made from 'Honey Dew' variety and identified as 'Coorg Honey Dew' (Aiyappa and Nanjappa, 1959). Systematic breeding at TNAU resulted in the development of several varieties (CO.1 to CO.8). The variety CO 1 was developed in the year 1971 (Sundarajan and Krishnan, 1984) and CO during 1972 (Madhava Rao et al., 1974) During the early eighties the focus was to develop varieties having medium sized fruits with good quality and high TSS. In this direction CO 3 and CO 4 were developed during 1983 (Veerannah et al., 1982). During 1985 CO 5 for papain (Veerannah et al., 1985) and in 1986 CO 6 (Kulasekaran et al., 1986) for dwarf stature were developed. Later, CO 7 (1997) was bred with pink pulp colour and gynodioecious nature and the recent development was CO.8 (2012) for dioecious, pink pulp with dual purpose.

At the 'Regional Fruit Research Station, Pusa, Bihar breeding work started during early sixties (1966 to 1982) resulted in the development of four superior cultivars Pusa Majesty, Pusa Giant, Pusa Delicious and Pusa Dwarf by following sibmating and selection for eight generations (Mansha Ram, 1982, 1984, 1987; Mansha Ram and Singh, 1984). At ICAR-IIHR, Bengaluru improvement work started in the seventies to develop gynodioecious types with pink pulp and superior quality, which resulted in the development of the Arka Surya during the year 1996 and Arka Prabhath in 2010.

Research work carried out at GB Pant Agricultural University, Pantnagar has resulted in the identification of Pant Papaya 1, Pant Papaya 2 and Pant Papaya 3 (Singh et al., 1984). At Punjab Agricultural University, Ludhiana, the cultivar Punjab Sweet (Singh et al 1992) was developed. At MPKV (Ganishkhind, Pune) the improvement work has resulted in the development of a dioecious cultivar Phule Vijaya (Washington x *Vasconcellea cauliflora*) for field tolerance to PRSV (Chalak and Hasbanis, 2017). At ICAR-Research complex Tripura, the improvement (Singh and Sharma, 1996) has resulted in the development of new hybrid HPSC-3 (Tripura Local X Honey Dew) with good yield potential. The regional station at Pune has developed selections viz., PS 1 and PS 3 for PRSV tolerance (Sharma and Tripathi, 2019).

As regards mutation breeding, very little work has been carried out. At Pusa, Bihar one dwarf mutant 'Pusa Nanha' was developed (Mansha Ram, 1983) through gamma irradiation (20-25 Kr using Pusa1-15 seeds).

The Papaya Ring Spot Virus (PRSV-P) is one of the major problems in almost all papaya growing regions of the country and worldwide. As the all the varieties under the genus *Carica* are susceptible to this disease, introgression of gene from the wild relatives is the only long-term solution for this. Thus, research is now being focused on the development of PRSV resistant types, involving wild genus *Vasconcellea* at ICAR institutes and SAUs. Some of the researchers found *Vasconcellea* species such as *V. cauliflora, V. cundinamarcensis* to be resistant against Papaya Ring Spot Viruses (Chalak et al., 2017), now the focus is on the development of PRSV disease resistant cultivars using the wild genus *Vasconcellea* as a source of resistance, as confirmed by several workers (Manoranjitham et al., 2008; Jayavalli et al., 2011; Sudha et al., 2013; Sharma et al., 2016; Linta et al., 2018; Pujar et al., 2019).

VARIETAL STATUS IN INDIA

Papaya being an exotic fruit crop, the varietal diversity available in the country is less. However, continuous research efforts made in this crop has resulted in the development of more than 19 cultivars, which are having commercial importance and their important traits are as follows;

VARIETIES DEVELOPED FROM TNAU, COIMBATORE

CO 1: It is a selection from the variety Ranchi. It was evolved by sibmating the cultivar Ranchi over a period of eight years. The plant is semi-vigorous, dioecious and the first fruiting takes place at a height of 60-75 cm from the ground level. Fruit is medium to big weighing around 1.5 kg and spherical in shape. Pulp is orange yellow in colour, medium firm, moderately juicy with a TSS of 12° Brix. Keeping quality is good and fruits do not have papain odour. It produces about 70 kg fruits per tree.

CO 2: It is a selection purified from a local type and it is dioecious in nature. Fruits are medium sized weighing about 1.5 kg. Fruits are obovate and skin is greenish yellow and ridged at the apex. Flesh is dark yellow in colour, soft to firm and moderately juicy. Fruit cavity is large and TSS is around 11° Brix. It produces about 70 to 80 kg fruits per tree. It has been mainly developed for papain extraction. It produces about 400-500 kg of dried papain per hectare.

CO 3: This is hybrid from the cross CO2 x Sunrise Solo and it is a gynodioecious variety. Fruits are obovate, smooth, weighing on an average about 800g. Fruit cavity is medium; pulp colour is red, firm and sweet to taste with a TSS of 13.5° Brix. Keeping quality is good. It has been bred for table purpose. It yields about 100 to 120 fruits weighing about 60 to 65 kg during the bearing period of two years.

CO 4: This is an improvement over CO 1. It is a hybrid progeny from the cross CO 1 x Washington. The fruit is round in shape; medium sized weighing about 1.3 to 1.5 kg. The tree has purple colouration in all parts of the plant. Pulp is yellow in colour firm and cavity is medium. It is quite sweet to taste with a TSS of 13° Brix. It produces about 80 kg of fruits per tree. It is dioecious in nature.

CO 5: It is a selection from the variety Washington and dioecious in nature variety producing fruits of about 1.5 kg. Pulp is yellow in colour and moderately soft. It gives 75 – 80 fruits per tree in two years with an average yield of 1500 to 1600 kg dried papain per hectare.

CO 6: It is a selection from the variety Pusa Majesty. It is dioecious in nature and dwarf in stature. It produces large sized fruits of 2 kg. It is a dual-purpose variety, being useful both for table and papain extraction. Pulp is yellow in colour, moderately firm with a TSS of 12°Brix. It yields about 745 kg papain/ ha. It yields about 60 kg fruits per tree.

CO 7: It is a hybrid from the cross Coorg Honey Dew x CP. 85. It is gynodioecious in nature and fruits weigh about 1.15 kg. Pulp is red in colour and cavity is small. TSS is reported to be 16.7 % under Coimbatore conditions. It yields about 340 tons per hectare.

CO.8 This is a red pulp dioecious variety developed by initial selective hybridization of CO.2 (yellow pulped) with red anthered male followed by intermating and repeated selection in segregating population for red pulp colour. Fruits are suitable for dessert purpose, pulping, processing (RTS, jam, tutti-fruity) and papain industry (Papain activity 138TU/mg). The fruits are big, oblong, weighing an average of 1.5-2.0 kg/fruit with a TSS of 13.5% with prominent apex. The tree can be economically maintained for 20-22 months under favourable condition with a yield potential of 230 t/ha when planted at a spacing of 1.8 x 1.8m.

VARIETIES DEVELOPED FROM ICAR – IIHR, BENGALURU

Coorg Honey Dew: It is a selection from Honey Dew and popularly called as Madhu Bindu variety. It is gynodioecious in nature and semi dwarf. Fruits are big sized, weighing about 1.75 kg to 2 kg. Fruits are dark green in colour and have slight ridging skin surface. Fruits from hermaphrodite trees are elongated and oval whereas, from female trees it is ovoid and not as long as bisexual ones. Pulp is yellow in colour, cavity large but with poor keeping quality. TSS in around 13.5^{o} Brix. It can be used for both table as well as for papain extraction.

Arka Surya: It is an advanced generation gynodioecious hybrid selection from the cross Sunrise Solo x Pink Flesh Sweet. The fruits are medium sized weighing about 600-800g. The pulp is deep pink in colour and firm. The TSS is about 13-14°Brix. The average yield per plant is about 60 kg.

Arka Prabhath: It is an advanced generation gynodioecious hybrid selection from the cross (Surya × Tainung-1) × Local Dwarf) with good yield potential. The fruits are big sized weighing 900-1200 g, firm and deep pink in colour with TSS of 13-14 ^{o}Brix and good keeping quality. The average yield is 90 - 100 kg / plant, has good keeping quality (storage life of 9 days when stored at RT of 25-30°C), fruit surface colour has a (redness) values of 26.3, firm pulp (5.9 kg/cm^2), good TSS (13%), sugars (10.7%), acidity (0.28%), Vit C (43.6mg/ 100g), carotenoids (3554µg/ 100g), lycopene (1469µg/ 100g) and pulp colour values (L-brightness 36.3; a-redness 16.8 & b-yellowness 21.0).

VARIETIES DEVELOPED FROM ICAR - IARI

Pusa Majesty: This is a gynodioecious line developed from the variety Ranchi by sib mating. It starts bearing at the height of 48 cm within 245 days after planting. The average fruit weight is about 1 to 1.5 kg. The fruit has firm pulp of 3.5 cm thickness with orange colour; fruit cavity is 17 x 9 cm. The TSS ranges between 9^{o} to 10 ° Brix. Its shelf life is good hence it is suitable for long distance transport.

Pusa Giant: This promising selection and dioecious in nature was developed by sibmating and selection from the variety Ranchi. Plants are vigorous and bear fruits of 2 to 3 kg, plant being highly vigorous it can stand well for storm and windy conditions. It bears first fruit at one-meter height. Pulp is yellow in colour and cavity is 18 x 10 cm, moderately firm and 5 cm thick. TSS is 7 to 8.5^{o} Brix. It yields about 40 kg per plant.

Pusa Delicious: This is a gynodioecious variety having medium sized plants. It is a high yielding variety developed by sibmating from the variety Ranchi. The first fruiting height is 80 cm. It starts bearing in 253 days after planting. The average fruit size is 1 to 2 kg. Fruits have distinct flavor, pulp is deep orange in colour, 4 cm in thickness and TSS varies between 10 to 13^{o} Brix. Keeping quality is moderate and seed cavity is 14 x 8 cm. It yields about 41 kg per plant.

Pusa Dwarf: This is a selection from the variety Ranchi developed by sibmating. Plants are dwarf in stature, dioecious in nature and are medium yielder. It is most suitable for high density planting and kitchen garden. Fruits are medium sized, weighing on an average about ½ to 1 kg and bears oval to round fruits. It bears fruit at the height of 40 cm above the ground level. Pulp is yellow in colour, moderate to firm 3.5 cm in thickness and cavity is 12x8 cm. TSS is between 6.5 to 8^{o} Brix. It yields about 40 kg / plant.

VARIETIES DEVELOPED FROM GBPUAT, PANTNAGAR

Pant papaya-1: This variety is a dwarf plant type (125 to 135 cm) bearing first flower at the height of 45 to 60 cm. Fruits are oblong and medium sized (1 to 1.5 kg), with good quality.

Pant papaya – 2: Plants are vigorous, medium in height (180 to 220 cm in the first year), and bearing first flower at the height of 80-100 cm from the ground level. It produces medium to large sized fruit (1 to 2 kg) of good quality, with a higher yield potential of 35 to 40 kg per plant.

Pant Papaya -3: Plants are vigorous with medium height (225 to 250 cm). It bears first flower at a height of 115-130 cm from the ground level. It produces small to medium sized fruits (0.5 to 0.9 kg) of excellent quality.

Varieties developed from PAU, Punjab

Punjab Sweet: This variety was developed by sibmating the lines obtained from Kenya. This line is dioecious in nature and bears fruits at a height of 103 cm from the ground level. Fruits weigh more than 1 kg and pulp is deep yellow and melting. It has an average yield of 50 kg fruits per tree. Its TSS ranges from 9 to 10.5° Brix. Fruit cavity is medium and it is moderately tolerant to cold.

GENETICAL STUDIES IN PAPAYA

With the generation of information on the inheritance pattern, breeding programmes are being taken up with the objective of incorporating a particular trait. Muthulakshmi et al., (2007) with the objective of introducing cold tolerance gene into cultivated type crossed dioecious variety CO 2 with its wild relative *Vasconcellea candamarcensis* and isolated three progenies for further forwarding to F_3 generation.

Correlation studies between traits are of great help in selecting suitable plant types and it is therefore important to establish genetic basis of correlations. Mansha Ram and Majumder (1984) and Arunachalam et al., (2021) in a correlation study with papaya lines observed that the fruit yield of papaya was highly correlated with fruit weight, leaf length and number of fruits per plant, while it was negatively correlated with fruiting height and number at first fruiting. Number of fruits per plant positively correlated with fruiting length, yield per plant, leaf length and plant girth. Weight of fruit was positively correlated with yield per plant; path coefficient value denoted that weight per fruit was having maximum direct effect on yield followed by number of fruits per plant and leaf length.

HETEROSIS BREEDING

Studies carried out to determine the heterosis have shown that it is possible and feasible to exploit heterosis. Dinesh et al., (1991), in a 6 x 6 diallel analysis observed that yield, fruit length, fruit breadth and TSS are maternally influenced in their inheritance. Shah and Shanmugavelu (1975), in a study of first-generation hybrids have indicated that yield is controlled by non-additive effects. Dinesh and Iyer (1993), suggested that selection for yield will not bring down quality characteristics like TSS and fruit cavity index. The varieties 'Coorg Honey Dew', Pink Flesh Sweet have been observed to be good combiners for yield and the varieties 'Waimanalo' and 'Sunrise Solo' for quality characteristics. Desikan (1972) has also reported heterosis for F_1's of CO1 x Coorg Honey Dew, its reciprocal and Washington x CO1, which had higher TSS compared to their parents. Khadi and Singh (1980) found that genotypic variability and heritability (broad sense) were quite high for yield per plant, number of fruits per plant, fresh and dry weight per fruit etc and additive genetic effects were recorded for leaf area, number of fruits per fruiting length, number of seeds per fruit and yield per plant. Ghanta and Mondal (1992) found that fruit per plant and number of leaves per plant showed high genetic coefficient of variation. Exploitation of heterosis is feasible as these characters are controlled by non additive effects to a greater extent.

RESISTANT BREEDING IN PAPAYA

Among biotic stresses, 'Papaya Ring Spot Virus' (PRSV) is a major limiting factor in improving papaya production. The virus was first recorded from western India in 1958 (Capoor and Varma, 1958) and since then it has spread throughout the country including Tamil Nadu. The virus isolates have been bio-typed to papaya infecting (Type P) and non-papaya infecting (Type W) types. Once introduced, PRSV has never been successfully eradicated from any region. In India breeding for resistance to Papaya Ring Spot Virus was started at Pune. The varieties screened were found susceptible to PRSV. It is reported that the wild species *Vasconcellea cauliflora, V. stipulata, V. cundinamarcensis, V. quercifloia* and *Vasconcellea cauliflora* were found to be resistant to PRSV. However, hybridization was not successful due to embryo abortion at 70-90 days and through *in vitro* culture hybrid plants were raised. In the F_1 generation progenies, some degree of resistant to PRSV was recorded (Phadnis et al., 1970; Pujar et al., 2019). The most effective and economical way to control PRSV is to incorporate resistance genes into papaya cultivars, thus avoiding the labor and expenses associated with preventive measures. Incorporation of resistant genes from wild relatives to the cultivated varieties is often hampered because of poor crossability, early embryo abortion, hybrid seed non-viability, hybrid seedling lethality and hybrid sterility due to incompatibility between the two genera. However, these post fertilization barriers in intergeneric hybridization are overcome by (1) the assemblage of diverse germplasm (2) application of growth hormones to reduce embryo abortion (3) improved culture conditions; (4) restoration of seed fertility by doubling the chromosomes of sterile F_1 hybrids and (5) utilization of bridge crosses where direct crosses are not possible. Subramanyam and Iyer (1984) observed that out of the several pollinations made between *C. papaya* and *V. cauliflora*, only one hybrid resulted, and even this limited success was achieved only by pollination on stigma smeared with five per cent sucrose. An attempt was made to overcome the intergeneric crossing barrier between *C. papaya* and *V. cauliflora*. Sucrose was used at different concentrations as a promoter to enhance pollen germination and tube growth. Sucrose at five per cent was observed to break the intergeneric barrier by enhancing pollen germination (Dinesh *et al*., 2007; Jayavalli, 2011; Thirugnanavel, 2010; Pujar et al., 2019).

The most effective way to minimize the losses due to PRSV infection is by combining host resistance and transgenic resistance developed by using viral coat protein (CP) gene. The virus isolates from India exhibited considerable heterogeneity in CP sequences. CP coding region varied in size from 845-858 nucleotides, encoding protein of 280-286 amino acids. PRSV isolates were divergent up to 11%. Though sequence variation could not be correlated with geographical origin of the isolates, yet the isolates from Southern India formed one cluster (Ramasamy et al., 2021). Available information only provides a partial profile of PRSV population from India. A number of aphids viz. *Aphis gossypii, A. malvae, A. medicaginis, Myzus persicae, Macrosiphum sonchi, Aphis citricola, A. craccivora, A. nerii, Acyrthosiphon pisum, Rhopalosiphum maidis, Lipaphis psuedobrassicae, Urolecon sanchi, Toxoptera citricida* either breed or colonize on papaya (Capoor and Verma, 1958; Bhaskar, 1983, Cheema and Reddy, 1985; Prasad and Sarkar, 1989; Ram and Summanwar, 1989). Further studies on virus vector relations revealed that the aphid vectors transmit the virus in a non-persistent manner (Bhargava and Khurana, 1970, Sharma et al., 1988). Studies conducted to document the dispersing aphid species in a papaya ecosystem and temporal fluctuations in aphid population as influenced by weather factors showed that *Aphis gossypii, A. craccivora* and *M. persicae* were the three major species of aphids caught in the trap, although *Aphis gossypii* was the major one and the peak catches of aphids were recorded during March-April and corresponding higher incidence of the disease during May (Kalleshwaraswamy et al., 2007). At ICAR-IIHR and TNAU, CBE intergeneric hybrids are being developed and the progenies developed have shown tolerance to 'PRSV'. Efforts are underway to evaluate them for fruit quality.

CONSERVATION OF PAPAYA GENETIC RESOURCES

Germplasm conservation plays an important role in the sustainable utilization of biological resources. The genetic resources of papaya are being conserved at several centres in the country through *Ex situ* method (Seed, conservation of plants in FGB, conservation of tissues or cells through *in vitro*, cryopreservation of pollen or seed / plant tissue and DNA storage). Among the different methods, seed conservation is the most suitable method for papaya as it is the commercial and practical means of multiplication. Being highly cross pollinated, seed purity can only be maintained by controlled pollination.

i. **Seed Conservation**: Conservation of seeds is an efficient and reproducible technique which is almost universally applied to the orthodox seed species. In the orthodox, the seed longevity is enhanced with decrease in moisture content and storage temperature. The studies conducted at ICAR-IIHR has shown that the seeds are orthodox in nature seeds can be dried to low moisture (<6%) and stored without affecting much loss in viability (Yogeesha et al., 2008). And the technology for seed storage has been standardized and can be stored for 16 months without drop in viability under ambient conditions (using moisture impervious containers) and for 24 months under controlled conditions (15 ^{0}C and 30% RH, seed moisture ranging from 6-8 % in moisture proof containers). Further ultra-dry seed storage carried out at ICAR-IIHR, has shown that seeds with 4-5 % moisture is ideal for medium to long term storage under ambient condition. And at 15 ^{0} C viability of ultra-dry seeds of papaya can be extended beyond 6 years (Yogeesha et al., 2017).

ii. **Cryo-preservation**: For long-term conservation of plant germplasm, cryopreservation is the only option. Studies carried out at IIHR, on pollen storage indicated that is a complementary genetic resource in the form of nuclear genetic diversity (Ganeshan and Rajashekaran, 1995). And the pollen cryopreserved at -196°C can be effective even after storage for eight years. The pollen of wild species *V. cauliflora* also showed germination to the extent of 82 to 83% (Shashikumar et al., 2005). This technique has also been used for intergeneric hybridization by storing the pollen of wild species (*V. cauliflora, V. cundinamarcensis,* and *V. parviflora*).

iii. Field gene Bank: The *Carica papaya* L. varieties and wild species are being maintained at various ICAR institutes and Agricultural Universities for maintenance breeding. The lines are being maintained by controlled pollination. A total of more than 80 accessions consisting of dioecious and gynodioecious types and wild species are being maintained at these centers.

iv. DNA storage: As a complementary technique, the DNA of the released varieties, promising types and wild species are being maintained at ICAR Institutes and SAUs that are being utilized in the papaya improvement.

QUALITY PRODUCTION OF PLANTING-MATERIAL

Conventional vegetative propagation techniques such as layering, grafting and rooting of cuttings have not resulted in efficient mass propagation of papaya. Due to cross-pollinated and seed propagated nature, variation in plant traits has been expressed in the population. Thus, vegetative propagation from selected clones is highly desirable for obtaining uniform plant with good yield potential. Rapid clonal propagation of desired genotypes is one of the applications of plant tissue culture. Hence, successful micro propagation technique of papaya is an urgent need for improvement. Research work carried out at ICAR-IIHR has resulted in the development of micropropagation protocol using shoot-tips from seedling grown explants under protected condition. As extremely high rate of microbial contamination by endogenous bacteria from mature plants of the field has been one of the major obstacles for the successful sterile culture of papaya (Thomas *et al*., 2007). For micro-propagation, early detection of the sex type of a particular papaya seedling would be advantageous since the desired sex type can be selected prior to micropropagation. This was achieved using molecular marker SCAR W11and T12. A higher success rate of tissue culture was found sub-culturing plantlets onto media with indole- 3-butyric acid (IBA) than with NAA. Indole-3-butyric acid (IBA) 10 µM was effective for inducing profuse rooting and plantlet formation on 1 cm in length shoots of papaya (Pandey and Rajeevan, 1983). Rooting was observed on shoots from fourth subculture of papaya with IBA 20 µM but plantlets produced and successfully hardened and field transplanted (Rajeevan and Pandey, 1986).

NUTRITION AND FERTILIZATION OF PAPAYA

Commercial papaya culture requires adequate nutrients and water supply to remain productive throughout the whole growth and productive cycle. Every growth phase is critical and any deficiency in nutrients would immediately reflect on the flowering and fruiting of papaya. It is an exhaustive crop requiring heavy and continuous supply of nutrients in order to sustain its high yield potential and also due to the indeterminate growth habit with simultaneous vegetative growth, flowering and fruiting (Jauhari and Singh, 1971; Purohit, 1993; Kumar, 1995, Kumar, 2008; Jhade et al., 2020). Factors such as soil types, rainfall, locations, cultural practices, and age of plant influence fertilization practices.

A dose of 250 g N, 250 g P_2O_5 and 500 g K_2O per plant per year applied in six split doses at bimonthly interval was found to be the best for the cv. Coorg Honey Dew which resulted in an estimated yield of 186.8 t per ha (Purohit, 1977). In Solo variety, 250 g N, 250 g P_2O_5 and 200 g K_2O per plant per year applied in six split doses was the best when spaced at 2 x 2 m (Sulladmath *et al*., 1984). At Coimbatore, for CO.1 papaya, 200 g each of N, P_2O_5 and K_2O per plant in split doses during the 1st, 3rd, 5th and 7th month after planting resulted in high yield (Satyanarayanan Rao, 1974). In CO. 2 papaya, application of 250 g N per plant per year in six split doses at bimonthly interval commencing from second month after planting was found to be optimum for good fruiting and papain yield (Irulappan *et al*., 1984). The maximum yield was found with higher fertilizer dose of 400g N, 350g P, 600g K (Hari and Bindu, 2021). In various trials, better response has been registered up to 250 g of N and 250 g of P and application of N and P at the same rates produced better results. However, time of application, may depend upon of season and availability of moisture. Application of K reflected in better fruit quality especially in TSS.

The higher fruit weight and more fruits were recorded with higher levels of nitrogen and phosphorus application (Sulladmath et al., 1984; Biswas et al., 1989). The soil application of 25 mg PP_{333} and spraying of 0.4% amino acid mixture along with recommended dose of NPK 300:300:300 g /plant/ year was found to be effective in improving economic traits. Foliar spray of GA_3 (150 PPM) and NAA (20 PPM) was found to increase the number fruits per plant and fruit weight was greatly influenced by spraying 3, 5 tri-ido benzoic acid @ 150 PPM (Ram, 2017; Auxcilia et al., 2020).

Fertigation of the papaya tree is extremely advantageous and should be encouraged, as long as it is correctly done, especially when localized irrigation is involved. All India coordinated trials revealed that application of 10 litres of water per day with 6 g each N and K_2O per week through fertigation and soil application of 45 g P_2O_5 per plant at bimonthly intervals improved growth, yield and quality characters of CO.7 papaya (Agrawal et al., 2021). In papaya cv. CO. 7, it was observed (Jeyakumar *et al.* (2008) that application of 100 per cent recommended dose of N @ 6.25 g week^{-1} and K_2O @ 6.25 g week^{-1} through drip irrigation in addition to soil application of 50 g P_2O_5 at bi monthly intervals resulted in increased number of fruits and fruit weight leading to higher fruit yield per tree (73.97 kg) and fruit yield per hectare (184.9 tonnes).

Effect of Micronutrients

Micronutrients play a major role in crop production due to their essentiality in plant metabolism and also to overcome the adverse effects due to their deficiency. In general, foliar application of Zinc Sulphate @ 0.5 % along with 250 g zinc sulphate as soil application significantly enhanced the quality of fruits in papaya (Jeyakumar et al., 2008).

Boron plays an important role in improving the fruit set. According to the Department of Agricultural Research and Education, ICAR, Government of India (1999-2000), in papaya variety Solo, fruit set was increased by 20% either by soil application or foliar spraying of boron. Application of boron had increased Ca in fruits which is an important element to increase the shelf-life of papaya. Deficiency of lime and B had often been observed in papaya orchards. Spraying of 0.5% zinc sulphate (twice) and one spray of borax (0.1%) may be done depending upon the nutrient status of soil. Application of 250 g N and 600 g K per plant per year with micronutrients of B, Zn, Mn, Cu and Fe (40 ppm each) had resulted in an yield of >100 t/ha in cv. Ranchi (Biswas, 1981). Foliar spray with borax @ 0.50% + zinc sulphate @ 0.25% had resulted in better growth, yield and fruit quality (Kavitha, 2000; Chandrashekhar *et al.,* 2010). Application of $ZnSO_4$ @ 0.5% and borax @ 0.3% recorded maximum plant height (175.6 cm) and total yield ha^{-1} (84.90 tonnes) along with increased levels of ascorbic acid (52.60 mg/100g), TSS (11.19%), reducing sugar (6.74%) and total sugar (8.12) in papaya cv. Taiwan Red Lady (Kumar et al., 2021).

The best performance of papaya was recorded by following integrated nutrient management approach (Kanwar et al., 2020) as it was found to reduce infection by transplanting in October and with a heavy dose of manure (10 kg FYM, 2 kg castor cake, 1 kg cake-o-meal, 200 g N, 200 g K_2O and 200 g P_2O_5 per plant per year) applied in two splits (once in June and 3 months later). Papaya plants treated with humic acid @ 2ml-4ml/plant at monthly interval + Foliar spray of micronutrients @ ZnSO4 (0.5%) + FeSO4 (0.5%) + MgSO4 (0.5%) + CuSO4(0.5%) +Boric acid (0.1%) at 3rd, 5th and 7th MAP + biofertilizers viz., AM Fungi @ 50g/pit, *Azospirillum* @ 20g/pit, Phosphobacteria @ 20g/pit at planting and 6th month after planting increased plant growth characters and potential yield (Deepika, 2014). Combined application of organic and inorganic growth stimulants individually had beneficial effect on yield and quality of papaya.

At ICAR – IIHR, Bengaluru research on increased water use efficiency and partial root zone drying revealed that scheduling the irrigation at 40 % evaporation replenishment through shifting of laterals had resulted in enhanced water use efficiency under limited water situations (Manjunath et al., 2017). Standardization of spacing and soil volume wetting for drip irrigation under water scarcity (Manjunath et al., 2020) indicated that irrigating papaya to meet only 30 per cent of soil volume through a package of 1.5 m x 1.5 m spacing by enhancing water use efficiency to the highest level (129.04 kg/ha).

VALUE ADDITION IN PAPAYA

i. Papain production: The papain is a milky latex which oozes out from green fruits when lanced and it contains a protein hydrolyzing enzyme (protease or proteolytic enzyme). In recent years, the demand for papain has increased in several states. Hence papain is produced at a commercial scale. Some achievements made on papain production are the improved varieties (CO.2, CO.5 and CO.6) from TNAU and Pusa Majesty from IARI, Pusa. The lanced fruits after latex collection are being utilized for processing. Standardization of papain-production technology from green papaya fruits is responsible for stabilizing papain industry as a commercial venture.

ii. Processing: There is an excellent opportunity for making use of both ripe and matured fruits of papaya into different processed products. The raw papaya fruits can be processed to give different products like tutti-frutti, Pickle, jellies and candies while ripe fruit can be processed to canned papaya, papaya nectar, canned papaya pulp, papaya bars, papaya toffee, osmotically dehydrated products and also it can be blended with other fruit pulps to use either in juice or fruit bar preparation. Blending of papaya (Coorg Honey Dew) and mango pulp (Alphonso) (0-50%) before juice making was studied for ready to serve juice making in order to improve the overall acceptability of papaya juice with an improvement in Vitamin C content over mango juice. The juice having 20% of blended pulp, 20^o Brix and 0.3% acidity was prepared heated to 85^{o}C filled into sterilized bottles, sealed with crown and heat processed. Blending of papaya to an extent of 30% produced acceptable quality of juice (Gowda, 1995). Papaya sauce from the extracted pulp of ripe fruits has been prepared by Kamin et al., (2011).

Minimally processed product from cut pieces of ripe papaya has also been prepared (Alam et al., 20130. Tiwari (2019) at IIHR, were successful in preparing fortified papaya fruit bar enriched with different nutrients. The papaya fruit bar was prepared by raising total soluble solids (TSS) of papaya pulp (9.8^o Brix) with skinned milk powder (25%), aspartame (0.1%) citric acid (0.6%) and different proportions of pectin (0.0, 0.2, 0.4 and 0.6%) 100 ppm bio-preservative was added and dried at 60$\pm$2^{o}C in four steps of 2.0 ha each with 1.0h time intervals in between two consecutive steps. The supplemented fruit bar was folded in butter paper, packed in aluminum foil and stored at RT (20-45^{o}C) for 7.5 months. The quality of SMP papaya fruit bar with 0.4% pectin having storage life upto 5 months was satisfactory (Singh et al., 2002). At ICAR-IIHR, the technologies developed for preparation of various products of papaya fruit *viz.,* 'Fruit Bar', RTS and Squash etc., are licensed to various private companies to promote the papaya industry.

EMERGING CHALLENGES AND APPROACHES

Some of the challenges are not bigger but need emphasis and implementation, some need inter-regional support for expression of better dynamism which will be visible in terms of output. Broadening of genetic base through intensification of collection missions and development of strong breeding programmes; development of varieties to suit the regional needs of small and marginal farmers, innovation of varieties with broad spectrum of adaptability to limited water resource utilization; bio-technological tools of improvement and fertilizer tailoring and judicious water harvesting and use of technologies to economize on the production cost are some of the issues which need attention. Ensuring quality of planting material using indexing and fidelity testing tools and efficient supply chain system with integration of quality control is needed. To contain the disease spread, knowledge on common disease forecasting models with information on distribution, spread, strains and dispersal pathways are essential. In case of its inadvertent entry into a new region, it is essential to be ready with contingency plans to combat the situation of disease outbreak. Development of non-chemical control strategy in terms of resistant cultivars, improved crop dynamics, biotization with endophytes and non-pathogenic Fusarium forms would be one of the approaches to control (fungal disease) collar rot and anthracnose. It would be essential to develop quick diagnostic tools for papaya diseases and rationalization of the existing diagnostic protocols.

FUTURE THRUST

Papaya, although has varied uses, papaya cultivation for processing and papain production has become a profitable venture in India. There is a need to effectively conserve wild spp and to use them extensively in the breeding programme along with the use of new biotechnological tools viz., CRISPR to develop varieties tolerant to 'PRSV'. Vegetative propagation holds immense value in the intergeneric hybridization, as resistance can be fixed in the F_1's. The use of efficient production technologies viz., water budgeting and carbon sequestration, growing papaya in shade net houses, crop protection technologies involving integrated management for major fungal and viral diseases, strengthening of value addition and processing are some of the pressing needs, which should be looked into so that GAP can become more vibrant.

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Review Article

Seventy five Years of research and development in litchi

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ABSTRACT

India is the second-largest producer of litchi after China in the world however national productivity of India is higher than China.It is a highly valued fruit that ensures farmers' income besides providing nutrition security to the consumers. The area under litchi is increasing in non-traditional areas due to scientific interventions so as the production, which is also showing increasing trends. Considering the importance of the crop in the country ICAR-National Research Centre on Litchi was established in 2001. The Centre has developed several productions and post-harvest management technology, and high-yielding varieties to improve productivity and shelf life of litchi fruits. Shahi occupied a major area in the country and Muzaffarpur, Bihar is known for the best quality production of Shahi litchi which also has GI Tag. Resultantly, now the focus is on the export of litchi and many companies have started working for the export of litchi from the country. The paper presents various facets and milestone of innovations which has led to the transformation in litchi production in India in the last 75 years.

Keyword: Litchi, China, India, technological changes, National Horticulture Board

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an evergreen fruit crop that requires a lower temperature in winter before flowering. It is commercially grown in a few countries due to its specific climatic requirement. China, India, Australia, Thailand, Taiwan, Vietnam, Africa, Mexico, and Central and South America are major litchi grower countries. The total world litchi production is around 2.11 million tons, in which Asia shares more than 95% of the area and production. China, India, Thailand, Taiwan, and Vietnam are the top five litchi-producing countries in the world. India and China contribute to more than 90% of the world's litchi production. India is the second-largest producer of litchi in the world. Over the years, significant growth has taken place in the area and production of litchi in the country. The Indian, as well as world markets of litchi, is expanding fast which opens up the further scope of this crop in the future. Litchi introduced in the country in the 18th century through North-Eastern states and established well in Gangetic plains having preferred soil and climate. Indian Litchi is mainly ready to harvest during the first week of May in eastern states to the last week of July in the Himalayan region of the Indian continent. However a small window of fruit availability exists during December-January in South India. India shares about one-fifth of the world litchi production with higher productivity than China. Other notable producers of litchi are Taiwan, Thailand, Vietnam, Australia, Mexico, South Africa, Hawaii, Florida, and California. The area and production of litchi in the country have increased in the last 75 years. The area of litchi has been increased from 9,400 ha in 1949-50 to 1,04,000 ha in 2021-22. The share of litchi to the total area under fruit has increased from 0.75 to 1.70 percent. The increase in area between 1991-92 and 2021-22 (30 years) has been more than 80 percent, while production increased during the same period is to the tune of above 150 percent. Productivity also recorded an increase of approx. 50 percent during the same time. Evidently, the production, as well as productivity of litchi, is constantly increasing in the country since independence.

History

The litchi originated in southern China, possibly Guangdong province and northern Vietnam seems to have been cultivated since 1500 B.C., by the people of Malayan descent where it is growing for more than 2,300 years (Li, 2008).The litchi reached Burma by the end of the 17th century and it was introduced in India about 300 years ago through Kingdom of Tripura from where it spread to Bengal and Assom. From Bengal, it spread to other parts of India and the rest of the tropical and subtropical regions. In India, due to suitable soil and climate, it was established as an orchard in Bihar and Bengal and sub-mountainous districts of Uttar Pradesh in the 19th century (Pandey and Sharma, 1989). It was introduced into Florida in 1883 from Saharanpur (India) and was carried from Florida to California in 1897. The fruit reached Europe in the early 19th century, but it never succeeded there (Hayes, 1953). The earliest known monograph on the fruit is a treatise written on litchi by Tsai Siang in 1059 A.D., which deals with the cultivars, areas of cultivation, methods of fruit preservation and popularity of the fruit growing during that period (Groff, 1921). The book by Groff (1921a) was probably the first comprehensive publication on litchi in English. The book written by Singh and Singh (1954) is the first Indian publication towards the identification of litchi cultivars grown in India.

Its home land China still remains leading in litchi in the world and southern provinces particularly Guangdong and Fukien are the main centres of production. *Litchi chinensis* Sonn. has various common names, viz. litchi, lychee, lici, li-ci, leechee, etc. (Hayes, 1957). In Thailand, it is called lin-chi while Malayan names are kalenkeng, lingking, laichi etc. and in China, it is termed as lizhi (Paull and Chen, 1987).The litchi is a highly environmentally sensitive fruit tree. It is well adapted to the tropics as well as warm sub-tropics between 13° to 32° N and 6° to 29° S. It grows best with winters that are short, dry and cool, but frost-free weather with temperatures around 15°C or lower and summers that are long and hot favours successful flowering. Due to this reason, its cultivation is restricted to a few countries in the world. In India, commercial cultivation of litchi is confined to the Northern parts of the country, particularly in the foothills of the Himalayas from Tripura to Jammu and Kashmir and Gangetic plains. The harvesting period of litchi is limited from May to June in north India but in South India, it is harvested during December–January and fruit is available during the off-season. The foothills areas of the Himalayas, i.e.Terai belt which is free from frost and offers good scope for litchi cultivation. Recently, it has been observed that litchi is performing well in some non-traditional areas (Southern India), particularly in above 800-900 m altitude. These include Kerala (Wynad, Idukki), Karnataka (Kodagu, Chikamangaloor), Tamil Nadu (Shevaroy Hills, Lower Pulneys and Gudalur), Andhra Pradesh (Vizag), Odisha (Raigarh), Chhatisgarh (Ambikapur), Maharashtra (Thane) and Gujarat.

In India and abroad, the nomenclature of the litchi cultivars is confusing with the presence of homonyms and synonyms. The confusion emanates due to derivation by translation from Cantonese and Mandarin to English (Goren *et al*., 2001). In a different area, the same cultivars have a different name and different cultivars may have the same name. Similarly, the same cultivars have different names in different dialects. Another source of confusion that is very difficult to resolve is the erroneous identification of varietiesthat closely resemble a certain cultivar as the genuine cultivar. Thus, some cultivars may consist of a mixture of genotypes. In the course of litchi dissemination to other countries, the confusion in cultivar identities increases. Many introduced cultivars lost their identity entirely or were misidentified. Cultivar identification of litchi has been based on morphological traitsmainly vegetative, floral and fruit characteristics and harvesting season (Batten, 1984). Considering the importance of litchi, Govt of India has established a fully dedicated ICAR-NRC on Litchi at Muzaffarpur, Bihar to provide technical support and promote litchi production in the country and solve the arising problems in litchi identification, germplasm resource management, cultivation practices and improved marketing including export.

CHANGING DEMAND IN DOMESTIC MARKET

The area and fruit production under litchi have changed due to its high demand and pharmaceutical values. The enhanced income and developing in health-consciousness among the population acted as driving forces for increasing demand for litchi in the domestic markets. This has resulted in an expansion of litchi cultivation even in non-traditional areas like Kerala, Karnataka, Tamilnadu, Maharastra and Madhya Pradesh. Nowadays, consumers are more conscious of health hence it has to be ensured by the growers that the practices adopted for litchi production will not affect the health of consumers. Litchi is a highly demanding fruit during summer in India. Due to the increasing demand in various parts of the country, its area and production are continuously increasing. According to horticulture statistics, the area of litchi was 90000 ha in 2016 which increased up to more than 1,00,000 ha by 2020 in India. Similarly, production was about 5,59,000 metric tons in 2016 which increased to 7,40,000 metric tons by 2020. Bihar shared nearly 50% of the total country's production, followed by Jharkhand, Chhattisgarh and Assam. Shahi litchi occupies a major area in the country. In India, the government and private companies have been taking initiatives to boost more value addition, exports, and value realization in litchi by the farmers. ICAR-National Research on Litchi (NRCL), Coca-Cola India, DeHaat, and Kedia fresh partner launched an initiative in Bihar called 'Unnati Litchi' in 2020 which aim was to enhance the efficiency of the agricultural value chain and capability of farmers for building high-density planting in litchi, farmer training for good horticultural practices (GHP), and the establish demo orchards through scientific support. The increasing demand for fresh products worldwide and favourable government policy helped in the growth of the litchi market nationally and internationally.

Vietnam established an agreement in 2019 with litchi farmers for the export of litchi to Japan. However, the pandemic trade restrictions posed a major roadblock for the exports from Vietnam. This unprecedented disruption due to covid-19 in the functioning of both the market demand and supply posed a barrier for all the stakeholders in the world. China is a lead producer and an exporter of litchi in the world. According to International Trade Centre (ITC) Trade Map, China exported fresh litchi of USD 53.2 million in 2020. China mainly exports to Europe and the United States. The rising demands of healthy litchi in these markets increased the export of litchi. According to General Administration Customs China (GACC), China (Guangdong province) exported 5,902.1 metric tons of litchi in 2020 which was 72.3% more in comparison to the year 2019. Madagascar also occupied a good position in the European market. The rising demand for litchi in France and other EU countries is supposed to boost litchi imports in the future. Thus, the demands of litchi in many countries are increasing tremendously. The fresh fruit market of litchi dominates the trade, followed by dried and canned products. The main litchi importing countries are Singapore, Canada, Japan, Hong Kong, the European Union and the United States. China, Thailand, Madagascar, Taiwan, Australia, South Africa, and Mexico are major litchi exporter countries. Litchi is exported to different countries from India has been given in Table 1.

PRESENT STATUS – WORLD VS INDIA

The world litchi production is estimated to be more than 6.0 million tons of which around 70% (4.2 million tons) of litchi is produced in China. India (0.74 million tons), Vietnam (0.38 million tons), Madagascar (0.10 million tons), and Thailand (0.048 million tons) are other major litchi producing countries. Litchi is also grown in Australia, Bangladesh, South Africa, Brazil, and Israel. USA, Hong Kong and Malaysia are major importers of fresh litchi from China. A small amount of litchi (about 150 tons) was exported from India (Mitra and Pan, 2020). Litchi is growing in1,04,000 ha with a production of about 7,40,000 MT. Bihar is the major litchi-producing state in India accounting for about 37% of both national acreage and production. The major litchi growing states are presented in fig 1. Muzaffarpur is famous for its Shahi litchi and is popularly referred to as the 'Litchi City' or 'Litchi Hub'. Recently, Muzaffarpur and adjoining areas have also been awarded the 'GI' tag for Shahi litchi. Bihar is followed by West Bengal, Jharkhand and Assam in terms of production, while the highest productivity of litchi (16 MT/ha) is reported from Punjab. In this regard, ICAR-NRCL has been instrumental in bringing newer areas under litchi cultivation, especially in Southern India (Kerala, Karnataka and Tamil Nadu) and North-Western India (Western UP, Punjab, Haryana, and Jammu).

Table 1: Export of Litchi from India

Country	2016-17		2017-18		2018-19		2019-20	
	Qty (MT)	Rs. Lacs	Qty (MT)	Rs. Lacs	Qty (MT)	Rs. Lacs	Qty (MT)	Rs. Lacs
Nepal	52.61	29.56	100.82	43.07	138.15	48.53	126.58	35.67
United Arab Emirates	20.37	52.68	5.10	10.78	10.46	56.87	6.69	8.49
Thailand	50.00	20.93	0.0	0.0	0.0	0.0	0.0	0.0
Kuwait	0.33	0.46	0.29	0.58	0.19	0.39	0.0	0.0
Canada	0.2	0.18	0.0	0.0	0.01	0.01	0.15	0.10
Qatar	0.05	0.06	0.0	0.0	1.74	2.76	0.54	0.50
United Kingdom	0.0	0.0	0.0	0.0	0.11	0.07	0.91	0.83
Bahrain	0.0	0.0	0.25	0.09	0.79	1.83	0.24	0.10
Oman	0.0	0.0	0.0	0.0	5.76	23.06	0.0	0.0
Singapore	0.0	0.0	0.0	0.0	0.49	0.23	0.13	0.03
Others	0.46	1.20	1.78	3.46	2.27	3.52	0.0	0.0
Total	124.02	105.07	108.24	57.98	159.97	137.27	135.26	45.74

Source: Horticultural Statistics at a Glance 2018 and APEDA website, 2022

Pockets such as Nilgiris, Wayanad, Idduki, Palani hills, Araku valley, Shahdol, Lakhimpur Khiri, Muzaffarnagar, Karnal, Yamunanagar, Pathankot, Peren etc. deserve mention where litchi cultivation is seeing unprecedented growth. Western UP, Eastern Haryana, and hills of South India have been identified as high potential areas for litchi cultivation. The area and production of litchi have increased in the country in the last 15 years (2005-06 to 2020-21) as shown in Fig. 2. The different states' share in the area and production of litchi are presented in Table 2. There is a wide range of variations in productivity among the different states. China and Vietnam are the two major exporters of litchi. Southeast Asian countries share 19% in the global litchi market. According to Litchi Cooperative, Guangdong, they exported litchi of valueabout USD 10.0 billion in 2018. China mainly exports litchi to Canada, the United States and Europe. Vietnam was the 2nd largest exporter of litchi during 2018. Vietnam's litchi is highly demanding due to better quality as compared to Indian and Chinese litchi. Around 98-99% of the litchi produced in India is domestically consumed. Currently, Indian litchi is exported mainly to UAE, Nepal, Thailand, France, Saudi Arabia, Canada and several other countries. The Agricultural and Processed Food Products Export Development Authority (APEDA) and the National Agency for Export Development (NAFED) are the major export promoters of litchi fruits in the country (APEDA, 2017). The demand for Indian litchi is increasing from the USA, Europe, Arab nations and other countries.

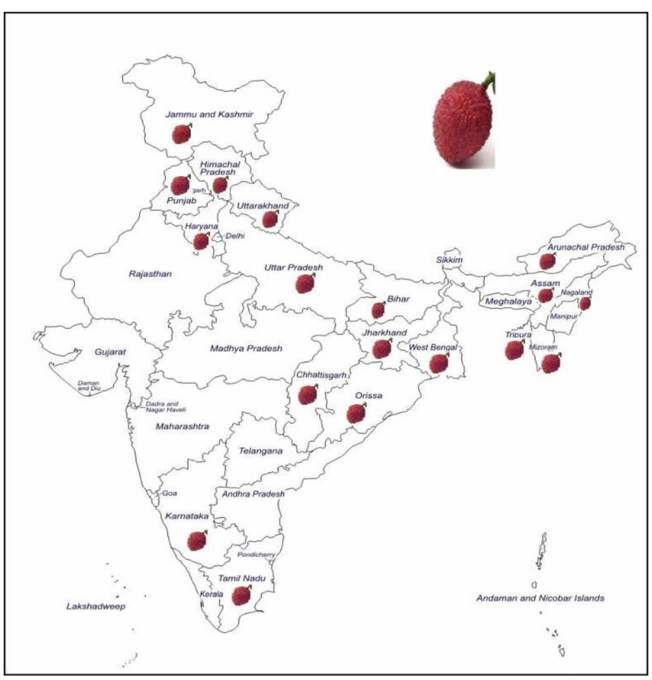

Fig.1: Major litchi producing states of India

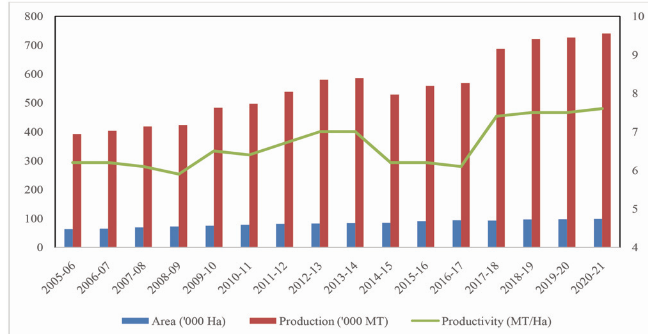

Fig. 2: Area, production and productivity of litchi over 15 years

Table 2: Share of area and production of litchi in different states

Country	2016-17		2017-18		2018-19		2019-20	
	Qty (MT)	Rs. Lacs	Qty (MT)	Rs. Lacs	Qty (MT)	Rs. Lacs	Qty (MT)	Rs. Lacs
Nepal	52.61	29.56	100.82	43.07	138.15	48.53	126.58	35.67
United Arab Emirates	20.37	52.68	5.10	10.78	10.46	56.87	6.69	8.49
Thailand	50.00	20.93	0.0	0.0	0.0	0.0	0.0	0.0
Kuwait	0.33	0.46	0.29	0.58	0.19	0.39	0.0	0.0
Canada	0.2	0.18	0.0	0.0	0.01	0.01	0.15	0.10
Qatar	0.05	0.06	0.0	0.0	1.74	2.76	0.54	0.50
United Kingdom	0.0	0.0	0.0	0.0	0.11	0.07	0.91	0.83
Bahrain	0.0	0.0	0.25	0.09	0.79	1.83	0.24	0.10
Oman	0.0	0.0	0.0	0.0	5.76	23.06	0.0	0.0
Singapore	0.0	0.0	0.0	0.0	0.49	0.23	0.13	0.03
Others	0.46	1.20	1.78	3.46	2.27	3.52	0.0	0.0
Total	**124.02**	**105.07**	**108.24**	**57.98**	**159.97**	**137.27**	**135.26**	**45.74**

Source: Indian Horticulture Database, 2017

RESEARCH AND DEVELOPMENT IN LITCHI

There is a need for improving productivity, quality and widening genetic variability, for which dedicated research efforts are needed. Suitable cultivars are required which can adapt in different agro-climatic conditions. It is required to develop promising cultivars which have heavy fruit, small seeds, high pulp, tolerance to sun burn and fruit cracking, and extra early and late maturity. Being an introduced crop, litchi hasa narrow genetic base in the Indian subcontinent, which needs to be widened. There is a need for identification and evaluation of local clones and varieties of introduced cultivars, which are regular and early bearers vis-à-vis fruits with small seeds. Target-oriented programmes should be focused so that genotypes of litchi can be conserved and used. A systematic approach is required to describe the cultivars (Singh and Babita, 2001). The genetic improvement of litchi worldwide has been carried out throughthe selection of open-pollinated seedling trees of known cultivars. There is a demand for high quality, early and late-season cultivars (Froneman and Oosthuizen, 1994). Despite the enormous potential of litchi cultivars, an ideal litchi cultivar for modern conditions is lacking. The existing old cultivars appear to have been selected for characters like fruit size, quality and period of maturity. However, the qualitative fruit characters, precocity, dwarfness and regular bearing, wider adaptability and resistance to physiological disorders in fruits are of vital importance and must be utilized for the development of cultivars for improving the productivity per unit area. As the fruit characters are of great interest to the fruit growers, the nature of the attachment of the flesh to the seed, the size and maturity of seed and prickly or smooth surface of the skin, as well as colour of fruit are of major importance. A highly valued characteristic of litchi under intensive culture is the immaturity of seed, which results in seedless fruits. The Chinese refer to these as chicken tongue seeds. This character is present only in a few cultivars e.g. Early Seedless and Late Seedless of Indian origin, No Mai Tsz and Kwei Sei of the Chinese origin and Brewster, a seedling selection of Chen Family Purple of Fukien in Florida, USA.

Similarly, attractive highly coloured pearl and fleshy aromatic aril characters are also limited to a few cultivars e.g. Rose Scented, Kwai Mi and Heung Lai. Practically, no breeding work has been taken up for the varietal improvement and to evolve an ideal cultivar. Breeding programmes so far initiated outside China, at Miami, Florida, Queensland, Saharanpur, Sabour and Muzaffarpur in India, could not much success to develop hybrid cultivars (Singh *et al.,* 2012). In the Horticultural Garden of Bihar Agricultural College, Sabour, litchi cultivars like Deshi, Dehra Rose, Ajhauli, Purbi, Early Bedana, Bedana, Shahi, Kasba, China and Mandraji are used in hybridization work and altogether 125 hybrid plants of different age groups are under screening. In the year 1991, for the first time 14 years old hybrid plants i.e. Hybrids No. 72, 73 (Purbi x Bedana), Hybrid No. 98 (Purbi x Early Bedana) and Hybrid No, 140 (China x Bedana) produced fruits (Singh *et al*., 2012). For the development of litchi as a main fruit crop in the tropics and sub-tropics, evaluation of ideal cultivars through breeding is essential (Chauhan, 2001).

In Asia, the cultivation and selection of litchi have been started for thousands of years. Kwai May (Red), Haak Yip, Zee Siu, Lanzhu, Bah Lup, Baitang-ying, No May Chee and Wai Chee are major cultivars of China. The litchi industry in many other countries is based on cultivars that have originated in China, e.g. Tai So and Wai Chee in Thailand, Kwai May Pink, Tai So and Wai Chee in Australia. India, Nepal, Vietnam and Bangladesh have seedling selections of Chinese cultivars. Cultivars developed in the last 50-60 years that are becoming popular are Donguan Seedless, Hexiachuan and Maguili (in Guangdong, China), Sah Keng (Taiwan, China), Kom and Chacapat (Thailand), UPLB Red (The Philippines) and Salathiel (Australia). Traditional breeding improved productivity rather than molecular breeding. The Chinese claim that litchi has more cultivars than any other fruit. The main cultivars in Guangdong are Bah Lup, Baitang-ying, Haak Yip, Fay Zee Siu, Kwai May, No Mai Chee and Wai Chee. Wai Chee accounts for over 80 per cent of plantations in Guangxi and bears consistently because it flowers late and avoids cool weather in spring. In Fujian, Lanzhu dominates litchi plantations. Donguan Seedless and Hexiachuan are recently developed that produce seedless/small-seeded fruits and Maguili is a late cultivar. Kwai May and No Mai Chee are suitable for fresh eating and a higher proportion of chicken-tongue or aborted seeds. Fay Zee Siu is big size fruit (24-32 g) that has excellent quality (Bose *et al*., 2001). Haak Yip is the most popular cultivar in Taiwan Province of China and accounts for over 50 per cent of the litchi plantations. Other important cultivars include Sum Yee Hong, No Mai Chee, Chong Yun Hong and Sah Keng (Bose*et al.,* 2001). In Vietnam, 80 per cent of the litchi plantations are under a single cultivar, Vaithieu. The main cultivars in northern Thailand are Tai So (Hong Huay) and to a lesser degree Wai Chee, O-Hia (Baidum) and Chacapat (Chakrapad). A different set of ecotypes has been developed for the areas around Bangkok, including Kom, Luk Lai, Sampao Kaow, Kalake Bai Yaow and Red China. The quality of these selections is not good. Seedling based cultivars are commercially grown in hilly areas of Nepal whereas Majfpuri, Raja Saheb, Dehraduni, China and Calcuttia are well-established cultivars in the plains. Most of these cultivars probably reached India. Muzaffarpuri, Bombai, Bedana and China No. 3 are major cultivars grown in Bangladesh. Bombai is the oldest cultivar whereas Bedana is the best quality cultivar, but is a shy bearer (Bose *et al*., 2001). Mauritius and Sinco are major cultivars in the hilly region in the Philippines, while an introduction from Thailand, UPLB Red is grown in the low lands. In Australia, Kwai May Pink accounts for more than 50% of plantations, with Tai So, Souey Tung, Fay Zee Siu, Salathiel and Wai Chee, the other main cultivars (Bose *et al*., 2001).

Most of the Indian cultivars are selections from seedlings origin which were introduced from China. Shahi (Muzaffarpur), China, Bedana, Calcuttia, Late Bedana and Longia are commercially important cultivars in India. These cultivars have large fruits and excellent fruit quality. Bombai, Rose Scented and Shahi may produce 40 kg/tree in West Bengal compared to 15-25 kg/tree in many other cultivars (Bose *et al*., 2001). ICAR-NRCL has developed three cultivars of litchi namely Gandaki Lalima (28-32 g, very late), Gandaki Sampada (28-34g, aril- more than 80%) and Gandaki Yogita (aril more than 70%, very late). They have also been selected from several genetic stocks. NRCL-29 is a most precocious and dropping branching dwarf seedling selection. NRCL-59 appears to be an inter-varietal hybrid seedling selection that has leaves similar to Shahi but fruit shape is similar to China variety.

Breeding methodologies for the improvement of litchi cultivars

Like any other crop, the common breeding methodologies are followed for litchi improvement and genetic enhancement in litchi too. The main methods are described in the following section:

1. Germplasm evaluation and clonal selection

Since many of the existing cultivars have originated from a relatively limited ancestral stock, the introduction of new germplasm from wild forms and varieties into the genetic composition of existing cultivars appears to be necessary to achieve the breeding objectives. Many important genetic resources have been identified for different characteristics that can be utilized in future breeding programmes (Table 3). Most of the cultivars, grown presently, originated from Chinese sources and the genetic base of commercial cultivars is relatively narrow. Almost all of these cultivars have arisen as the result of clonal propagation of high-performing parents.

Table 3: Genotypes and their characteristics

S.No.	Genotypes	Major Characteristics
1.	NRCL-29	It is a drooping and dwarf growth habit. It is most precocious in flowering (3rd year of planting). It is an early ripening genotype. It has compact flowering panicle. It can be grown under HDP. It is easy in peeling. The high content of anthocyanin (94.62 mg/100 g)
2.	NRCL-59	Flowering and fruiting started during the 5th year onward. Leaves are similar to Shahi, but fruits are similar to China. It is a deep pink colour. It is attractive to consumers. It is tolerant of sunburn (6.23) and fruit cracking. It is a late-maturing genotype having a fruit weight of 22.56 g, TSS: 21.59 Brix, and high anthocyanin content in peel (96.56mg/100g).
3.	NRCL-83	It is slow-growing and dwarf. It can be used in HDP. Leaves are small, and curved upward from the midrib. The average fruit weight is 17.31 g, and the yield is 12.43 kg/plants at 7 years. Pulp content is 72.48%, and seed is small, with an account of 8.73%. It is tolerant of sunburn and fruit cracking (3.54%).
4.	NRCL-85	It is fast growing with very vigorous growth. The trunk surface is very rough. High nutrient efficient and does not show hunger symptoms in leaf near fruit bunch. It can be grown in marginal land. Heavy fruit-bearing intensity (30-40 fruits/cluster). Panicle girth is high. Tolerant to sunburn and fruit cracking. The pulp is dull white, acidic in taste, juicy and is highly suitable for processing industries.
5.	NRCL-86	Plant height (5 m) during 12 years old. It can be grown under medium density. It is a regular and heavy bearer (heavy bunch). Fruit weight (24.25 g). Panicle girth is high. Pulp content is high (72%). Suitable for the processing industry. Chicken tongue seed (6.9%). Tolerant to sunburn and fruit cracking.
6.	NRCL-87	It is a regular and heavy bearer. High fruit weight (29.69 g). Panicle girth is high. High pulp content (>70%). Tolerant to sun burning and cracking. It can be used as a female parent in hybridization.
7.	NRCL-88	It is slow-growing, and the plant is dwarf having spreading branches. It can be grown under HDP. Leaves are small, and curved upward from the midrib. The average fruit weight is 16.22 g, and the yield is 16.48 kg/plant. Pulp content is 76.38%, and seed is small, with an account of 7.63%. No sunburn is found, and fruit cracking is 6.45%.
8.	NRCL-89	It is a regular bearer. Leaves were small like Bedana which curved upward from the midrib and a fruit-like Shahi, but the shoulder is similar to Kasba. The fruit shape is oblong, and the colour is pinkish-red at maturity. The number of fruits per panicle is 15-18. The average fruit weight is 25.63 g, peel weight-3.73 and seed weight is 3.75g. The pulp content is more than 70%. It is a late-ripening genotype that matures in mid-June. No sunburn and fruit cracking is observed.

No genetic characteristic has been observed to be controlled by segregation and no experiment appears to have been conducted on the heritability of desirable and undesirable characteristics. Wild forms or types of the three known litchi subspecies have been widely collected for integration in breeding programmes, but collections of commercial cultivars have been established at various research institutes in different countries. The commercial cultivars are selections from open-pollinated seedlings, mostly of Chinese origin. High heritability and high genetic advance were recorded for leaf length, rachis length, length of panicle, number of fruit per panicle and Yield (Lal *et al.*, 2022) and they also observed positive relation of yield with the number of the leaflet, leaf length, lead width, rachis length, petiole length, length of panicle, fruit weight, pulp weight, TSS total sugar, seed weight but negative relation with ascorbic acid. Fruit weight was positively correlated with the number of leaves, leaf length, leaf width, rachis length, petiole length, panicle length and negatively correlated with the number of fruit/panicles. TSS was positively correlated with the number of leaves, leaf length, leaf width, rachis length, petiole length, panicle length, fruit weight and pulp weight. In nature, the extent of out-crossing in litchi varies from 65-87 per cent depending on the nearness to the pollen source. There is a clear exhibition of inbreeding depression with respect to fruit and seed weight if selfing takes place (Stern *et al*., 1993).

2. Inter-varietal crosses

The selection of high-yielding, better quality litchi has taken place over a long period, but the breeding of new hybrids have not been undertaken to any appreciable extent. Very recently two hybrids, namely Sabour Madhu and Sabour Priya have been recorded (Table 4). They are the products of a breeding programme carried out at Sabour (India) involving ten cultivars, namely, Deshi, Early Bedana, Ajhauli, Dehra Rose, Purbi, Shahi, China, Kasba and Late Bedana. The hybrid seedlings grew slowly and only 4 per cent of the total population floweredfor the first time at the age of 14 years (Singh *et al*., 2012). Thus, in addition to a short period of seed viability, the late bearing habit of the seedlings poses serious problems for hybridization work. Also, the erratic flowering of the seedlings makes it difficult to obtain the appropriate type of pollen at the required time for further crossing, if the breeding programme continues further. Thus, the improvement of litchi appears to be confined mainly to selections of improved chance seedlings or genotypes.

Table 4: Litchi cultivars developed through selection or hybridization

S.No.	Cultivar	Major Characteristics
1.	Groff	It is a seedling selection from the Hak Ip variety. The fruit quality is superior to Hak Ip, a Chinese variety.
2.	Brewster	It is quite similar to Chenzi. It requires a relatively severe winter (Maximum temperature <7ºC) to initiate flowering. Fruits are medium (20-22 g), slightly fragrant and sweet. Seeds are small to medium-sized. Flesh recovery is 65 to 75 per cent.
3.	Saharanpur Selection	This is a chance seedling selection. It is a late maturing type. Fruits ripen in the third week of June. TSS is around 19.8 per cent. Fruit weight is 17.6 g and it has low fruit cracking (2% only) compared to other cultivars.
4.	Swarna Roopa	This is the outcome of the selection made at Ranchi from different collections of litchi cultivars. It has an attractive deep-pink fruit colour, small seed and high TSS/acid ratio. Fruits are highly resistant to cracking. Fruits mature a week later than the late cultivar China. It is shy bearer and panicle is very delicate thus, fruit retention is very low.
5.	Sabour Madhu (H-105)	This hybrid resulted from Purbi x Bedana. It has a higher number of fruits (24) per panicle and ripens 8 days later than another late-maturing cultivar, Kasba. It has a higher TSS and aril percentage than Purbi. The fruit shape resembles Purbi.
6.	Sabour Priya (H-73)	This is a product of Purbi x Bedana. It has better fruit quality than Purbi in terms of higher aril percentage and TSS content. The fruit shape has a combination of both the parents. The fruit weight is higher than the better parent (Purbi).
7.	Gandaki Sampada	It is a selection from Bedana group. Fruits are large (36.85 g), conical in shape, vermilion to carmine colour and crack resistant. Pulp recovery is 80 to 85 % thus, suitable for industrial purposes. It is attractive to consumers. It is small-seeded fruit. It ripens during mid-June.
8.	Gandaki Lalima	A highly nutrient efficient strain possessing darkgreen leaves and the capability to withstand climaticaberrations. Fruits are conical, bright marigold-orange red incolour. Fruit weight is 28-32 g.• Heavy yielder with an average yield of 130-140 kg/tree.• Tolerant to sunburn and fruit cracking.• It does not show hunger symptoms on a leaf near fruit bunch.• Late maturing cultivar ripens in the second week of June.It is attractive to consumers.• Good compatibility with many cultivars in hybridization.• Good fruit retention capacity as the female parent.
9.	Gandaki Yogita	It is slow-growing and a dwarf type, can be used in high-density planting. It is tolerant to hot waves and fluctuations in soil moisture. The fruit is free from fruit borer, sunburn and fruit cracking. Fruits are round in shape; tyrant rose in colour. Good yield potential (70-80 kg/tree). It is very late mature in the third week of June.

(Contd.)

3. Intergeneric hybridization

Hybridization was also attempted between litchi and other related genera. Between the hybridization of litchi and longan, no improved hybrid was obtained. Seedling progeny were quite variable with small fruit size, which appeared to be the dominant characteristic. Longan cultivars have a strong biennial bearing tendency, and thus, incorporation of this character into the hybrids may cause more erratic fruiting. Among the diallel crosses between *Nephelium lappaceum*, *N. rambutan* akee, *Dimocarpus longan* and *Litchi chinensis*, only intergeneric crosses between longan and litchi were successful. A variable progeny was produced when litchi was the female parent and longan the female, but this only occurred approximately once in one thousand controlled pollinations and then only in specific combinations. The pollen of both litchi and longan germinated on the stigma of rambutan but was arrested in the embryo sac. However, there appears to be no breeding barrier between cultivars or species within a genus except when seedless fruits are commonly produced. The reciprocal crosses were attempted between commercial cultivars of litchi (Bengal and Kwai May Pink) and longan (McLeans Ridges and Duan Yu) and found that hybrid progeny could develop only when litchi was used as a female parent (Singh *et al*., 2012). Morphologically the hybrid litchi plants were similar to the maternal parent, but leaves were smaller than parents. Three types of seeds were developed in litchi when pollinated with pollen grains of longan: (1) normal seeds with a developed testa and embryo; (2) seeds alongwith aborted embryo but normal testa development; and (3) seedless, where ovule did not grow. Wild species of *N. philippinensis* (syn. *N. intermedium*) can provide an important gene for breeding work.

Some seedless varieties are occasionally found in the wild, and these could have the potential for fruit production for the canning industry. Seedless forms of pulsan (*N. mutabile*) can also be used to hybridize with rambutan to produce new types of fruits. It could also be possible to explore the potential of hybrids of *N. mutabile* and other wild species with rambutan for use as rootstock material, which could be more resistant to root diseases than rambutan. Longan is a source of cold or drought tolerance or resistance to the mite. Litchi x longan hybrids are produced in China and Australia, but no commercial cultivars have been released. The developments of superior cultivars are very slow as seedlings take several years in bearing and when they reach the fruiting stage results in less than 1% worth. Groff was selected out of 500 seedling populations of Brewster, Tai So and Haak Yip but Groff was never grown commercially. Thus, cross-pollination for desirable traits is concentrated in future. Close planting of seedlings can be done to accommodate 2000 to 2500 plants per hectare as compared to the normal density of 100 to 200 trees per hectare. The conventional way of creating variation is through hybridization or crossing two different plants.

VARIETAL SITUATION

In India, almost all the cultivars growing are of seedlings origin introduced from China which can cultivate in dry and hot conditions. More than 30 selected cultivars are growing but commercially Shahi, China, Bedana, Late Bedana, Calcuttia and Longia are growing. In West Bengal, Bombai, Rose Scented and Shahi yield up to 40 kg/tree compared to 15-25 kg/tree in many other cultivars. These cultivars are large-fruited and have excellent eating quality. In Bihar, the important cultivars are Shahi, China, Bedana, Late Bedana, Dehrarose, Deshi, Trikolia, Rose Scented, Late Large Red, Green, Seedless No. 2, Purbi, Mandaraji, CHESS-II, Surguja Selection 1, Bombai-I and Bombai-II. In Uttarakhand, Punjab and Haryana, the varieties are Calcutta, Early Large Red, Early Seedless, Gulabi, Khatti, Late Seedless and Rose Scented, whereas the varieties recommended for growing in Punjab and Haryana are Calcutta, Dehradun, Muzaffarpur, Rose Scented, Saharanpur and Seedless Late. At ICAR-NRC on Litchi, Muzaffarpur, three new improved varieties viz., Gandaki Sampada, Gandaki Lalima and Gandaki Yogita have been developed. The development of improved cultivars coupled with efficient cultural practices is vital for improving crop production in a region. Improved varieties of litchi have been identified and evaluated for their potential. Gandaki Sampada is a late-maturing strain that ripens during mid-June. Fruits are large in size, conical in shape and vermilion to carmine in colour at maturity with dark blackish-brown tubercles. Pulp is creamy white, soft and juicy, with a large fruit size (35-42 g), cracking resistance, pleasant aroma and good yield potential (120-140 kg $^{-1}$ tree). This variety has potential for export purposes. Gandaki Yogita is a dwarf type variety, comparatively compact, and tolerant of heatwaves and fluctuations in soil moisture. The fruits are free from fruit borers and are of very late maturity (10-15 June). Fruits are round in shape, tyrant rose in colour with dark tubercles and flexible seeds at maturity. Pulp recovery is 70-75%, possessing a melting texture with a pleasant aroma and a good blend of sugar and acid. This variety can be recommended for high-density planting as a specialist variety. Gandaki Lalima is moderately vigorous, attaining a height of 10-12 m and almost uniform spread. It is the most nutrient-efficient strain having dark green leaves and the capacity to withstand climatic aberrations. A late-maturing cultivar ripens in the second week of June; a heavy yielder has an average yield of 130-140 kg per tree and the fruit weighs between 28 and 32 g. Several genetic stocks have been identified from the genetic pools. Shahi is the most popular early cultivar having excellent eating quality but susceptible to sunburn and fruit cracking. China is also popular but late cultivar tolerant to sunburn and fruit cracking. NRCL-29 is a chance seedling selection that is precocious in bearing and having dwarf stature (Lal *et al*., 2019). NRCL-59 is also a chance seedling selection which leave are similar to Shahi but fruits resemble China variety. Similarly, NRCL-83, 86, 88 and 89 are suitable for high pulp recovery, NRCL-85 is reported to be bunch fruiting (30-40 fruits/bunch) and suitable for marginal land. NRCL-87 is a large-fruited (>28g) selection thatripens very late,during mid-June.

PRODUCTION CONSTRAINTS – BIOTIC AND ABIOTIC STRESS

Biotic stress

Although, litchi is free from major pests and diseases, some major pests recorded are fruit borers (*Conopomorpha cramerella*, *Platypeplus aprobola* Meyer and *Dichocrosis sp*.), leaf mite (*Acerya litchi* Keifer), shoot borer (*Chlumetia transversa,* leaf webber (*Platypepla aprobola* Meyer), bark eating caterpillar (*Indarbela quadrinotata* and *I. tetraonis*) and litchi bug (*Tessarotomajavanica* Thunb). The infestation varies with location, age of the tree, cultural practices, and the orchard ecosystem. Borer is a serious problem as it directly hits on fruits and reduces the marketable yields. Very few diseases have been noticed in litchi which infects leaves, flowers, and fruit. Some leaf spot diseases are becoming important that are caused by fungal pathogens. No bacterial or viral infections have been reported so far. A few reports of algal infections are also available. Anthracnose (*Colletotrichum gloeosprioides* Penz.) is a pre-harvest disease that occurs on leaf and fruits and *Aspergillus, Botryodiplodia, Cylindrocarpon* and *Colletotrichum* causes post-harvest fruit rots (Awasthi *et al*., 2005). Anthracnose mainly affects fruit but also affects the leaves, twigs, and flowers. Infected fruitsare not suitable for marketing. Anthracnose first appears as brown pinhead lesions on the top of maturing fruit. Circular dark brown to black sunken lesions later become easily visible on mature fruits. Further, spots slowly cover the fruit surface (Kumar, 2016). Anthracnose development is highly favoured by high temperature and higher relative humidity. Outbreaks are common after warm wet weather. The highest latent infection rate of anthracnose of fruit causes more serious post-harvest losses and browning of fruit skin. Kumar *et al.* (2011) reported two emerging insect viz., *Apoderoussp*., a weevil and *Conopomorpha cramerella*, a borer pest that causes severe damage to new flush. They have also found twig blight in a young orchard where young trees wilt within a week. Leaves become yellow and start drooping followed by slowly wilting and drying which lead to the death of the plant within 4 to 5 days. Fruit rot of litchi has been a serious problem. Litchi is host to a range of post-harvest pathogens, often with quite different modes of infection. Leaf Spot is another disease that mainly affects older leaves. Gupta (1992) reported algal leaf spot (*Cephaleuros virescens*) in litchi from Punjab, Bihar (Pusa), and Uttar Pradesh (Saharanpur). The infection reduces the vitality of the plant by hampering photosynthetic activity. The plant growth is retarded by defoliation which indirectly affects yield. A wide range of fungi, such as *Colletotrichum, Alternaria, Aspergillus, Botryodiplodia, Fusarium*, and *Penicillium sp*., was reported from India by Kumar *et al*. (2016), causes post-harvest fruit rots if the fruits are not handled properly. Initial symptoms appear on the injured portion of the fruits and with the progress of the disease, the decayed areas become depressed and the rotting penetrates upto the pulp.

Abiotic stress

Abiotic stresses may reduce the longevity of trees along with the yield and quality of fruit. The various abiotic stresses such as salinity, drought, heat and cold stress, osmotic stress, etc. have an adverse influence on the growth, development, and productivity of fruit crops. Environmental conditions especially low temperature before flowering and high temperature during maturation of fruits are very important for higher quality production. In order to survive under stress conditions, the plant responds by activating its inherent defence machinery and counteracting through inducing various molecular and cellular responses. Whenever plants perceive any stress signals, their defence machinery activates appropriate stress-inducible genes. The products of these genes are osmotic regulatory protein; enzymes for synthesizing betaine, proline, and other osmoregulator. Certain stress hormones such as abscisic acid (ABA) and ethylene also play determining role in regulating abiotic stress responses in plants. Drought is the predominant factor that causes enormous loss of productivity of fruit crops. Water stress has an inhibitory effect on the plant vigour, stem extension, leaf expansion, functioning of the stomata, CO_2 assimilation, flowering, and fruit growth and yield. Litchi being an evergreen subtropical plant requires an adequate amount of rainfall and soil moisture for optimum growth, development, and fruit production. Litchi varieties are found in hot and dry geographical regions and are considered hardy plant species, but they are highly affected by seasonal droughts. Since water paucity is a genuine threat to litchi production, an adequate supply of irrigation water plays an important role in maintaining the productivity and quality grown in tropical or subtropical areas. Litchi varieties showed a range of complex responses at various levels of plant organization to drought stress. Litchi plants are highly susceptible to drought stress during their initial years of establishment (1–3 years old); however, adult plants are comparatively drought tolerant. It has been observed that shoot growth is highly sensitive to drought stress as its growth decreases as the level and period of drought increases. Severe water stress leads to a decrease in leaf water potential and in turn, inhibits leaf expansion and photosynthesis in litchi. One of the recent studies revealed that when litchi trees cv. Kwai Mi was subjected to long term drought, leaf mass-to-area ratio (LMA) increased as an adaptive mechanism to limit evaporation. The amount of starch per unit leaf area was found to be decreased sharply whereas the concentration of total soluble sugar increased with water stress. The decrease in photosynthetic capacity was also observed with increasing water stress (Damour *et al*., 2008). The litchi tree starts flowering from the third week of February, and its fruit ripens in the month of May. High moisture preceding floral induction in litchi promotes vegetative growth and suppresses flowering. Several studies have indicated that flower initiation or reproductive phase is promoted in litchi by mild water stress during the preceding autumn and winter (Stern *et al*., 1998). However, the period from flowering to early fruit development is mainly susceptible to water deficit.

Lack of moisture for an extended time during this period may lead to poor fruit setting, reduced fruit size, and abnormally high fruit dropping. The availability of calcium, a structural component of the cell walls, during early fruit development is important for resistance to fruit cracking in the litchi fruit. The high level of water stress diminished the calcium content of the litchi fruit which in turn reduces the strength of fruit skin and thus aggravate the fruit cracking and curtail the postharvest shelf life of fruits (Rab and Haq, 2012). Once harvested, if litchi fruit is exposed to heat or dry air, it loses water rapidly, which cause pericarp dehydration and browning. Endogenous plant growth regulators play a crucial role in managing plant responses to stress. Studies have reported a many-fold increase in the level of abscisic acid and a decrease in auxin and gibberellic acid content in lychee in order to reduce the damaging effect of drought and other abiotic stresses. Flowering in litchi is affected by many factors but the temperature is one of the most crucial factors. Low temperatures during autumn and winter trigger floral initiation in litchi (Chen and Huang, 2005). Subsequently, the apical buds break and elongate as temperature and soil moisture increase. Whether the development of mixed buds proceeds toward the development of flowers or toward the development of leaves is entirely dependent on prevailing environmental conditions. If the temperature is not too high, then under normal conditions, panicle primordia grow and develop functional flowers. Simultaneously the rudimentary leaves will abscise. On the contrary, if the temperature is high, the rudimentary leaf develops into a fully expanded leaf with no or little development of panicle primordia and hence no flowers and subsequently no fruits (Zhou *et al*., 2008). Thus, high temperature is detrimental to lychee crop production. Global warming has resulted in an overall rise of temperature across the globe, resulting in warm winters and hot springs that presents very unfavourable conditions for lychee cultivation.

Hence, it is essential to develop an understanding of the molecular mechanisms governing litchi panicle development and the abscission of rudimentary leaves to deal with the defective flowering problem. The suppression of rudimentary leaf growth enhances panicle development. Two stress signalling molecules, viz., nitric oxide (NO) and reactive oxygen species (ROS), have been implicated in governing the abortion of rudimentary leaf and formation of functional panicles (Zhou *et al*., 2012). APETALA (AP1) and LEAFY (LFY) are very well-documented genes required during the floral transition (Weigel and Meyerowitz, 1993). Accumulation of ROS and NO showed increased expression of litchi homologues of LFY (LcLFY) and AP1 (LcAP1) (Zhou *et al*., 2012). Ethylene is a gaseous plant hormone and has proven roles in stress signalling (Wang *et al*., 2013). Earlier studies have determined that the abortion of rudimentary leaves is associated with ethylene production. Furthermore, ethylene production is associated with an increase in H_2O_2 levels (Biyan *et al*., 2013). ABA is also shown to promote flowering and diminish the growth of rudimentary leaves in litchi (Cui *et al*., 2013). Application of exogenous ABA to mixed buds of litchi tree reduced the leaf number per panicle and increased axillary panicles per panicle, and therefore an increase in the percentage of axillary panicles in relation to total nodes per panicle was seen. Early application of ABA to trees prior to floral primordium initiation also resulted in better floral output (Cui *et al*., 2013). Application of naproxen, an inhibitor of ABA biosynthesis, inhibited flower formations and also resulted in suppression of LcAP1.

The Litchi pericarp colour is red, very attractive to the consumers but in many cultivars, it gets cracked near the ripening of the fruits. Fruit cracking is a common problem in early cultivars of litchi. In litchi, some of the highly prized varieties like 'nuomici' litchi is highly susceptible to fruit cracking (Peng *et al*., 2004). The cell wall of a plant is made up of cellulose, hemicellulose, pectin, and various structural proteins that are arranged as a complex network (Carpita and Gibeaut, 1993). During fruit development, the components of the cell wall loosen to allow growth. The primary cell wall is made up of cellulose and hemicellulose. Xyloglucan is a primary component of hemicellulose that is cross-linked with cellulose via hydrogen bonds in the cell wall. An enzyme called xyloglucan endotransglycosylase (XET) is a cell wall loosening enzyme that catalyzes the reversible formation of xyloglucan cross-links by breaking the xyloglucan polymer and facilitates insertion of new chains of xyloglucan and thereby loosens the cell wall (Kaku *et al*., 2004). In parts of India and China, the application of NAA is done on the litchi trees to reduce fruit cracking especially in the 'Nuomici' variety (Li *et al*., 2001). NAA reduce fruit cracking by facilitating the growth of pericarp as auxins are associated with cell division and cell expansion. Calcium ions are known to be an important signalling component for cell elongation and stabilization of cell membrane during cell wall formation. Calcium also plays an important structural role in the cell wall of the pericarp. Pectin requires calcium ions for cross-linking which is required for the adhesive properties of pectin that binds the cells together (Daher and Braybrook, 2015). The deficiency of calcium is shown to cause severe pericarp cracking in lychee (Huang *et al*., 2005). Brassinosteroids are a class of hormones that are associated with cell division and cell growth. They are known to work in coordination with auxins. Foliar spray of brassinolide (a type of brassinosteroid) to lychee trees before anthesis is shown to significantly increase the concentration of calcium in fruit pericarp (Peng *et al*., 2004). A recent study involving whole-genome expression analysis of pericarp of cracking and non-cracking fruits using high-throughput RNA sequencing has allowed identification of an array of candidate genes that may govern the mechanism of pericarp cracking in litchi (Li *et al*., 2014). Litchi, being a non-climacteric fruit, has a short post-harvest life under normal ambient conditions and senesces quickly after harvest.

Skin colour loss or pericarp browning is one of the first visual signs of senescence of fruit in lychee. Once harvested, the bright red colour of litchi gets lost within 2 days and the pericarp turns brown. This browning is induced by the degradation of anthocyanins, a group of secondary metabolites synthesized via the flavonoid pathway, by enzymes polyphenol oxidase (PPO) and peroxidase (POD) and subsequent production of brown-coloured by-products (Pureby *et al*., 2019). Different methods such as wax coating, acid treatment, etc. have been tried by various researchers to solve the problem of postharvest pericarp browning. One of the methods where precooled litchi fruits were treated with 0.6% sodium metabisulfite solution for 10 min followed by dipping in 2% HCl solution for 5 min seems to be the best approach for delaying pericarp browning and extended their shelf life up to 9 days at ambient conditions (Neog and Saikia, 2001). ABA accelerates fruit ripening as well as the accumulationof anthocyanin in litchi pericarp (Wei *et al*., 2011). The transformed litchi plants also exhibited significant improvement in fruit flavour, colour quality, including fruit ripening time (Das *et al*., 2016). Increased spermidine and spermine are associated with upgraded plant resistance to multiple abiotic stresses. Therefore, manipulation of genes involved in PAs biosynthesis pathways using genetic engineering technology can be used to increase the shelf life of litchi by delaying the process of fruit ripening.

TECHNOLOGICAL CHANGES WHICH HAVE REVOLUTIONISED LITCHI PRODUCTION IN INDIA

In some areas, litchi is the source of livelihood for many people as it is both on-farm as well as off-farm employment. Commercial litchi plantation creates 'a source of job opportunityfor the people associated with growing and managing orchards, harvesting and post-harvest handling, packing, transportation, export and value addition. Commercial litchi production is attaining the status of an industry in certain pockets with forwarding and backward linkages. Litchi is a highly profitable crop that needs only 2-3 months of investment during flowering and fruiting. Canopy management, bagging, girdling and production systems have played important role in the litchi industry.

Quality production of Planting-material

The growing of litchi with seed takes about 7–12 years to come in bearing stage. Moreover, its seeds lose viability within 7 days when removed from the fruits. Hence, litchi is commercially propagated by Gootee. With the advancement of the plant tissue culture, micropropagation techniques can be opted to overcome the propagation problems. ICAR-NRC on Litchi Muzaffarpur has a national repository of litchi germplasm in the country. They have maintained a modern nursery and produce a large number of genuine quality planting materials. ICAR-NRCL conforms to ISO 2008:2015 certifications and adheres to the best of cultivation practices and produce the best quality and genuine planting material, and sells in different parts of the country. They have a well-established mother orchard for most of the cultivars. Commercial varieties viz., Shahi, China, Bedana, Rose Scented, Purbi, Mandraji and newly released varieties viz., Gandaki Sampada, Gandaki Lalima, Gandaki Yogita are being propagated and sold in the country. The best time for air layering is June or the beginning of monsoon season. The air layers are removed in August when sufficient roots develop. These plants are shifted to nurseries and may be transplanted in the field when well establishedin the polythene bags. However, it would be preferable to do the planting at the beginning of the next monsoon. The layering can also be started in August, and the plants (2–3 cm diameter and 30–60 cm long) can be removed from the trees in October and planted during the next monsoon. Treatment of ringed portion with 200 ppm of a PGR (naphthalene acetic acid) helps in root formation. This method is much cheaper than the former. Recently, plastic material for wrapping the air layer has become easily available and is very useful. The new plants are thus raised and planted in the field. Recent experiments have shown that litchi can be propagated successfully from cuttings. The cutting of two year old treated with 0.02% of Indole acetic acid (IAA) and 0.005–0.01% of indole butyric acid (IBA) for 24 hours give very good results. A higher concentration of these hormones is harmful.

Production System Management

The production system has been changed which includes drip irrigation, fertigation, girdling, bunch thinning, bagging, Y trellis system, high-density planting (2500-3000 plants) and mulching. Nutrients are applied based on leave and soil nutrient analysis. Diseases and pests are managed to utilizean integrated management system. Bunch bagging is becoming popular to safeguard against fruit borer and post-harvest diseases. Rejuvenation of old litchi trees results in good fruiting within three years of practice which give quality production. Pruning just after harvesting ensure regular fruiting in litchi and canopy management is well adopted in litchi to produce quality fruits even from the inner canopy of the plants. Proper thinning of fruit not only improves fruit weight and quality but also reduces transpiration rates and decrease the level of water stress in the trees. The use of organic sources and biofertilizers improved fruit weight and quality in litchi. Traditionally, litchi trees are planted with wide spacing of 9 m or 10×12 m or even 12×12 m, with about 70-80 trees/ha and with large trees, there are problems with harvesting, spraying and protection from birds and bats (Menzel *et al.,* 2000). The planting density of 6×6 m (277 trees/ha) in a square planting system accommodate a higher population and results in higher productivity. Shahi is a highly preferred cultivar due to its sweet and acid blended taste.

Value Chain Management

Canopy management is very important for quality production. Pre-harvest quality and efficient post-harvest management ultimately determine the quality of the produce to the consumer end. Pre-harvest factors have a major role in the quality of litchi. Canopy management, balanced use of fertilizers including micronutrients, water quantity and quality, protection from insectpests and diseases and physiological disorders like sunburn and fruit cracking, pruning and girdling for regular bearing, bunch bagging for quality fruit production and time of harvest are some of the pre-harvest factors which determine the quality. After reaching the pack house, the bunch is de-handed, treated and packed in an appropriate size of boxes and transported under cool condition. Firstly, pre-cooling should be applied to remove field heat and provide effective temperature management during transportation. This helps to maintain the quality and flavours, reduces water losses and prevents browning of the skin. The desiccation of pericarp and losses of anthocyanin along with phenolic oxidation by polyphenol oxidase (PPO) increases pericarp browning (Jiang *et al.,* 2004). Several techniques such as heat water treatment, coating with wax, sulphur fumigation, acid dipping, irradiation, fungicide application, and modified atmosphere packaging have been attempted to overcome the problem of pericarp browning and shelf-life extension of litchi. Secondly, postharvest treatment with fungicides is required to prevent fruit decay. Shelf life at room temperature (30!) is less than 72 h which is the major problem where high temperature and humidity promote the growth of *Botryodiplodia sp*., on the surface of the fruit. Work has been done on these aspects and adopted by farmers to boost production. Post-harvest management needs appropriate handling at harvesting time and during the transport to the pack house. Baskets and containers prepared from straw, bamboo, palm leaves and gunny bags are commonly used in a developing country. Bags are prepared from fibres such as jute, sisal, coconut coir, etc. Wooden containers of 18-22 kg capacity are still being commonly used in the form of reusable boxes or crates in major parts of India. They not only offer the benefits of strength and reusability, wooden boxes when made to a standard size stack well on trucks or storage rooms. Plastic crates are usually made of high-density polyethene (HDPE) or PP by injection moulding. Polyethene has higher strength and a low degradation by ultra-violet radiation while polypropylene is better in scratch resistance. The normal capacity is 20 – 40 kgs.

Nowadays, the use of cardboard boxes has increased which is made from solid or corrugated fibreboard. CFB boxes were very effective in significantly reducing mechanical and pathological losses whereas browning and fresh weight loss (FWL) was reduced by about 50% (Purbey *et al.,* 2019). Litchi fruit cv. Shahi harvested morning (up to 6.00 AM) and kept in perforated polymer bags and packed in CFB box (2 Kg) resulted in the least physiological losses in weight (6.8%), respiration rate (116.2 mL CO_2 $kg^{-1}h^{-1}$),browning index and maximum anthocyanin content 28.36 mg $100g^{-1}$ pericarp) after 5 days of storage at ambient conditions (Purbey *et al*., 2018).Thermocol packaging is another packaging technology developed and popularized by ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar.

In China, litchi is packed in foam plastic boxes by putting ice inside which can maintain the quality of litchi for 7-10 days under ambient conditions (Li, 1999). The influence of various packaging materials on litchi fruits stored in cold conditions exhibited that the shelf life of litchi increases by 16 days. Polyethene and polyvinylchloride are found to be the most efficient. The packing of litchi in ventilated punnet boxes and overlapping with semi-permeable material reduces the respiration rate of fruits besides providing a barrier to water loss. This practice has been found to enhance the shelf life of litchi fruits by 5- 7 days at ambient conditions (35-38 !) and by 15 to 18 days at low temperature (5-7 !) (Purbey, 2014). The process of 'sulfitation' of litchi which was initially developed in South Africa has a fungicidal effect and also ensures the fixing of the red colour of the rind and prevents brittleness during storage and transportation. The accepted level of SO_2in the pulp of litchi was fixed at 10 ppm in imported litchi by French authorities in 1989. French expert, Dr. J. Marchal, reported that in Madagascar it was an established practice to use 550 g sulfur for fumigation of 1 MT of litchi for 45 min by burning pure sulfur in a closed chamber, and it was good enough for storing litchi at 0-2! for a period of up to 6 weeks (Kumar *et al*., 2011). As a matter of fact, the effect of SO_2 on the surface growth of fruit, SO_2 injury to the rind, and SO_2 residue level in the treated fruits depends on the fruit concentration of SO_2 applied and varies with cultivar, particular crop (locality wise), and the duration of fumigation. That is why it is necessary to work out the specific dose of sulfur for fumigation of litchi.

EMERGING CHALLENGES AND APPROACHES

Litchi is a highly nutritious fruit and highly demanding crop in national and international markets. There is a wide gap between potential and existing yield. The probable reasons for the lower productivity are the narrow genetic base, poor plant establishment, less fruiting span, irregular bearing, non-availability of superior cultivars, traditional production systems, poor technological support and incidence of insect pests (fruit borer and mite), aberrant weather during phonological phases, premature fruit drop, and fruit cracking due to non-scientific water and nutrient management, coupled with poor post-harvest management and lack of suitable cultivars with extra-early and -late maturity and quality of fruits are the factors that hinder the growth of litchi industry at commercial scale. The litchi tree has luxuriant vegetative growth, which causes problems in harvesting. Thus, canopy management is a very important practice to achieve good architecture. Lack of scientific knowledge on various critical stages like flower bud differentiation, time of water requirements and nutrients application significantly affect the yield. Erratic flowering due to changing climate is recently noticed where late blooming of the flowers results in lower fruit set and weight. Pericarp browning is a major post-harvest disorder that leadsto short shelf-life (Purbey *et al.,* 2019). Techniques which may enhance the post-harvest life of fruits would definitely be useful to get higher productivity (Singh and Babita, 2001). A profitable litchi industry depends on the production capacity of orchards. Lack of proper planning at the initial stage and orchard management practices at the later part may lead to various kinds of production-related problems in the established litchi orchard. Trees must be in a position to produce a sufficient quantity of fruits every year for market balance. Therefore, it is important that the trees are managed with the scientific tree management system. Besides, the crop growing conditions, the cultural practices and the cultivar selection determine the quality of litchi at a particular location. Mineral deficiencies, improper water and nutrient management, poor pest management and cultural neglect eventually affect the yield and quality. The present scenario of litchi production with the increased quantum of post-harvest losses due to fast deterioration and lack of quality produce is attributed to be the main reason not to meet the demand as well as economic return to the grower. Fruit borer is a major insect that causes heavy losses due to low market values. All early cultivars are highly susceptible to sunburn and fruit cracking, and the intensity of these problems depends on the prevailing weather conditions.

Besides, the development of improved cultivars is a very slow process because it takes several years to come in bearing. When a plant starts fruiting, less than 1 percent seedlings results in worth. The seed viability is for a very short period. Also, the erratic flowering of the seedlings makes it difficult to obtain the appropriate type of pollen at the required time for crossing, if the breeding programme continues further. Now, the omission of male flowers (M1) is another problem that results in barren panicles due to the non-availability of pollen grain during receptivity of stigma (Lal *et al*., 2019). Seedling progeny was quite variable with small fruit size, which appears to be the dominant characteristic. Traditional breeding methods take 40 years to develop new cultivars in litchi (Zheng *et al.*, 2001). Future efforts in hybridization require focusing on the cross-pollination of promising selected cultivars having desirable traits. For evaluation of seedlings, planting can be close at the density of 2000–2500 trees/ha compared with standard orchard densities of 70–280 trees/ha. The hybrid seedlings grew slowly and only 4 per cent of the total population flowered for the first time at the age of 14 years (Thakur, 1992). Thus, the improvement of litchi appears to be confined mainly to selections of improved chance seedlings or genotypes. In hybridization where chicken tongue producing cultivars are used as female parents, most of the fruits drop off before harvesting (Puchooa, 2004). The improvement of litchi by conventional breeding methods has produced few new cultivars. This has been due to the long juvenility period of the species, the apparent lack of diversity in the existing germplasm and the great expenditure that is required in terms of land, time and money. Keeping the importance of litchi in the country, efforts are made to give technological support through research and development, promoting modern production techniques, improved post-harvest management practices and easy marketing through various development programmes and schemes. Keeping the constraints that prevail and opportunities that exist in India as a whole and Bihar in particular, the FAO had initiated a Technology Support Project for 'Improving productivity as well as the quality of litchi in Bihar' which has been implemented at the cluster level in litchi growing districts of Bihar. Based on up to date knowledge and experience gained during the last 15 years including that of the FAO project, the proposal was moved to DAC to disseminate the knowledge and underline the need of GAP in litchi among different functionaries and stakeholders. Efforts are made to enlighten field functionaries, scientists and farmers regarding preventive practices that can be adopted to avoid the losses and curative options that can mitigate the problems.

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Review Article

Post-independence scenario of table grape cultivation in India

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ABSTRACT

Grape is a high value export oriented fruit crop which has gained significance in India due to location specific suitable modifications. Now it is being practiced in almost all climatic conditions from tropical to temperate and spread over different states of the country. Grape cultivation on a commercial basis is about seven decades old in India and now considered as most remunerative amongst all fruit cultivation in the country. In India around 78-80% of grape is produced for fresh consumption and about 17-20% for raisin making and around 2% collectively for juice and wine production. If we looked 75 years back, the country has shown implausible progress in the grape production. The endeavors of Indian research institutes and innovative grape growers in respect of varietal development, adoption of grape rootstocks and modification of grape cultivation practices pertinent to Indian climatic conditions has made India prominent table grape producing country in the world next to China. To lead global market of table grapes, India needs indigenous grape cultivars with better fruit quality, varieties with vivid aromas/flavors, wider adaptability, climate resilience and inherited tolerance against biotic as well as abiotic stresses. Besides widening of varietal base and development of abiotic stress tolerant rootstocks some important areas needs to be look into like adoption of protected cultivation, off-season availability and mechanization friendly crop husbandry techniques for enhancing the export potential of the country.

Keywords: Export potential. grape, productivity. Varieties,

INTRODUCTION

Grape *(Vitis vinifera* L.*)* is a high valued and premium quality fruit crop. Worldwide it is being grown mostly for wine, fresh consumption, raisin and juice. Grape is the third most widely cultivated fruit after citrus and banana. It is a primarily crop of temperate region and has been widely adopted in tropical and subtropical conditions across the globe. Indian viticulture is unique as it is being practiced in almost all climatic conditions from tropical to temperate. Grape is a high value export oriented fruit crop which has gained significance in tropical climatic India due to location specific suitable modifications.

HISTORY OF INDIAN GRAPE CULTIVATION

The grape cultivation begun in Asia Minor between the south of the Black and Caspian Seas. From there, the Phoenicians carried the vine varieties to Greece, Rome and Southern France before 600 B.C. At the end of the second century A.D the Romans took the vine varieties to Germany. Then it spread eastward through Turkey, Iran and to the undivided India (ICAR, 1977). As per the historical evidence the existence of grapes in India dates back about 4000 years ago. Medical treatises of India like Charak Samhita and Shushrut Samhita written between 1356-1220BC had mentioned grapes and their utilization in the preparation of medicines. Aryans were well versed with grapes and knew its cultivation and processing into different kinds of beverages. A Buddhist pilgrim from China who visited India during 629-645 A.D., reported that grapes were found in India right from Kashmir to everywhere in the country. Cultivated grapes are believed to have been introduced into the north of India by the Persian invaders somewhere in 1300 A.D(Olmo, 1970). In the 14th century, Mohamed-Bin-Tughlak brought grapes to the southern parts of the country when he shifted his capital from Delhi to Daulatabad. From Daulatabad, grape cultivation spread to Hyderabad in Deccan during the Nizam's period. Nizam of Hyderabad had also introduced some grape varieties into Hyderabad from Persia in the early 20th century. Introduction of grapes into South India seems to have yet another course. The grape was introduced at Melapatti, in Salem district of Tamil Nadu by a French priest in 1832(Shanmuga Velu, 1998). A little later, a French Jesuit priest Rev. Fr. Larney at Michel Patti village in Madurai district introduced it in 19th century (Ayyanger, 1930). From Daulatabad, Hyderabad, Salem and Madurai, the grape cultivation spread to the states of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu.[14] (Chadha and Shikhamany 1999).

Tropical Viticulture in India originated in Nashik region of Maharashtra where the first grape garden was planted by Raosaheb J. K. Gaikwad at Azar in 1923. In 1930, the on-farm demonstration by Adarsh Godrej near Nashik shown that grape cultivation can be done in profitable manner on large scale. From Nashik the grape cultivation spread to Satara, Pune and Solapur districts of Maharashtra. Mr. Dadasaheb Shembekar, Mr. N. C. Barawake, Mr. Ganukaka Datey and Mr. Mamasaheb Tilekar were the pioneers who started growing around the year 1930 in the Baramati area of Pune district in Maharashtra (Chadha, 2008). Indian grape cultivation is unique in many ways like short productive span of grape orchard (15-20 years), highest productivity in world, special pruning practices to regulate the fruiting and the absence of Phylloxera in the country

GRAPE CULTIVATION IN INDIA

India is gifted with variety of soil and different types of climatic zones like temperate, subtropical and tropical. Temperate zone includes Jammu and Kashmir, Kulu and Kangara valley in Punjab, Kotegarh and Nahan in Himachal Pradesh, Kumaoon hill in Utter Pradesh and extreme north eastern part of Arunachal Pradesh. This zone extends from low lying hills of the Himalayas to the height of 3200m. i.e. northern part of the nation. The average temperature of this region is 4ºc to 10ºc and falls below freezing point in winter. Subtropical Zone lies from central cancer 23 ½ towards north. Mild winter, dry and hot summer, medium sunlight and low rainfall are the characteristics of this zone and are suitable for grapevine cultivation. This zone is again divided into two subdivisions viz., i) Northern Subtropical zone comprised of the chief region of Punjab, Utter Pradesh, Haryana and Rajasthan and ii) North-eastern Subtropical zone comprised of Eastern part of India convincing West Bengal, Bihar, Assam and Meghalaya. Tropical zone comprises Madhya Pradesh, Maharashtra, Karnataka, and Kerala of South India. The region has average climatic conditions and receives abundant of sunlight for long duration. It has mild winter and hot humid summer (Todkari, 2012).

Grapevine has diffused remarkable from its original areas to other parts of the country. Its production, productivity and quality have won international appreciation. Commercial grape cultivation in India is of recent origin. Grape is one of the important fruit crop in India occupying 1.70% of the total area under fruit cultivation. In India around 78-80% of grape is produced for fresh consumption and about 17-20% for raisin making and around 2% collectively for juice and wine production. Presently grapes are grown in India over an area of 1.40 lakh ha with production of 31.25 lakh tons and productivity of 21.00 tons/ha. India ranks first in world for grape productivity and secured 7th position in the world for table grape export with the quantum of exported fresh grapes 2.22 lakh tons (NHB, 2020). Major grape-growing states in India are Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, and the north-western region of country. Maharashtra ranks first in terms of production accounting for more than 82.56% of total production and highest productivity in the country. Nashik, Solapur, Sangali

Table 1: Grape cultivation system adopted in different climatic regions of India#

Growth stages	Climatic region*		
	Sub-tropical	Hot-tropical	Mild–tropical
Cropping pattern	Single pruning & single cropping	Double pruning & single cropping	Double pruning &double cropping
Dormancy	November-January	No dormancy	No dormancy
Foundation pruning	Not practiced	March-April	May-June
Shoot growth period	March-May	April-June	June-August
Fruit bud differentiation	April	May	July
Shoot maturity	May	July-August	September-October
Pruning for cropping	December-January	September-November	November-January
Fruit set	April	November-January	Jan-July/Jan.-Feb.
Veraison	May-June	January-March	Aug.-Sept./March-April
Harvest	May-June	January-March	Sept.-Nov./April-June

#(Chadha, 2008)

*States included in specific climatic region-Sub-tropical: Punjab, Haryana, Rajasthan, Delhi and west Uttar Pradesh; Hot-tropical: Mid Maharashtra, North Karnataka, Telangana and Andhra Pradesh and Mild–tropical: South Karnataka and Tamil Nadu and Pune are the major grape growing district of Maharashtra. India is a major producer of the fresh grapes after China, Italy, USA, Spain, France and Turkey producing around 6% of total world grape with the production 3.04 million tones grapes. India is a major exporter of fresh table grapes and contributes 4.32% of world grape export Over 50% of Indian grapes are exported to the European Union (EU). It is the most preferred destination by Indian table grape exporters. Top importing countries for Indian grapes remain the Netherlands (51%), Russia (36.53%), United Kingdom (13%), Bangladesh (9%) and Germany (8%) (APEDA, 2021).

VARIETAL DEVELOPMENT OF GRAPE IN INDIA

India is an emerging leader as a table grape producer and amongst the major grape exporters in the world arena. In India, a large number of grape varieties were introduced firstly under the leadership of Prof. S.B.S. Lal Singh at Punjab Agricultural College, Lyallpur in 1928 (116 grape varieties) and late 1950s by Dr. S. G. Randhawa (about 1002 grape varieties) of Indian Agricultural Research Institute, New Delhi especially from USSR, Yugoslavia, Australia, France, Germany, Italy, Bulgaria, and many other countries. The grape gene pool thus created through introduction contained the various commercial grape varieties for the table, wine, and raisin from all over the world. The introduction of the exotic varieties viz., Abi or Bhokari, Fakiri, Habshi, Sahebi, Anab-e-Shahi in the Deccan region of the country was an important event in Indian viticulture. But the grape cultivation in a commercial manner was started in the 1960s when grape growers started the cultivation of Thompson Seedless (Chadha, 2019).

Various Indian institutes and innovative Indian grape growers has developed different grape cultivars since 1930 with their continuous efforts and wisdom (Table 2 and 3). During the 1930s, Dr. G. S. Cheema then Director of Agriculture, Bombay State (Maharastra) attempted to breed superior varieties from the indigenous types. He made a selection from the open-pollinated progeny of the Pandhari Sahebi raised at Ganeshkhind Garden, Pune in 1928. Pandhari Sahebi was one of the best-adapted table varieties of that time but did not achieve commercial popularity because of poor cropping. The poor cropping of Pandhari Sahebi was reported to be due to self-sterility. Dr. Cheema raised a large number of seedlings of the Pandhari-Sahebi and from that, he made two selections i.e. Selection No. 7 and No. 94 (Phadnis *et al.* 1968). Indian Institute of Horticulture Research (IIHR), Bengaluru is the first horticultural research institute in the country established in 1967. IIHR, Bengaluru released four hybrids namely Arkavati, Arka Kanchan, Arka Shyam, and Arka Hans for commercial cultivation in the 1980s to fulfil the increasing demand of the grape industry. Similarly, during 1992, hybrid Arka Neelamani and in 1994, six other hybrids viz., Arka Chitra (Table grape), Arka Trishna, Arka Soma, Arka Krishna, Arka Majestic, and Swetha Seedless were released by IIHR for various purposes (IIHR, 2021; Chadha and Shikhamany, 1999). Indian Agricultural Research Institute (IARI), New Delhi initiated the grape improvement program and standardization of agro-techniques for quality grape production in 1950s. After few years, cultivars like Perlette and Beauty Seedless and a selection 'Pusa Seedless' were recommended for commercial cultivation in the north-western plains. Whereas two successful hybrids *viz.,* Pusa Urvashi and Pusa Navrang were evolved and released during 1996-97 after several years of multi-location trials by IARI. (IARI, 2021; Verma and Usha, *2006*). Agharkar Research Institute (ARI) situated at Pune in Maharashtra is engaged in the collection and evaluation of wild relatives of grapes for their utilization as rootstock (for abiotic stress tolerance) and in hybridization (for disease resistance) since its inception in 1946. The institute has three grape hybrids on its credit *viz.,* ARI-302 (for improved fruit quality, raisin making), ARI-27 (juice and wine fermentation), and hybrid ARI-516 for juice and winemaking (ARI, 2021). Punjab Agricultural University, Ludhiana has released juice-purpose grape variety 'Punjab-MACS-Purple' developed by ARI, Pune in the year 2008. ICAR-National Research Centre for Grapes, Pune was established on 18th January 1997 with the mandate of need based research on the grape considering the felt needs of the grape growers and other stakeholders. Three decade back area under the grape was about 45000 ha with the production of 1100 thousand tones. The scientific inputs from ICAR-NRCG and the innovativeness of the grape growers led to almost three times expansion in the grape area and its production than it was in 1995-96. The institute has released four varieties with different quality traits viz., Manjari Naveen (Table purpose), Manjari Medika (juice), Manjari Kishmish (raisin) and Manjari Shyama (Table purpose). The release proposals of Manjari Medika and Manjari Shyama are under consideration at the state as well as central level (Gawande, 2021). Manjari Medika is the only juice purpose grape variety in the country which is registered under the Protection of Plant Variety and Farmer's Right Authority (PPV&FRA), New Delhi (https://plantauthority.gov.in).

Table 2: Grape varieties developed by various Indian Research Institutes

S.No.	Variety	Parentage	End use
	Ganeshkhind Garden, Pune		
1.	Selection No. 94	Clonal selections Pandhari-Sahebi	Table grape
2.	Cheema Sahebi	Clonal selections Pandhari-Sahebi	Table grape
	ICAR-Indian Institute of Horticulture Research, Bengaluru		
1.	Arka Chitra	Angur Kalan x Anab-e-Shahi	Table grape
2.	Arka Majestic	Angur Kalan x Black Champa	Table grape variety
3.	Arka Neelamani	Black Champa x Thompson Seedless	Table grape variety
4.	Arkavati	Black Champa x Thompson Seedless	Raisin making
5.	Arka Shweta	Anab-e-Shahi x Thompson Seedless	Fresh consumption
6.	Arka Soma	Anab-e-Shahi x Queen of Vineyards	White dessert wine
7.	Arka Kanchan	'Anab-e-Shahi' and 'Queen of the Vineyards'	Table grape
8.	Arka Trishna	Bangalore Blue x Convent Large Black	Wine making
9.	Arka Shyam	Bangalore Blue x Black Champa	Dry table and dessert wines
10.	Arka Hans	Bangalore Blue x Anab-e-Shahi	Wines making
	ICAR-Indian Agricultural Research Institute, New Delhi		
1.	Pusa Seedless	Clonal selection from Thompson Seedless	Fresh consumption/ Raisin
2.	Pusa Navrang	Madeleine Angevine x Rubi Red	Juice and wine making
3.	Pusa Urvashi	Hur x Beauty Seedless	Table/raisin grape variety
4.	Pusa Aditi	Banqui Abyad x Perlette	Fresh consumption/juice
5.	Pusa Trishar	[(Hur x Bharat Early) x Beauty Seedless]	Table grape /juice
6.	Pusa Swarnika	Hur x Cardinal	Table grape /Manuka
	Agharkar Research Institute, Pune		
1.	ARI-516 (Punjab MACS Purple)	A cross of Catawba x Beauty Seedless	Juice
2.	ARI-302	—-	Table grape
3.	ARI-27	——	Juice & wine making
	ICAR-National Research Centre for Grapes, Pune		
1.	Manjari Naveen (2008)	Clonal selection from Centennial Seedless	Fresh consumption
2.	Manjari Medika	Pusa Navrang x Flame Seedless	Juice variety
3.	Manjari Kishmish (2019)	A white mutant derived from 'Kishmish Rozavis'	Raisin making
4.	Manjari Shyama (2019)	Black Champa x Thompson Seedless	Table grape

CONTRIBUTION OF INDIAN GRAPE GROWERS IN VARIETAL DEVELOPMENT

India is mainly table grape producing country Major grape cultivation in. Thomson seedless was the first variety under commercial cultivation during the 1960s in the country. Clonal selection has played a pivotal role in varietal development in India. Indian grape growers with their experience, knowledge, and efforts identified and developed several promising natural mutants from Thompson Seedless and Kishmish Chernyi in respect of berry and bunch characters (Chadha and Shikhamany, 1999; Anonymous, 2017). In India these clones are widely accepted for commercial cultivation (Table.3). India adopted the system of plant variety registration to protect the intellectual property rights of the newly developed plant varieties. Since 2015, PPV&FRA start receiving applications for grape variety registration and till date five farmer's grape varieties (Nanasaheb Purple Seedless, Sudhakar Seedless, Jay Seedless, Danaka Seedless and Sarita Purple Seedless) and a variety from ICAR-NRCG, Pune i.e. 'Manjari Medika' are successfully registered (https://plantauthority.gov.in).

RULING EXOTIC GRAPE CULTIVARS IN INDIA

Despite the release of several indigenous grape varieties, some exotic varieties like Thompson Seedless, Kishmish Chernyi, Perlette, Muscat Hamburg (Gulabi), Bangalore Blue, Red Globe, Flame Seedless, Fantasy Seedless, Crimson Seedless etc. are still under cultivation due to their distinctiveness. Thompson Seedless is the leading table grape in Peninsular India with wider adaptability. Thomson Seedless was the first variety under commercial cultivation during 1960's in the country. Thompson Seedless has excellent eating and keeping quality but it does not perform well under North Indian conditions due to late ripening and shy bearing. It performed well in Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Perlette is another white table grape variety which is commercially successful in North India (Upadhyay et al., 2021). It bears spherical and whitish berries. It has soft flesh with mild Muscat flavor. It has good keeping quality. This cultivar is semi vigorous, bears on basal buds and is easy to train and maintain.

Table 3: Grape cultivars developed by Indian grape growers

S. No.	Variety	Parentage	End Use
	Mr. Nanasaheb Kale, Nannaj, Solapur, (Maharashtra)		
1	Sharad Seedless	It is a bud sport from Kishmish Chernyi	Table purpose
2	Sonaka	Clonal selection from Thompson Seedless	Table/Raisin grape variety
3	Nanasaheb Purple Seedless	Clonal selection of Sharad Seedless	Table grape
4	Sarita Purple Seedless	Bud-sport from Sharad Seedless	Table grape
	Mr. Dattatray Nanasaheb Kale, Nannaj, Solapur (Maharashtra)		
1	Danaka	Clonal selection from 'Sonaka'	Table grape
	Mr. Raosaheb Kadalag, Sangamner, Ahmednagar (Maharashtra)		
1	Rao Sahebi	Natural mutant from Cheema Sahebi	Table grape
	Mr. Venkatratnam at Hyderabad		
1	Dilkush	It is a bud sport of Anab-e-Shahi	Table grape
	Mr. T. R. Dabade, Solapur, Maharashtra		
1	Manik Chaman	Clonal selection from Thompson Seedless	Table grape
	Mr. Vithal Nivrutti Thorat, Kalamb, Pune (Maharashtra)		
1	Nath Jambo Seedless (2006)	Clonal selection of Sharad Seedless	Table grape
	Mr. Vasantrao Arve, Borgaon, Sangali (Maharashtra)		
1	Tas –a-Ganesh (1970)	Clonal selection from Thompson Seedless	Table grape
	Mr. Vithal Appana Mali, Bedag, Sangli, (Maharashtra)		
1	Ambe Seedless (2007)	Clonal selection from Sonaka Seedless	Table grape
	Mr. Narayan Sangapa Mali, Mhaisal station, Sangli (Maharashtra)		
1	Krishna Seedless (2006)	Clonal selection of Sharad Seedless	Table grape
	Mr. Gausmohammed Saipan Shaikh, Boramani, Solapur, (Maharashtra)		
1	Mahadev Seedless (2007)	Clonal selection from Kishmish Chernyi	Table grape
	Mr. Maruti Ramchandra Mali Mhaisal, Sangli, (Maharashtra)		
1	Maruti Seedless (1994)	Clonal selection from Thompson Seedless	Table grape
	Mr. Haribhau Maruti Waykar, Gunjalwadi (Aarvi), Pune, Maharashtra		
1	Jay Seedless	Clonal selection from Sharad Seedless	Table grape
	Mr. Sudhakar Kshirsagar, Shivadi (Ugaon), Nashik, Maharashtra.		
1	Sudhakar Seedless	Clonal selection from Thompson Seedless	Table grape

Amongst colored varieties Red Globe, Crimson Seedless Flame Seedless, Fantasy Seedless, Gulabi and Bangalore Blue are popular in the country. Crimson Seedless is an American cultivar which produces well filled, medium sized (0.5 kg), conical and semi compact bunch with a shoulder. The berries are medium in size (3-4 grams) and are cylindrical to oval in shape. The flesh is translucent and firm and crisp. Crimson Seedless is the late ripening seedless table grape. Crimson Seedless has neutral and sweet flavor. Due to its excellent eating quality it is popular among the consumers. Crunchiness of Crimson Seedless is only comparable with Flame Seedless. Flame Seedless produces small, round, firm and crisp berries. Bunches are conical and medium in size. Flame Seedless is well known for its crispness and eating quality. Fantasy Seedless is also popular cultivar among Indian grape growers. It is a midseason, attractive, blue-black, seedless grape with naturally large berries. The berries of 'Fantasy Seedless' are large and are mostly oval. The berries are well spaced, resulting in medium to loose clusters. The clusters are conical and medium in size (weight-0.5 kg; length-24 cm). Red Globe is the world's second most cultivated table grape variety spread globally on 165000 ha. Red globe is well known for its very bold berry size (e"24 mm) with rouge berry colour. It produce compact and heavy bunch (>600g). The berry has firm berry attachment and suitable for distant market transportation. Despite of seediness it has tremendous demand in international market. Gulabi and Bangalore Blue are the leading grape varieties in southern India. Gulabi is also known as Karachi, Paneer Draksha and Muscat. It resembles Muscat Hamburg of Australia (Gandhi, 1960). It is grown widely in Tamil Nadu. Bunches are small and loose with deep purple, spherical and small-sized berries. The berry skin is thick and shipping quality is good. The fruit ripens early and uniformly with Muscat flavour. Bangalore Blue is an important cultivar of Karnataka where it gives more than one crop in a year. It does well on bower and Kniffin systems of training. It is being used mainly for juice and wine. Bunches are small, well filled with small to medium sized berries. It is susceptible to cracking and rotting during rains. Recently a Farmer Producer Company (FPC) 'Sahyadri Farms' has imported three patented grape varieties *viz.,* ARRA-15 (white), ARRA-19 (red coloured), and ARRA-32 (black coloured) (Grapa, 2021) for commercial cultivation in India but these are still under evaluation phase.

SIGNIFICANCE OF ROOTSTOCKS IN INDIAN VITICULTURE

In India salt-affected soils are mainly confined to the arid and semiarid and sub-humid (dry) regions and also in the coastal areas. The salt-affected soils account for 6.727 million ha equivalent to 2.1 % of the geographical area of the country. Out of the total 6.727 million ha of salt-affected soils, 2.95 million ha (44% of the total salt affected soils) are saline and the rest 3.771 million ha are sodic. Major grape growing states of the country like Maharashtra and Karnataka has 2.02 lac ha saline soil and 5.70 lac ha sodic soil.Major constraints of salt affected soils are that excess sodium on the soil exchange complex and/or soluble salts in the soil reduces the productivity of salt affected soils. Its soil structure poses problem of water and nutrient availability and these soils show micronutrient deficiency (Arora *et al.,* 2017). The rootstock can help in mitigating the vineyard problems associated with different abiotic stresses like soil salinity, acidity, nutrient imbalances, water scarcity etc. In terms of moisture stress tolerance, rootstocks are known to encourage the growth of scion varieties and perform normally when there is scarcity of water availability. It also alter the scion properties time of bud burst, fruitfulness, vine vigour, apical dominance, fruit composition etc. Roots anchor the vine to the soil, take-up water and nutrients, play important role in production and transport of plant hormones. Root activities directly influences the physiological processes of plant and hence rootstock can be held responsible for the performances of scion (Rom, 1987).

The rootstock made their entry in grape cultivation first time in late eighteen century to address the issue of *phylloxera* in Europe. In India majority of grape cultivation is concentrated in semiarid regions where soil moisture stress and salinity stresses are prevalent concurrently. Poor vine growth, severe foliar damage due to excess salt accumulation coupled with drastic reduction in productive life span of own rooted grapevines necessitated the use of rootstocks to combat these abiotic stresses also. Higher concentration of salts in both soil and irrigation water is one of the major abiotic stress which reduces vine yield to a greater extent. Water stress in grape orchard badly hampers growth and development of vegetative parts, fruit bud differentiation, fruit development and finally reduced yield and fruit quality. Severe moister stress leads to desiccation and vine death (Satisha *et al.,* 2019). In early 90s, own rooted grape orchards in the country experienced declined productivity due to these abiotic stresses. As a result grape production on rootstocks came into existence to overcome adverse effects of abiotic stresses.

It has been evident from many studies conducted at different regions of the country that rootstock vineyards outperformed compared to own rooted gardens under conditions of moisture stress (Satisha, 2015). Under Indian condition various studies have been conducted to check the performance of available rootstocks in the country especially in relation to table grape varieties in respect of yield and quality attributes (Somkuwar and Ramteke, 2006); variation in apical dominance (Satisha *et al.,* 2004); moisture and nutrient uptake (Ramteke *et al.,* 2001); in-situ grafting (Satisha *et al.,* 2006); dry matter partitioning and nutrient uptake (Somkuwar *et al.,* 2008); comparative performance of own rooted and grafted grapevines (Somkuwar and Adsule, 2009); raisin recovery and its biochemical parameters (Somkuwar *et al.,* 2013; biochemical content and disease incidence (Somkuwar et al., 2014); vegetative and photosynthesis (Somkuwar *et al.,*2015); growth parameters, yield and quality (Ghule *et al.,* 2021), stress relieving enzymatic activity during bud break (Somkuwar *et al.,*2021) etc. These studies revealed that Dogridge performed better in respect of drought tolerance, graft success and dry matter distribution in roots. Likewise Thompson grafted on Dogridge had shown better growth yield and fruit quality parameters. Number of canes/vine, shoot length, shoot diameter, leaf area and stock: scion ratio varied significantly among the rootstocks and were found maximum in vines grafted on Dogridge rootstock followed by Salt Creek and 110R rootstocks. Red Globe grapevines grafted on Dogridge followed by Salt Creek rootstock proved better for growth parameters. Amongst Dogridge, 110R, 140Ru and 1103P; Dogridge and 1103P performed well for vegetative growth and physiological parameters when grafted with Crimson Seedless, Manjari Naveen and Nanasaheb Purple. Whereas, higher fruit yield (16.35 kg/vine), raisin recovery (29.90%) and higher amount of carbohydrate (82.25 mg/g) was recorded in Thompson Seedless when grafted on 110R. The disease incidence (powdery mildew and anthracnose) was recorded least in vines grafted onto 110R compared to Dogridge and own rooted vines. Grapevines grafted on 110R exhibited positive interactions were observed between enzymatic activities of stress relieving enzymes, increased bud break (64.25 %) and reduction in days taken to bud sprout (8.43 days). Higher apical dominance was evident on vines grafted on Salt creek coupled with highest nitrogen content in cane than Dogridge. These studies shows that genetic combination of grape rootstocks like 110R, 1103P, 140Ru and Salt Creek may solve the need of dual resistance to drought and salinity stresses in the country.

Climate change has impose great burden on the farming community through frequent incidences of natural vagaries like unseasonal heavy rain, flooding, high day temperature, chilling or frost incidence, hail storm, typhoons etc. Flooding during critical vine growth period is now a common phenomenon in the grape growing region of the country. There is a great urge to develop the rootstock genepool which will curtail the influence of changing climate and ensure the quality fruit production under unforeseen stress conditions.

CHALLENGES AND PROSPECTS OF INDIAN GRAPE INDUSTRY

Indian viticulture requires indigenous grape cultivars with better fruit quality, wider adaptability, and tolerance against biotic and abiotic stresses. Grape varieties with uniform colour development attributes under rising day temperature are also required to expand the area under coloured grape varieties under a subtropical climate of India. India needs the varieties with better shelf life i.e. more than 50 days under cold storage for allowing their transport to distant markets within the country as well as outside the country. Early maturing varieties for the regions where fruit maturity coincides with rain and to expand grape cultivation to newer areas is a need of the time. Grape varieties with heritable resistance against diseases like mildews, anthracnose, and rust as well as against insects viz., sucking pests, borers, leaf-eating caterpillars, etc. to minimize the expenditure on agrochemicals are highly required. Grapes varieties with specific attributes like seedlessness, bold berries (>20mm), self-thinning properties to curtail the labour cost involved in the recurrent operations like fruit thinning and PGR applications, variety with elongated berries for domestic market, varieties with vivid aromas and flavors are need of the time. Although India is an important exporter of table grape in world arena, the country has its own limitations like narrow genetic base of the Indian grape cultivars. Various Indian research institutes has released the grape varieties but those did not take up by growers due to lack of commercial potential. In India growers are still cultivating Thompson Seedless, its clones and clones of Kishmish Cherneyi developed by growers. Widening of varietal base in grapes to sustain in the most competitive global market need urgent attention. The marketing window available in global is very crucial criteria that decides the direction of the grape production in the country. Grape varieties with diverse maturity periods are essentially required to avoid the glut in the domestic market and to fulfill the market demand during lean period. It will also help in broadening the production window so that grapes can be supplied in the global market around the year and the country will sustain as a competent supplier in the global market.

Development of a single grape rootstock suitable for all conditions is not possible because different viticulture sites have different horticultural needs. In this line screening of the available genepool for different biotic and abiotic stresses and identifying the promising entries is a baseline work need to be initiated. Later, considering the rootstock requirement of different grape growing region of the country such identified genotypes should be evaluated on grafted vines under stress environment to select elite material. Breeding of new grape rootstock genotypes, which can deal with the environmental changes, is essential for Indian viticulture. Indeed, development of new grapevine rootstocks with a higher tolerance to environmental stresses, drought in particular, should be a successful strategy to overcome climate limitations. In many situations, rootstocks having tolerance to multiple stresses may be desirable. Employing the genotypes like *V. berlandieri x V. rupestris* (salinity stress tolerence), *V. Champanii* (soil moisture stress tolerance) V. rotundifolia (phylloxera, nematodes, fan-leaf degeneration, and downy and powdery mildew resistance), *V. riparia* (cold hardiness) and *V. flexousa* (flood tolerance) in resistance breeding programme will be useful in deriving the resistant genepool of grape rootstock which will address various abiotic and biotic stresses under changing climate scenario. Including salt tolerant genepool like *Vitis berlandieri x Vitis rupestris* (110R, 140Ru and 1103P) in breeding programme and crossing them with water efficient genotypes which thrive well on meagre soil moisture like *Vitis Champanii* (Dogridge & Salt Creek) to get the combined resistance for drought and salinity stresses is a viable rootstock improvement strategy.

Quality plating material is a key for quality grape production and the longevity of productive grape orchards. Unavailability of quality planting material leads to graft failure and death of young vines. Certified nurseries supplying authentic planting material of grape is urgently required for production of quality grapes. Development of technologies for enhancing climate resilience of grapes like protected cultivation, improved input use efficiency, off-season availability are some key area needs to be addressed. In nutshell some important areas need to be addressed for holistic development of Indian Viticulture are: 1. Evolving climate resilient grape varieties with superior fruit quality that would appeal the global market, varieties with broad genetic base, wider adoptability and diverse maturity period, 2. Modified crop husbandry techniques like protected cultivation which will support grape cultivation under different agro-climatic conditions of the country 3. Development of rootstocks tolerant to abiotic/biotic stresses 4. Mechanization friendly systems of training and pruning practices.

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Review Article

Five decades of research and development of Kiwifruit in India

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ABSTRACT

The kiwifruit is a recent crop introduction to horticulture practices of Mid-Himalayan states of India such as, Himachal Pradesh, Uttarakhand and J&K in the North-West and Sikkim, Arunachal Pradesh and Nagaland in the North-Eastern Himalayas. Over past few years, this fruit has attained immense popularity among consumers due to its nutritional value and has gained appeal among small and marginal farmers owing to its high benefit-cost ratio, particularly through Hi-Tech cultivation techniques.

The kiwifruit, also known as Chinese gooseberry (*Actinidia chinensis* Planch.) is believed to have originated in China, although it gained popularity in New Zealand. In India, it was first introduced at Lal Bagh garden in Bengaluru around sixties; however, it was soon observed that the fruit could be cultivated well only in the semi-temperate climate of Himachal Pradesh, around 1963. Subsequently, it was broadly introduced in this North-West Himalayan state of Himachal Pradesh and also to some extent in Jammu & Kashmir and Uttarakhand. Now, it is extensively cultivated in the North-Eastern Himalayan states namely; Arunachal Pradesh, Sikkim and more recently in Nagaland, Meghalaya, Mizoram and Manipur. The kiwifruit holds great scope for expansion in almost all states of Northeastern region barring Tripura and Assam, owing to their warmer climate. In India, it is cultivated in an area of 5000 ha with the production of 13,000 metric tonnes. Over the past five years, the area under kiwifruit production in Himachal Pradesh has not increased much, but the production has shown a steady increasing trend. Arunachal Pradesh, Nagaland, Mizoram, Sikkim, Himachal Pradesh, and Uttarakhand are the major kiwifruit-producing states of the country.

The idea for inter-cropping of kiwifruit with large Cardamom, a widely grown spice crop was conceptualized through the author's field awareness initiatives along with encouragement from the State Departments of Horticulture. Given that large cardamom is a shade-loving plant, this requirement can be met when grown underneath the kiwifruit vines. Due to suitable soil and climatic conditions in the states of Sikkim and Arunachal Pradesh, it lends great credibility to the beneficial intent of introducing this concept. Eventually, it is hoped to standardize organic farming in this areas as a cultural practice in the suitable regions. This Inter-cropping practice of large cardamom with kiwifruit is greatly gaining importance in Sikkim and Arunachal Pradesh, adding to the farm income of the growing community in these states. This hi-tech also ensures income security in a way that if one crop fails in a season the other would provide necessary sustenance. This model of inter-cropping has lately also been expanded to other kiwifruit producing states. The kiwifruit of North-Eastern area in India has managed to attain its commercial identity at a national as well as international markets in southeastern Asia and Gulf countries. Of late, other states have also begun to prioritize this fruit for area expansion under Horticulture Technology Mission.

Despite suitable climate and soil, the lack of quality planting material, package of practices for organic farming, modern technologies of precision farming and trained manpower have been observed as the major constraints in enhancing the productivity of temperate fruits in general and kiwifruit in particular. Keeping in view these concerns, the ICAR Roving Team for Temperate Fruits recommended the road map for cultivation of temperate fruits in North Eastern Hill Region with main emphasis on kiwifruit. Implementation of modern horticultural practices for growing kiwifruit in the Mid-Himalayan region of the country should benefit its rural economy comprising mainly of small and marginal farmers whose practice of subsistence agriculture is under challenge from changing climate scenario.

As the kiwifruit originated in China on the Northern front of the Eastern Sub-Himalayan ranges, the inherent potential for its commercial cultivation in Indian mid-Himalayan ranges is worth considering by the scientific community and policymakers. The chapter deliberates upon the key technologies developed for increased productivity of kiwifruit along with large other crops.

It is worth mentioning that kiwi is the emerging crop of mid-Himalayan states in general and North-Eastern Sub-Temperate Zones in particular, which are most suitable for horticulture based integrated farming system such as inter-cropping. The high potential for transformation from subsistence farming to sustainable horticulture is discussed here with.

Keywords: Cropping system,Himalyan region, Kiwi, North eastern hill, varieties

INTRODUCTION

The kiwifruit has garnered an assortment of odd names throughout the century, including "melonette," "strange fruit," and the especially appetizing name of "hairy bush fruit." The fruit got its current name, kiwi, as a result of a cleverly designed marketing campaign hatched in New Zealand in 1959. Unsurprisingly, its original name, "Chinese gooseberry" wasn't appealing to the US market. When it was newly dubbed as the kiwifruit, sales took off. Because the name was never trademarked, however, other growers in various countries adopted the same name. New Zealand farmers have since adopted and trademarked the name "Zespri" for all of their kiwis.

Kiwi is native to Central China, and the Chinese today know the fruit as *mihoutao,* or, monkey fruit. Despite growing wild throughout China for centuries, cultivation of this fruit didn't begin until the late 19th century. According to the "Encyclopedia of Fruit and Nuts," Europeans and North Americans planted kiwis in their gardens in the early 1900s. When New Zealand got a hold of the fruit by the 1920s, orchards of the fruit took off. Forty years later, the country was refining cultivation techniques and exporting to several other countries. According to a senior scientist at the National Bureau of Plant and Genetic Resources, its cultivation was introduced to the Shimla hills in 1963 as it failed in Lal Bagh of Bangalore introduced from Australia in sixties. In the world, the kiwifruit is cultivated in an area of 2,47,793 ha with the production of 40,38,872 tonnes with an average productivity of 16.30 ton/ha. The area and production under kiwifruit cultivation have increased at a steady pace since 2000 up to 2017. Approximately, 93.7 per cent of the world kiwifruit production is contributed by China, Italy, New Zealand, Iran, Greece, and Chile. The highest productivity of 35.18 ton/ha is in New Zealand (FAOSTAT, 2018).

Availability of Kiwifruit in India

Farmers grow several commercial varieties of kiwis throughout many of India's cooler regions, including Himachal Pradesh, Sikkim, Jammu and Kashmir, Arunachal Pradesh, Meghalaya, Uttarakhand, and the Nilgiri Hills. Of these areas, Himachal Pradesh produces some of the best kiwis. Serious cultivation efforts have only begun recently on account of growing demand from India's large metropolitan cities centers. The Dr. Yashwant Singh Parmar university of Horticulture and Forestry has been instrumental in commercializing and popularizing scientific cultivation and distribution of planting material throughout the country India's kiwifruit season is October through December, with several varieties coming and going in this time.

Kiwifruit Species

The genus Actinidia contains around 60 species. Though most kiwifruit are easily recognized due to basic shape and their fruit is quite variable. The skin of the fruit can vary in size, shape, hairiness, and color. The flesh can also vary in color, juiciness, texture, and taste. Some fruits are unpalatable while others taste considerably better than the majority of the commercial varieties. The most common kiwifruit is the Fuzzy Kiwifruit and comes from the species *A. deliciosa*. Other species have fruits that are commonly eaten; some examples are: Golden Kiwifruit (*A. chinensis*), Chinese Egg Gooseberry (*A. coriacea*), Baby Kiwifruit (*A. arguta*), Arctic Kiwifruit (*A. kolomikta*), Red Kiwifruit (*A. melanandra*), Silver Vine (*A. polygama*), Purple Kiwifruit (*A. purpurea*). Kiwifruit can be grown in most temperate climates with adequate summer heat. Where fuzzy kiwis (*A. deliciosa*) are not hardy, other species can be grown as substitutes.

Nutritional Value of kiwifruit

Health benefits of Kiwifruit

The kiwifruit is the most nutrient-rich of the top 26 fruits consumed in the world today. It also has the highest density of any fruit for vitamin C and magnesium limited mineral in the food supply of most affluent countries and a nutrient important for cardiovascular health. Among the top three low-sodium, high-potassium fruits, kiwifruit ranks number one, having more potassium than a banana or citrus fruits. In Cancer, Kiwifruit has been shown to contain an anti-mutagenic component, helping to prevent the mutations of genes that may initiate the cancer process. The presence of glutathione may account for the reduction. Carcinogenic nitrates are formed during the smoking or barbecuing of foods. When nitrates are ingested, a process called nitrosation can occur, in which free radicals 'nitrosamines' are formed that may lead to the formation of gastric or other cancers. Kiwi has been demonstrated to aid in the prevention of nitrosation. In another in vitro test with cultured mammalian-cell lines, kiwifruit extract was found to inhibit melanoma, or skin cancer.

The amino acid arginine, present in kiwifruit, is being looked at by cardiologists to improve post angioplasty blood flow and actually prevent the formation (or reformation) of plaque in the arteries. Kiwifruit is ranked as having the fourth highest natural antioxidant potential next to the red fruits containing high levels of beta carotene. Lutein, an important phytochemical found in kiwifruit, has been linked to the prevention of prostate and lung cancer.

Kiwifruit being recognized by the FDA as an excellent source of dietary fiber, studies indicate that it contains another not-yet-isolated compound that accelerates digestive transit time even faster than dietary fiber alone - important for colorectal cancer prevention. The benefit of this laxative action is to decrease the build-up of cancer-promoting metabolites.

Kiwifruit is one of the few fruits that are green at maturity, and chlorophyll is responsible for that color. Several studies have suggested that chlorophyllin, a derivative of chlorophyll, is an inhibitor of liver carcinogenesis. In depression, Inositol is found in kiwifruit and recent studies have shown that inositol, because of its function as a precursor of an intracellular second messenger system, can be beneficial in the treatment of depression. Diabetes Inositol, a sugar alcohol naturally occurring in kiwifruit, may play a positive role in regulating diabetes. Inositol supplements may improve nerve conduction velocity in diabetic neuropathy. Inositol plays a role in intracellular responses to hormones and neurotransmitters. It acts as a second messenger in cell signaling processes. Eye health/ Macular degeneration Kiwifruit contains a wealth of carotenoids (beta carotenes, luteins and xanthophylls); phenolic compounds (flavonoids and anthocyanins) and antioxidants, including vitamins C and E. The excellent complement of antioxidants in kiwifruit may help prevent the oxidation of the good cholesterol (HDLs).

Kiwifruit is particularly high in two amino acids: arginine and glutamate. Arginine may help promote an increase in arteriolar dilation, working as a vasodilator and improving blood flow that is important for heart health. The FDA considers kiwifruit a good source of vitamin E, crucial for a healthy heart. Kiwifruit contains magnesium at 6 per cent DV. Magnesium is thought to be in short supply in the diets of affluent countries. Poor magnesium status is associated with heart disease, myocardial infarction and hypertension. Kiwifruit contains pectin, which has been shown to lower cholesterol. Hypertension Cardiologists believe the sodium-to-potassium ratio is critical for heart health. That ratio is extremely favorable in kiwifruit.

Kiwifruit has been shown to be an immune booster, most likely due to its extremely high vitamin C content and its complement of antioxidant compounds. The kiwifruit contains the amino acid arginine, a well-known vasodilator and has been used to treat impotance in men.

For physical fitness Kiwifruit contains a wide range of minerals (electrolytes) essential for replenishing those lost during exercise especially in hot environments. It is also a naturally significant source of electrolytes for a pre-workout regimen. In China, a kiwi-based sport drink was designed to overcome athletic training in a hot environment, where large amounts of minerals can be lost in sweat. A 5% addition of carbohydrates to the kiwifruit juice helped to maintain a normal glucose level during exhaustive training. In stress reduction, kiwifruit contains a relatively high level of serotonin. Serotonin causes a calming effect in most individuals Weight Control Calorie for calorie, kiwifruit is one of the most nutrient-rich fruits. You get the best balance of nutrients per calorie (the most nutrients for the fewest calories) from kiwifruit, cantaloupe, papaya and lemons.

Nutritional content and dietary requirement

The table below shows the amounts of specific nutrients in a kiwi weighing 69 g. It also shows how much of each nutrient an adult needs per day, according to the Dietary Guidelines for Americans 2015–2020. However, specific requirements vary, depending on a person's age and sex.

Nutrient	Amount in 1 kiwi (69 g)	Daily adult requirement
Energy (calories)	42.1	1,600–3,000
Carbohydrates (g)	10.1, including 6.2 g of sugar	130
Fiber (g)	2.1	22.4–33.6
Calcium (mg)	23.5	1,000–1,300
Magnesium (mg)	11.7	310–420
Phosphorus (mg)	23.5	700–1,250
Potassium (mg)	215	4,700
Copper (mcg)	90	890–900
Vitamin C (mg)	64	65–90
Folate (mcg)	17.2	400
Beta carotene (mcg)	35.9	No data
Lutein & zeaxanthin (mcg)	84.2	No data
Vitamin E (mg)	1.0	15
Vitamin K (mcg)	27.8	75–120

Kiwi also contains small amounts of iron, vitamin A, and vitamins other than folate.

Cultivation aspects

Soil and Climate

Deep well drained, sandy-loam soil with good amount of organic matter is ideal for its cultivation. A soil pH 5.5 to 6.5 is considered ideal for vine growth and fruit production.

It can be grown successfully in warm temperate to sub-tropical regions lying between 3000 to 5500 feet amsl which provide 600 800 chilling hours to break dormancy. Low temperature (-2.5°C or below) and frost during spring and autumn is very injurious, which kills immature shoots and fruit buds. In summer, high temperature (>38°C) accompanied by high insolation (loo) and low humidity may cause scorching of leaves and sun burn of fruits and even death of the plant. A rainfall of about 120-150 cm well distributed throughout the growing period is sufficient for proper growth and development.

The kiwifruit can be grown on a wide range of soils with adequate soil moisture. Well-drained, sandy–loam soil with a good amount of organic matter is ideal for the cultivation of the kiwifruit. Heavy clay soil with poor drainage is not suitable. A soil pH of 5.5-6.5 is considered ideal for vine growth and fruit production, but higher pH up to 7.3 affects adversely due to Mn deficiency. As the kiwifruit plant has vigorous growth and viny habit, it does not resist strong winds during growing period (April–May). Therefore, a wind break plantation is essential well before the planting of vines. This can be easily and cheaply accomplished by planting *Populus nigra*, *Sesbania agyptica*, and *Salix babilonica* and later on controlled their growth by topping and trimming to make a good shelter.

Varietal Status

Kiwifruit is a dioecious plant, bears staminate and pistillate flowers on separate plants. The commercially grown pistillate cultivars in different agro-climatic conditions of our country are Hayward, Allison, Abbott, Monty and Bruno, and staminate cultivars are Allison, Matua and Tomuri.

Rootstocks and Nursery Production

Seedlings of some cultivated cultivars like Bruno and Abbott are commonly used as a rootstock in kiwifruit. Seeds of these two cultivars are preferred because of good germination and strong seedling vigour. Propagation through cuttings is most rapid and easiest method. Both soft, semi-hard and hardwood cuttings are used to raise own rooted plants (Kishore et al., 2001). The ideal cutting is 0.5 to 1.0 cm thick with relatively short internodes about 10-15 cm in length having at least 3 to 4 buds. Cuttings should be taken from middle portion of current season's growth shoot during July in case of semi-hardwood cuttings and one year old shoot during January February in case of hardwood cuttings. After preparation, the cuttings are dipped in 4000 to 5000 ppm IBA solution for 10-15 seconds.

Although budding or grafting takes two years to develop a nursery plant, yet is easiest, economical and used for large scale multiplication. Before sowing, seeds are stratified for 30-35 days at 0-5°C to break dormancy. Stratified seeds are sown in the sand beds during February. Germinating or baby seedlings are very sensitive to direct sunlight so it must be protected by creating a shade. Seedling are transplanted in nursery beds during July August, which attain a graftable size within a year. Tongue grafting and chip budding done in last week of January to end of February gave 90-95 per cent budtake success (Chandel et al., 1998). Nursery plants are also produced through tissue culture.

Planting

Flat land with gentle slope is ideal for planting of kiwifruit. Plant spacing varies according to cultivar being grown and training system adopted. In general, planting is done at a spacing of 6 m from plant to plant and 4 m from row to row in vigorous varieties like Allison, Abbott and Monty trained on T-bar trellis system. Whereas, Hayward is less vigorous and planted at a spacing of 5m x5 m. In pergola system of training, a spacing of 6.0 m × 6.0 m is recommended for getting better fruit production. Planting is done during dormant season i.e. December-January. While doing the planting, the male plants are spread throughout the block with every female adjacent to a male. This is achieved by 1:8 or 1:9 male to female ratio.

Pollination

Wind and insects play a significant role in pollination, however, introduction of honeybees in the orchards further increase fruit set and size of the fruits. Palmer Jones and Clinch (1974) recommended 9 colonies per hectare for better pollination. Male flowers produce viable pollen for 2-3 days after opening, after which they become senescent and die. Female flowers in contrast are receptive for 7-9 days after opening even when the petals have started falling. Besides, insect and wind pollination, hand pollination is essential to get fruits of better size and quality.

Canopy Management

Kiwifruit is a vine like grape, thus require similar training structure but more stronger than grape. In T-bar trellis system, the pillars of iron or concrete about 1.8 m in height above the ground level are erected at a distance of 6 m from each other in a row in straight line. A cross arm (1.5 m) is fixed on each pole, which carries 5 outrigger wires at a distance of 45 cm each. Vine is trained up to the wire as single stem, than two leaders in opposite direction along the center wire are selected or developed. From these permanent leaders, temporary fruiting arms 25-30 cm apart are selected at right angle along both sides of each leader. Training of vine on pergola system is similar to that of T-bar.

The fruit is developed on current season's growth arising from one year old shoot. Only the basal buds of nodes 4 to 12 current season's growth are productive. Vine grows 2-3 m every year, which become over-crowded if not controlled by both summer and winter pruning. The shoots developed on older wood by heading back will not fruit normally in the first season. Vine pruning is carried out in such a way that the fruiting areas are available every year requiring the wood to be young. This is achieved by 3 to 4 years lateral replacement system. In dormant pruning, the fruiting lateral is cut back to 2 vegetative buds beyond the last fruit. In the second year these vegetative buds produce the fruiting shoots, which is pruned again. The arm on lateral shoots are pruned and allowed to fruit for 3 to 4 years. After this the lateral is removed from the main branch and other laterals. are selected and pruned accordingly so that the balance between vegetative and reproductive growth is maintained for the continuity in the fruit production. In summer pruning, a fruiting shoot is headed back beyond 6-8 buds from the last fruiting bud during June-July.

Training

- T- bar trellis and pergola systems.
- In T- bar trellis system, the pillars of iron and concrete about 1.8m in height
- Above the ground level are erected at a distance of 6m from each other in a

  row in straight line.
- A cross arm (1.5m) is fixed on each pole, which carries five outriggers wire
- At a distance of 45 cm each
- Vines are trained upto wire as single stem then two leaders in opposite direction along the center wire are selected or developed.
- From these permanent leaders, temporary fruiting arms 25-30 cm apart are selected at right angle along both sides of each leader.
- Training of vines on pergola system is similar to that of T-bar. A flat topped network of criss-cross wire is prepared on the erected pillars.
- This system is costly to prepare but vine trained on this system gives higher yields.

T Bar trellis system

Pruning

The following principles should be kept in mind at the time of pruning:

- The fruit is developed on current season's growth arising from one year shoot.
- Only the basal buds of the nodes 4-12 on current season growth are productive.
- Vines grow 2-3 m every year, which become over-crowded if not controlled by summer and winter pruning.
- The shoots developed on older wood by heading back will not fruit normally in the first season.
- In dormant pruning, the fruiting lateral is cut back to 2 vegetative buds beyond the last fruit.
- The arm on lateral shoots are pruned and allowed to fruit for 3-4 years.
- After this the lateral is removed from the main branches and other laterals are selected and pruned accordingly so that the balance between vegetative and reproductive growth is maintained for the continuity in the fruit production.

- In summer pruning shoot is cut beyond 6-8 buds from the last fruit during June-July.

Orchard Floor Management

The vines make much vegetative growth, and yield heavily, thus require adequate amount of manure and fertilizers for normal vine growth and quality fruit production (Sale and Clark, 2002). In general, a basal dose of 20 kg FYM along with 0.5 kg of NPK fertilizer mixture containing 15 per cent N be applied each year age of vine. After 5 year of age, 40-50 kg FYM, 850-950 g N, 500-600 g P, O, and 800-900 g K_2O per vine is applied every year. FYM along with full dose of P, O, and K,O is applied during December-January, while the nitrogen is applied in two equal dressing, half before bud-burst and remaining half dose at the onset of monsoon i.e. in July.


Black polythene mulch Grass mulch

Water requirement of kiwifruit is very high because of vigorous vegetative growth and larger leaf surface area. In general, fully grown vine requires 80-100 litres of water for total daily transpiration from 16-17 m² canopy area during summer. Young plants should be irrigated at 2-3 days interval, while bearing plants are to be irrigated at 20 per cent depletion of soil moisture from field capacity (5-6 days interval) during summer to get better size fruits (Rana et al., 2000).

Clean cultivation with mulching of tree basin area with 15 cm thick hay grass is recommended for kiwifruit orchards. In the initial two years, inter-crops like strawberry, peas, beans, cowpeas and vegetable crops like tomato, zinger etc. can also be grown.

Irrigation

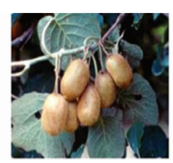
The kiwi plants require much water due to vigorous vegetative growth and larger leaf size, vine habit, and high humidity in the natural habitat. In general, fully grown vine requires 80–100 L of water for total daily transpiration from the 16 to 17 m² canopy area during summer. Due to scanty and irregular distribution of rainfall in most of kiwifruit-growing areas, the irrigation is important means for increasing the productivity of fruits. Young trees should be irrigated at a 2–3 days interval, whereas bearing trees are to be irrigated at 20% depletion of soil moisture from field capacity at a 5–6 days interval during summer to get better-sized fruits. Clean cultivation with mulching of the tree basin with 15 cm thick hay grass is recom- mended for kiwifruit orchards.

As the kiwifruit requires heavy water for its cultivation, there is need to screen out various cultivars that can be easily adaptable to those areas where water availability is very less. Pratima et al. (2017) have reported that the deficit irrigation results in an increase in the chlorophyll stability index and decrease in the relative water content of kiwifruit cultivars, namely, Allison, Hayward, Abbott, Monty, and Bruno. Among different cultivars, Bruno was found to exhibit more resistance to deficit irrigation, whereas the cultivar Hayward exhibited the least resistance to deficit irrigation.

Crop and Quality Regulation

All the cultivars of kiwifruit except Hayward bears heavily every year. This heavy crop create a severe competition between the fruits for water, nutrients and photosynthates, which leads to production of small sized fruits. Therefore, to harvest quality crop of good size, hand thinning is essential, as chemical thinning is ineffective. In a study on thinning in kiwifruit, flowers or fruit thinning (20% thinning) to the extent of retaining 5 to 6 fruits/ flowering shoot produced more fruits of A grade without any adverse effect on total yield (Thakur, 2000). In hand thinning only lateral flowers or fruits are removed.






Stage of thinning Thinning to 4 flower buds Thinning to 6 flower buds Unthinned


Optimum stage for CPPU application Method of CPPU application

Maturity, Harvesting and Marketing

The stage of maturity at which the fruit is harvested is of paramount importance in the kiwifruit which is harvested hard and there is no perceptible change in color. The determination of fruit maturity is also very important for obtaining good price from the produce. The early harvesting of the kiwifruit results in the development of poor flavor and aroma. On the other hand, if the fruits are left on the vine, they will mature, ripen, and eventually abscise from the plant at a slightly over-ripe stage. Individual fruits on the vine are observed to ripen at quite different times. The irregularity of natural ripening pattern makes it impractical to harvest and cause damages during harvesting, grading, and packing operations. Keeping all the factors in mind, the physiologically mature fruits can be harvested and allowed to ripen off the vine.

The kiwifruits having 6.2% TSS are ideal for harvesting. The delay in harvesting deteriorates their storability. They are easily harvested by snapping off the fruit at the abscission layer at the base of the stalk. Under Indian conditions, the fruits are plucked from mid-October to the last week of December, depending upon the climatic conditions and cultivars. Harvesting coincides with the commencement of the dormant season, which means that allowing fruit late on the vines will make them prone to frost and birds damage. In a study on "Allison" kiwifruit, flesh firmness, total soluble solids, total sugars were considered as dependable indices of maturity, which could be used in conjunction with days from full bloom for assessing optimum maturity (Rana et al., 2003).

A large number of factors such as cultivars, training system, pollina tion, nutrition, age, irrigation, and climatic conditions are responsible to determine the yield. Under Indian agro-climatic conditions, the approximately 60–120 kg/plant yield can be achieved at the age of seven years of planting. After harvesting, fruits can be stored for 3-4 weeks at room temperature and for 4-6 months in cold storage at 0°C with 80-90 per cent relative humidity. Fruits can be processed into jam, juice and squash.

The kiwifruit has a wider scope in the domestic as well as international market. As the apple has revolutionized the economy of farmers in high hills, kiwifruit is a boon to the farmers in the mid and low hills owing to very high economic returns. The kiwifruit cultivation has an important advantage that it comes in the market from October to December when practically no other fresh fruit is available to compete with it. Another major benefit of its cultivation is that the fruit is harvested hard and can be transported to long distances without using any sophisticated packaging material. Although there is a great potential for its cultivation in India, its cultivation yet has not gained momentum because of poor productivity and lack of transfer of cultivation technology to the farmers. Consequently, the kiwifruit produced in our country is not able to compete with the fruits imported from New Zealand, Australia, Italy, and other countries (Rana and Gitesh, 2021)

Way Forward for Kiwi Fruit Growing in India

In kiwi fruit major strategies should be aimed at following constrains:

(a) Lack of genetically superior planting material.

(b) High cost of plantation whole establishment.

(c) Lack of standardized techniques of cultivation like pruning cum training.

(d) Since Sikkim is an organic state, the package of practice of organic cultivation is adhoc

(e) Lack of use of proper proportion of pollinizers, practice of hand pollination

(f) Concept of hand thinning and use of biostimulants to increase fruit size is non-existent.

Prospects

Kiwifruit has a bright prospects in our country and has been assessed as one of the important future commercial fruit. It provides high return per unit area and the farmers can earn about Rs. 4 to 5 lakhs per hectare annually. Kiwifruit bears heavily every year with no crop failure. The fruit is highly acclaimed for the nutritive and medicinal value. It hold a wealth of health giving property, thus recommended for patients suffering from diabetes and heart diseases. In kiwifruit, no serious pests and diseases have been observed, thus it has a better scope to become commercial eco-friendly fruit crop of the country. Due to hard nature of the fruit with hairy skin surface, the fruits are not damaged by any bird and even not by the monkeys. It has a longer shelf life and can be stored for one month in open at room temperature and for 4-6 months in cold storage.

Value Addition in Kiwi Fruit

- Kiwi Squash
- Kiwi Appetizer
- Kiwi plus Apple Jam
- Kiwi plus Pineapple RTS
- Kiwi Pineapple Sauce
- Kiwi plus Ginger Appetizer Flakes
- Kiwi Candy
- Kiwi Package [refrigerated]

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Review Article

Technological innovations in commercial high tech horticulture, vertical farming and landscaping

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ABSTRACT

Hi-tech horticulture is a technology that is trendy, less environment-dependent and capital intensive however with a capability to boost productivity and farmer's financial gain. Hi-tech horticulture is beneficial not just for raising fruits, vegetables and flower crops however conjointly for conservation, plant protection and post-harvest management together with value-addition. Vertical greening can provide a cooling potential on the building surface, which is very important during summer periods in hot climates. The cooling effect of green facades has also an impact on the inner climate in the building by preventing warming up of the facade. Micro greens are perfect when time and space becomes a barrier. Growing micro greens in vertical gardening is the best idea as it won't consume much of our time and space and also micro greens are extremely easy to grow. Micro greens are the super healthy foods as they do not include any chemical spraying activities during their growth. Vertical farming utilizes the vertical unused space which or else left unused in other farming systems. This can also facilitates the people to get the fresh cut vegetables regularly. The world is developing new techniques day by day if one incorporates modern innovations and techniques with traditional farming. We can feed the increasing population despite having so many challenges. This will not only help in sustainability of the produce but will also help to improve the economic condition of the farmers. Landscape gardening is becoming important in mitigation and adaptation to climate change, its different types such as indoor, outdoor gardening, vertical gardening, terrace gardening and commercial park management are high in demand and generate employment to un-employed youth. Landscaping combines elements of art and science to create a functional, aesthetically pleasing extension of indoor living to the outdoors.

Keywords: Climate change, landscape gardening, micro green, value addition, vertical farming

INTRODUCTION

The horticulture sector encompasses a wide range of crops *i.e.*, fruits, vegetables, flowers and ornamental crops, medicinal and aromatic crops, spices and plantation crops. The wide range of agro-climatic conditions of India is conducive for growing a large variety of horticultural crops, including, root and tuber crops, ornamental crops, plantation crops like coconut, areca nut, cashew and cocoa. India has maintained leadership in the production of many commodities like mango, banana, acid lime, coconut, areca nut, cashew, ginger, turmeric and black pepper. India has made a good place for itself on the Horticulture Map of the World with a total annual production of horticultural crops touching over 326.58 million tons during 2020-21(NHB). India has retained its status as the second largest producer of fruits in the world and is first in the production of fruits like mango, banana, papaya, lemon & lime. Presently, it is the second largest producer of fruits and vegetables in the world is next only to China in area and production of vegetables and occupies prime position in the production of cauliflower, second in onions and third in cabbage in the world. Further, it is the largest producer, consumer and exporter of spices. India is home to a wide variety of spices like black pepper, cardamom, ginger, garlic, turmeric, chilli and a large variety of tree and seed spices. Almost all the States in the country grow one or more spices. India has also made noticeable advancement in the production of flowers.

High-tech farming mainly refers to horticulture operations involving the latest technologies. It is a capital intensive farming since large capital outlay is required towards purchase of specialized equipment, maintenance of assets, training of labour *etc*. Hi-tech horticulture mainly relates to commercial farming system aimed at catering to the needs of both, domestic as well as export markets. It uses farming technology to increase yields, ensures high quality (usually pesticide-free) and realizes increased market value.

Innovation is more important in modern horticulture than ever before. High-technology horticulture is being implemented in urban areas across the globe using vertical farm systems, hydroponics and aquaponic systems and nearly fully automated production as well as rooftop, underground and floating farms. Vertical farm systems and hydroponics are food production and delivery systems that have the potential to redefine horticulture by optimizing yield, quality and supply. It will identify a range of high technology systems and assess their applicability to urban India by considering: regulation and planning, farm input and waste, supply chain logistics and social, environmental and economic aspects. These new systems certainly are the modern face of horticulture that should complement the current supply chain in a key range of nutritious and delicious produce.

Potential areas for Hi-tech Horticulture

- Urban and peri-urban areas to meet requirements of fresh produce like vegetables, fruits and flowers round the year.
- Areas with limited land and water resources
- Areas where availability of land for cultivation is restricted because of snowfall and where low temperature is prevalent restricting cultivation of crops under open field conditions.
- Small and marginal land holdings for adopting intensive production technologies
- As an horti-business enterprise for enterprising youth in rural and urban Peripherals

Advantages of hi-tech farming

- Yield increases up to 5 to 8 times- high productivity per unit area
- Better quality growth and uniformity.
- Big savings in key inputs such as water (up to 50 percent), fertilizers (up to 25 percent) and pesticides.
- Possible even in problematic areas like undulating terrains, saline and waterlogged areas.
- Produce is available during off-seasons
- One can reap the benefits throughout the year
- Impact on natural ecosystems will be reduced
- Less runoff of chemicals into rivers and ground waters

Technologies led Horticulture

Hi-tech horticulture involves the following

Soil less culture

Soilless culture is an artificial means of providing plants with support and a reservoir for Nutrients and water. The simplest and oldest method for soilless culture is a vessel of water in which Inorganic chemicals are dissolved to supply all of the nutrients that plants require. The retention of Nutrients and water can be further improved through the use of spaghnum peat, vermiculite, or bark chips. Since the major constituent of the media in artificial growing systems may be solid or liquid, it is appropriate to use the term soilless culture in reference to this general type of growing system and reserve the term hydroponics for those in which water is the principal constituent. Soilless culture methods may thus be classified as either solid- or liquid-medium systems.

Protected cultivation

Protected cultivation or greenhouse cultivation is the most promising area where production of horticultural crops has improved qualitatively and quantitatively world over in the last few decades. Presently, Spain, the Netherlands and Israel are the leaders in cultivation of crops in polyhouses and greenhouses. The application of Plasticulture can substantially decrease the costs and therefore can lead to high productivity with a better quality of crops. India and the Netherlands having more or less same land under flower cultivation but in world's flower export, the Netherlands' contribution is 70 per cent and India's contribution is just 1 percent or even less because of advanced poly house technology in the Netherlands. Polyhouses can also be used for rain water harvesting. The rough annual demand for a 175 square metre poly-house is of the order of 52,000 litres. The semi-annual demand for a crop duration of six months is 26,000 litres of water. In a place with an annual rainfall of 400 mm, the rainwater falling on the roof of the poly-house is of the order of 70,000 litres. Assuming a collection efficiency of 80 per cent, 56,000 litres of rainwater can be harvested, which is more than the annual demand.

Production of vegetables under protected condition is the best alternative to use the land and other resources more efficiently under changing climatic scenario. By adapting protected cultivation, year round availability of quality vegetables both for domestic use and export can be assured.

Protected cultivation means some level of control over plant microclimate to alleviate one or more of abiotic stresses for optimum plant growth, which can be achieved in green houses, poly houses, net houses, poly-tunnels, cold frames, etc. Crop yields under these structures can be several times higher than those of open field conditions. Quality of produce is also superior and input use efficiencies are usually higher under such structures. In a greenhouse together with solar and photovoltaic systems. Pumps, UV filters and lighting can be sustainable and environment friendly through the use of modern solar technology and can be supported and operated independently. The aquaponic solar greenhouse allows the simultaneous production of vegetables, fish and solar power. This leads to a very low or even negative CO_2 footprint (CO_2 sink) for the food produced.

Hydroponics

The concept behind hydroponics is to eradicate imminent barriers that exist between the roots, water, nutrients and oxygen for proper growth. It is a method of growing plants without soil by using mineral nutrient solutions in water solvent. The nutrients used in hydroponic systems can come from an array of different sources, including (but not limited to) from fish excrement, duck manure or purchased chemical fertilizers. Plants commonly grown hydroponically include tomatoes, pepper, cucumber and lettuces.

Aeroponics

Aeroponics is the process of growing plants in an air or mist environment without the use of soil or an aggregate medium. Unlike hydroponics, which uses a liquid nutrient solution as a growing medium and essential minerals to sustain plant growth or aquaponics which uses water and fish waste, aeroponics is conducted without a growing medium.

Vertical farming

Vertical farming, with vegetables grown in temperature, moisture and nutrition-controlled indoor environments can also guarantee improvements in yield while at the same time limiting environmental externalities.

Main characteristics of vertical farming

i. It is one step higher than greenhouse technology and open field cultivation.

ii. It is being progressively practiced in mushrooms, poultry, hydroponic fodder, strawberry, leafy-vegetables particularly lettuce, herbs and other crops production including ornamental horticulture.

iii. It is considered potential to provide sustainability to farming, combat chronic climate change and reduce major inputs to crop production like land, water, nutrients, pesticides and others.

iv. It has the immense potential to attract the youth to farming by adding pride to the profession, agriculture.

High Value Crops (HVC)

High Value Crops (HVCs) are those, which give significantly higher value productivity or net income per unit of resources used for production, compared to other competing national activities. Diversification towards high-value crops such as fruits, vegetables, especially in a country like India where demand for high-value food products has been increasing faster than for staple crops, has proven to increase income level of farmers. Some of the important activities under high value crops are

- Fruit and vegetable cultivation especially catering to urban and metro markets (in the urban peripheral)
- Cultivation of off-season and exotic vegetables under greenhouse for exports (asparagus, celery, bell pepper, sweet corn, green and lima beans)
- Floriculture- open and greenhouse production for domestic and export markets
- Exclusive production of crops for processing/ specific to user industry needs/under contract farming arrangements- *i.e.* gherkins, potato, fruits and select vegetables for processing, flowers (for extracts), medicinal and aromatic plants
- Mushroom cultivation
- Hi tech nursery units for fruit crops, vegetables, flowers, etc.

Productivity

India has made progress in horticulture but productivity of the major horticultural crops is very low in comparison to other countries. Indian horticulture is still technology deficit. Yields per hectare of fruits and vegetables in our country are far below the global averages. Even India's most productive states lag global average. Similarly, the productivity of fruits and vegetables can be increased 2.3 to 2.5 times, through attention to seeds, soil health, pest management, irrigation and post-harvest technology. India's population is expected to reach 1.5 billion by 2025, making food security the most important social issue and food production will have to be increased considerably, to meet needs of growing population. According to the FAO, India is still home to some 217 million undernourished people, or a quarter of all under nourished people globally. There is an urgent need to embrace new technologies like biotechnology, nanotechnology, high-tech protected cultivation and modern irrigation methods to accelerate agriculture production.

Development of new varieties

Technologies like molecular markers, tagging, sequencing, cloning etc., made it possible to isolate and study specific genes or genomic regions conferring resistance to one or more biotic and abiotic stresses (Malhotra, 2021).

Varieties developed with specific purpose

- Mango: Arka Arunika (Export purpose), Pusa Arunima (Export quality), Pusa Surya (Long shelf life), Arunika (Anthracnose resistant)
- Papaya: Arka Prabhat (Better storage life)
- Coconut: Kalpa Sankara, Kalpa Raksha, Kalpa Shree -Resistant to root wilt, Abhaya Ganga **(**Moderately resistant to bud rot disease), Vynateya Ganga **(**Moderately resistant to ganoderma, bud rot and stem bleeding diseases)
- Tomato: Arka Samrat, Arka Rakshak-Triple resistant to ToLCV+BW+EB, Arka Abed (ToLCV+BW+EB+LB)
- Onion: Bhima Super, Bhima Subhra- Kharif season
- Carrot: Arka Suraj -Resistant to powdery mildew and tolerant to nematode
- French bean: Arka Anoop (Resistant to bacterial blight)
- Water melon: Arka Madhura (Seedless type)
- Coriander – Suruchi
- Chilli – LCA-620, LCA-625
- Potato: Kufri Chipsona-3, Kufri Chipsona-4, Kufri Himsona- Chip making and Kufri Frysona- French fries, Kufri Pukhraj (High yield and input efficient), Kufri Frysona, Kufri Chipsona (Chips making)
- Taro: Jhankari, Sonajuli- Tolerant to blight, drought and salt tolerance
- Chrysanthemum: Anmol, Royal Purple – Pot culture
- Gladiolus: Arka Amar - Fusarium wilt resistant
- Aonla – Goma Aishwarya (Early maturity)
- Guava – Lalit (Pink pulp)
- Grape – Pusa Navrang (Red pigmentation, juice making)
- Litchi: Swarnroopa : Cracking tolerant
- Papaya: Surya and Prabhat

Quality planting material

- Micro-propagation techniques for various fruits and spices
- Seed production techniques in vegetables
- Cleaning of infected materials
- Shoot tip grafting
- In vitro propagation for quality assurance
- Quality seed and planting material-health management

Aeroponic seed production

Plants are grown in troughs, tubes or other type of chambers. Roots are hung in air and are sprayed with nutrient mist. Easily absorb nutrients, oxygen and less chance of root diseases.

Advances in seed production

- Isolation
- Seed growing/ certification standards
- Hybrid seed production technology-Male sterile lines
- Packaging and labelling
- Seed storage technology
- Hybrid technology

New propagation techniques

- Wedge/softwood/ epicotyl grafting in mango
- Wedge grafting in guava, jackfruit, aonla, jamun, cashew
- Shoot tip and Mini crown grafting in citrus
- Serpentine and Bamboo method in black pepper
- Cleft grafting and Patch budding in walnut

Micro rhizomes

In crops like potato, ginger, turmeric and a few tuber crops, micro rhizome technology is very efficient in production of disease free clonal planting material of elite genotypes.

Why micro-propagation?

- Development of disease-free planting material
- Development of micro-propagation protocols for recalcitrant crops
- Mass multiplication of vegetatively propagated plants
- Safe exchange for disease safety
- Direct use of *in vitro* plantlets for minituber/rhizome production.

Plant architecture engineering and management

- Enhances the resource efficiency
- Effective conversion of solar energy for productivity
- High economic yield
- Enhanced quality of produce
- Reduced cost of production.
- Rejuvenation of overcrowded and senile orchards of mango,
- High density planting.

Integrated Nutrient Management

- Balanced use of nutrients
- Leaf and soil test based fertilizer recommendations
- Use of amendments and micronutrients
- Understanding nutrient dynamics
- Site specific nutrient management
- The 'fertilizer tailoring equations' for banana and citrus based on soil test crop response approach

Biotechnology

Use of biotechnological tools in horticulture could make crops high yielding and more robust to biotic and abiotic stresses. This could stabilize and increase food supplies, which is important against the background of increasing food demand, climate change and land and water scarcity.

Nanotechnology

Nanotechnology can be used in horticulture in many ways which help in promoting soil fertility and balanced crop nutrition; effective weed control; enhancing seed emergence using carbon nanotubes; delivery of chemicals, field-sensing systems to monitor the environmental stresses and crop conditions and improvement of plant traits against environmental stresses and diseases. Nanotechnology offers considerable opportunities for the development of innovative products and applications for Horticulture, water treatment, production, processing, preservation and packaging and its use may bring potential benefits to farmers, industry and consumers alike. Nanotechnology-based food and health food products and food packaging materials are already available to consumers in some countries and additional products and applications are currently in the research and development stage and some may reach the market soon. In view of such progress, it is expected that nanotechnology-derived food products will be increasingly available to consumers worldwide in the coming years.

The use of nano size silver particles as antimicrobial agents has become more common as technology advances, making their production more economical which may be used for controlling various plant pathogens in a relatively safer way compared to commercially used fungicides. Silver is known to affect many biochemical processes in the microorganisms including the changes in routine functions and plasma membrane.

Nanoparticles are also effective against insects and pests and can be used in the preparation of new formulations like pesticides, insecticides and insect repellents. It can be used to deliver DNA and other desired chemicals into plant tissues for protection of host plants against insect pests. Porous hollow silica nanoparticles (phsns) loaded with validamycin (pesticide) can be used as efficient delivery system of water-soluble pesticide for its controlled release. Such controlled release behaviour of phsns makes it a promising carrier in agriculture, especially for pesticide controlled delivery whose immediate as well as prolonged release is needed for plants. Nanotechnology has a huge potential in revolutionizing the food packaging. Nanoparticles such as titanium dioxide, zinc oxide and magnesium oxide, as well as a combination of them, once functionalized can be efficient in killing microorganisms and are cheaper and safer to use than metal based nanoparticles.

Horticulture Mechanization

Farm mechanization and use of modern gadgets/ machines/ equipments/ tools for timely and effective completion of different operations in the field is one of the most important factors for maximizing profitability. Smaller machines suitable for horticultural operations in the hills and mountains will also enhance operation effectiveness and farm income. Mechanization will help to enhance the overall productivity and production with the lowest cost of production. Farm mechanization can help in 15-20 per cent savings in seeds, 15- 20 percent savings in fertilizers, 5-20 percent increase in cropping intensity, 20-30 per cent savings in time, 20-30 per cent reduction in manual labour and 10- 15 per cent overall increase in farm productivity.

Following machines are developed and are currently used in horticulture

- Harvester for mango, lime, sapota, guava, cassava & potato
- Cassava chipping machine
- Potato chipper
- Shell fired copra dryer
- Solar-cum-electric dryer
- Potato digger, Potato planter
- Graders (potato, onion etc.)
- Sorting, grading & wax treatment of citrus fruits
- Aonla destoning machine
- Manual-cum-motorized spawn grain cleaner
- Electric operated grain boiler
- Raised bed former
- Transplanter-cum-planter for vegetable crops
- Raised bed weeder for vegetable crops
- Snowball tender coconut machine

Use of Modern Irrigation Methods

The modern techniques of irrigation will increase irrigation potential and stretches out in the direction of the optimal utilization of water resources through optimum irrigation scheduling i.e., determination of accurate crop water requirement through micro irrigation. Micro irrigation is an advance technique of irrigation which will increase water use efficiency and crop productivity. Micro irrigation methods are promising methods for applying fertilizers at root zone of the crops. There by micro irrigation helps in efficient utilization of scarce and costly inputs in vegetable production. Micro irrigation is growing fast in India. Further, government is providing significant subsidies through several schemes to promote micro irrigation. The nature and type of micro irrigation systems available are as follows: Drip system, Micro sprinkler system, sprinkler system.

Enhancing water use efficiency

Water saving up to 40-60%, Yield increase 60-100, saving in fertilizers and chemicals (40 - 60%) along with Improved produce quality and higher returns and less pest and diseases incidence.

16. Modernize Technology Transfer Tools

Technology transfer needs effective interactive groups like self help groups (SHGs) and farmers clubs which should become tools of disseminating information about various government sponsored schemes and these entities will help in liaising with various government village knowledge centres and online databases in local languages should be established.

Resource conserving technologies

Resources are an important asset for a country. Unfortunately the non judicious use of these has put them in very critical situation. Some of the resource conservation practices are as: reduction of tillage and retention of adequate surface crop residues over the soil. Similarly by using drip and sprinkler type of irrigation methods more area can be brought under irrigation than the conventional irrigation methods by canals the use of farm yard manure (FYM), compost and bio fertilizers also reduce the over dependence on the chemicals led intensive cultivation. These also are beneficial for soil health, soil micro organisms and soil fertility in the long run. Promoting diversification of horticulture with subsidiary occupations also lead to enhancement of farm incomes and reduction of risks in case of failure of one of the components.

Post harvest technologies

Big boost to the horticulture sector by promoting value addition and food processing. which can also help in creating employment opportunities for the others also. Post-harvest technology is an interdisciplinary "Science and Technique" applied to horticulture produce after harvest for its protection, conservation, processing, packaging, distribution, marketing and utilization to meet the food and nutritional requirements of the people in relation to their needs. Some of the modern post-harvest and processing techniques which can be adopted in small scale by rural people are discussed hereunder.

a. Dehydration

The techniques of dehydration offer a highly effective and practical means of preserving horticultural produce to reduce post-harvest losses. Osmo-air drying is a simple process that can be adopted as home-scale industry by small entrepreneurs like self-help groups for preservation of vegetables for longer duration.

b. Hurdle technology

Innovative technologies based on hurdle techniques have been developed to give extended shelf life to high moisture foods without refrigeration. Hurdle technology treated fruits were found microbiologically safe with extended shelf life under ambient conditions in flexible pouches. The product can be eaten as such and also have the utility in preparation of salads or can be used in other food formulations.

c. Minimal processing

Minimal processing is an emerging technological concept, which has gained increased popularity in recent past. The technique enables global marketing of pre cut fruits and vegetables in pre - packaged form and the products are made for specific end uses viz., curry, salads, pies, stuffing, toppings and garnishing. Minimal processing allows consumers to have fresh like quality fruits and vegetables with convenience.

d. Steeping preservation

Large quantities of vegetables during peak season of production can be preserved in steeping solution consisting of permissible chemical preservatives and other food additives, which is non-thermal and alternate to processing technology with considerable scope for adoption at rural sector by women.

Developed technologies in post harvest management

- Maturity standards worked out
- Harvesting and handling
- Physiology of fruits and vegetables
- Packing for enhanced shelf life
- Storage system to enhance shelf life
- Diversified products
- Pre and Post harvest management

Climate resilient technologies

The basic purpose is to enable the farmers to cope up with the climatic variability and the resultant biotic and abiotic stresses through efficient management of resources.

Plant health management

- Chemical control method for insect pest and diseases
- Integrated management of insect pests and diseases
- Exploitation of botanicals for management of pests
- Bio-control of pests and diseases: Trichoderma, Pseudomonas, Bacillus for reducing soil-borne pathogens like Fusarium, Rhizoctonia, Pythium and Phytophthora.
- Bio-agents like Trichogramma, NPV and Paecilomyces for control of a number of pests in vegetables
- Successful management of papaya mealy bug
- Trap crops

Remote sensing

Horticulture crops play significant role in improving the productivity of land, generating employment, enhancing exports, improving economic conditions of the farmers and entrepreneurs and providing food and nutritional security to the people. For better management of the existing crops and to bring more area under horticulture crops, updated and accurate database is necessary for systematic planning and decision making. Remote sensing (RS) is an advanced tool that aids in gathering and updating information to develop scientific management plans. Many types of sensors namely microwave radiometers, laser meters, magnetic sensors and cameras collect electromagnetic information to derive accurate, large-scale information about the Earth's surface and atmosphere. Because these data and images are digital, they can easily be quantified and manipulated using computers. RS can be used in efforts to reduce the risk and minimize damage. The same data can be analyzed in different ways for different applications.

It can be exploited for efficient site specific management and precision horticulture.

RS can be used for crop identification, crop area, biomass and yield estimation.

It can be exploited for soil and nutrient management.

It can be used for assessing damage by biotic and a biotic stresses

Emerging technologies

i. Robots

Self-steering tractors have existed for some time now and works like a plane on autopilot. Technology is advancing towards driverless machinery programmed by GPS to spread fertilizer or plow land. Agricultural robots, also known as AgBots, already exist, but advanced harvesting robots are being developed to identify ripe fruits, adjust to their shape and size and carefully pluck them from branches.

ii. Drones and satellite imagery

Advances in drone and satellite technology benefits precision farming because drones take high quality images, while satellites capture the bigger picture. Light aircraft pilots can combine aerial photography with data from satellite records to predict future yields based on the current level of field biomass. Aggregated images can create contour maps to track where water flows, determine variable-rate seeding and create yield maps of areas that were more or less productive.

iii. Artificial Intelligence

The rise of digital agriculture and its related technologies has opened a wealth of new data opportunities. Remote sensors, satellites and UAVs can gather information 24 hours per day over an entire field. These can monitor plant health, soil condition, temperature, humidity, etc. The amount of data these sensors can generate is overwhelming and the significance of the numbers is hidden in the avalanche of that data. The idea is to allow farmers to gain a better understanding of the situation on the ground through advanced technology (such as remote sensing) that can tell them more about their situation than they can see with the naked eye and not just more accurately but also more quickly than seeing it walking or driving through the fields. Remote sensors enable algorithms to interpret a field's environment as statistical data that can be understood and useful to farmers for decision-making. Algorithms process the data, adapting and learning based on the data received. The more inputs and statistical information collected, the better the algorithm will be at predicting a range of outcomes. And the aim is that farmers can use this artificial intelligence to achieve their goal of a better harvest through making better decisions in the field.

iv. The Internet of things

The Internet of things is the network of physical objects outfitted with electronics that enable data collection and aggregation. For example, farmers can spectroscopically measure nitrogen, phosphorus and potassium in liquid manure, which is notoriously inconsistent. They can then scan the ground to see where cows have already urinated and apply fertilizer to only the spots that need it. This cuts fertilizer use by up to 30%.

VERTICAL FARMING

The world's overall population is expected to increase by another 2 billion by 2040. Feeding such a large population will be the toughest part. Due to urbanization, every day we are losing lands that could be used for farming and cultivation. A study suggests that the Earth has lost one-fourth of its arable land over the last 50 years. India is the country with the maximum population. India is evolving every day with something new. Also, industrialization is increasing dramatically due to which many arable lands are at greater risk. **Vertical farming in India** is the answer to all these problems. **Vertical farming** is an innovative way of maintaining the farming practices. In India, vertical farming is mostly polyhouse-based farming. Poly-house farming is a protected way that gives higher productivity and yield of vegetables and fruits across India.

Vertical gardening is basically growing ornamentals upwards on vertical surfaces, be it on the wall of a home, office, hospitals or on a large facade of a building. As horizontal space is a limitation for gardening for many urban areas in the present era, installation of a vertical garden is undoubtedly a viable option to include some greenery in the house / building. Vertical green walls can be installed along highways, expressways, metros, railway lines, airports etc. to bring down the deleterious effects of noise pollution. Vertical gardening can aid in cooling and insulation of buildings and reduces the need and cost for high voltage air-conditioning units.

Vertical farm will be defined as a highly controlled indoor plant production system (Sharath Kumar *et al*., (2020) is a multilayer indoor plant production system in which all growth factors, such as light, temperature, humidity, carbon dioxide concentration (CO_2), water and nutrients, are precisely controlled to produce high quantities of high-quality fresh produce year-round, completely independent of solar light and other outdoor conditions."

Vertical farms are divided according to size and purpose of use (Butturini and Marcelis, 2020).

a. Plant factory with artificial lighting, an industrial-scale vertical farm located in a devoted building.
b. Container farm, a modular vertical farm contained in a shipping container.
c. In-store farm, a vertical farm located at the place of consumption or purchase (i.e., retail and restaurants).
d. Appliance farm, a vertical farm appliance integrated into a home or office

Need of Vertical Gardening

Poor air quality has been associated with health problems throughout the world due to rapid urbanization and industrialization. Urban air pollution is a matter of global health concern. Neglecting the air pollution results in acute health risks like frequent illness, allergies, asthma, strokes, heart attacks, bronchial infection, dry eyes, sore throat, sinus, headache, cancer, cardiovascular emergencies, loss of concentration, nausea, dizziness, fatigue, skin and eye irritation and many other ailments. Vegetation can dramatically reduce the maximum temperatures of a building by shading walls from the sun, with daily temperature fluctuation being reduced by as much as 50%.

Classification of Vertical Greening System: According to the method of growing, vertical garden can be classified as green façades and green walls / living walls (Yeh, 2012).

I. Green facades II. Living walls

Green facades	Living walls	
A. Created by flower pots	A.	Landscape walls
B. Created by rewind wall	B.	Vegetated mat walls
i. Modular Trellis	C.	Modular Living walls
ii. Grid and wire-rope net system		

GREEN FACADES

It can be anchored to existing walls or structures viz. fences/ columns and it involves climbing plants or cascading vegetation (Gonchar, 2009).

i. Modular trellis panel system

The building block of this modular system is a rigid, light weight, three-dimensional panel made from a powder coated galvanized and welded steel wire that supports plants like *Asparagus* sp., *Pilea microphylla*, *Alternanthera* sp., *Mentha* sp., Jade plant, *Sedum morganianum*, *Portulaca* sp., Dusty miller, Cuphea sp., Ophiophogon sp., Dianella tasmanica, Baby's tear, Callisia repens etc with both a face grid and a panel depth (Erdogan and Khabbazi, 2013). This system is designed to hold a green facade off the wall surface so that plant materials don't attach to the building provides a 'captive' growing environment for the plant with multiple supports for the tendrils and helps to maintain the integrity of a building membrane.

ii. Grid and wire-rope net system

It involves cables and wires. Grids are employed on green facades that are designed to support faster growing climbing plants like Ivy, Trumpet vine, Clematis sp., *Wisteria chinensis*, Star jasmine, Bougainvillea sp., Climbing rose, *Trachelospremum jasminoides*, *Vitis vinifera* etc. with denser foliage. Wire-nets are often used to support slower growing plants that need added support provided by this system at closer intervals. Both systems use high tensile steel cables, anchors and supplementary equipment (Wong *et al*., 2010). Various sizes and patterns can be accommodated as flexible vertical and horizontal wire-ropes connected through cross clamps.

LIVING WALL

A. Landscape wall

These walls are an evolution of landscape 'berms' and a strategic tool in an approach to 'living' architecture (Jacobs, 2008). Landscape walls are typically sloped as opposed to vertical and have the primary function of noise reduction and slope stabilization (Sahu and Sahu, 2014). They usually are structured from some form of stacking material made of plastic or concrete with room for growing media and plants *viz. Lonicera japonica, Nephrolepis sp., Parthenocissus tricuspidata, P. quinquefolia, P. inserta, Vitis berlandieri, V. riparia, Polygonum auberti, Pyracantha sp., Selaginella sp., Wisteria chinensis* etc.

B. Vegetated mat walls

It is composed of two layers of synthetic fabric with pockets that physically support plants viz. *Actinidia sp., Akebia quinata, Aristolochia sp., Campsis sp., Celastrus sp., Clematis sp., Cotoneaster sp., Euonymus fortune, Hedera helix, Heuchera sp., Humulus lupulus, Hydrangea petiolaris* etc. and growing media. The fabric walls are supported by a frame and backed by a waterproof membrane against the building wall because of its high moisture content (Jacobs, 2008). Nutrients are primarily distributed through an irrigation system that cycles water from the top of the system to down.

C. Modular living walls

A modular living wall system emerged in part from the use of module for green roof applications, with a number of technological innovations. Modular systems consist of square or rectangular panels that hold growing media to support plant material (Ottele *et al*., 2010). *Pepromia sp., Syngonium sp., Philodendron sp., Epipremnum sp., Begonia sp., Anthurium sp., Chlorophytum sp., Pilea sp., Rheo discolor, Fittonia sp., Spathiphyllum sp., Schefflera sp., Zebrina pendula, Setcreasea purpurea, Nephrolepis sp*. etc. are apposite for this.

Suitable Plants for Living Wall System

Plants selected for vertical garden walls should be dense, compact, well-formed, slow growing, evergreen with healthy root system, attractive and graceful in appearance and appealing to eyes. While selecting plants, pattern of sun exposure should be taken into consideration. For creating a vertical green-wall in sunny location drought-tolerant plants need to be selected; whereas for a shady spot or indoors or for growing under a pergola or verandah– shade loving plants should be selected.

Plants for Outdoor / Exterior Green walls

Herbaceous Perennials: *Alternanthera green* , *Alternanthera sessilis*, *Asparagus densiflorus, Mentha spp* and *Duranta variegate.*

Shrubs: *Ficus species, Plumbago auriculata*, *Plumbago indica* and *Trachelospermum jasminoides.*

Grass like foliage forms: *Dianella tasmanica, Ophiophogon, Pandanus tectorius*, *Pennisetum setaceum* and *Phalaris arundinacea*

Plants for Indoor Green Walls /shaded areas

Herbaceous Perennials: Anthuriums, Aralia, Begonia and *Philodendron selloum.*

Shrubs: *Cordyline terminalis*, *Ficus* spp, *Rhoeo discolor*, *Schefflera* and *Setcreasea purpurea*.

Succulents: *Zebrina pendulata* (Praveen *et al*., 2020)

Green Façades

Hedera helix, Parthenocissus spp, Hydrangea petiolaris, Polygonum bauldschianicum, Lonicera spp. Clematis spp. Aristolochia spp. Jasminum officinale, Passiflora caerulea, etc.

Living Wall

Dracaena, Phalaenopsis spp, Asparagus sprengeri, Kalanchoe, Cordyline spp.Chlorophytum spp., Haworthia spp., Tradescantia sp, Fittonia spp, Nephrolepsis, Clematis, Gardenia spp., Asplenium nidus, Maranta spp., Cotoneaster, Euonymus fortune, Hedera, Hydrangea, Lonicera, Parthenocissus, Polygonum, Pyracantha, Selaginella, Wisteria, Rose, Petunia, Nasturtiums, Daisies, Bromeliads and even some vegetables like tomato, chillies, cucumber, peas lettuce, etc.

Exterior Wall

Lavendula, Thymus, Rosmarinus or Salvia for full sunlight while Begonia, Arum, Davallia, Asplenium and Fuchsia for shady locations.

Interior Wall

Philodendron, Epipremnum, Aeschynanthus, Columnea, Saintpaulia, Begonia or different *ferns* like *Nephrolepis, Pterisandmany* species of *Peperomia*. (Jain and Janakiram. 2016)

LEAFY VEGETABLES

Micro greens are trending to be nutritionally beneficial vegetable to the best our knowledge, scientific data are very less as findings in this area are still in lime light. Micro greens are the leafy greens which are harvested just after the appearance of 2-3 true leaves, having a length of 2-4 cm and are harvested including stem and leaf. Average time duration for harvesting micro greens ranges between 10-14 days. For urban dwellers sprouts and micro greens are very easy to grow and they can maintain the plants as a hobby during their free time in available vertical space at their home by using method of vertical gardening where land is a limiting factor. Due to their short life cycle micro greens can be grown easily without soil and also any other pesticides and fertilizers. Various vegetable seeds can be used to grow edible young micro greens. Micro greens are majorly used in fine dining restaurants for their visual and flavour component. Micro greens will be colourful; hence they can be used in garnishing of their dishes by chefs and also to enhance unique favours, vivid colours and tender textures. Therefore, micro greens can be added as a new ingredient in various dishes like salad, soups and sandwiches, to enhance flavour, textures and colour.

Suitable greens

Dil, Fenu greek, Green amaranthus, Red amaranthus, Spinach (Kusumitha *et al*., 2021)

Vegetable crops suitable to grow in vertical farming

Economic factors typically limit a realistic set of crops that have a small growing habit (to maximize the number of plants grown in confined spaces) that are prolific producers (such as tomatoes on the vine), or grown and sold. Can be fast (e.g microgreens). Another feature of standing crops is their dependence on the fresh market. For many reasons, processing vegetables almost always has a much lower price than their fresh counterparts. Crops compatible for vertical structure include Tomato, Cauliflower, Chilli, Lettuce, Brinjal, Sweet basil, Green bean, Parsley, Bell pepper, onion, Potato, Cucumber and cabbage (Anil kumar *et al*., 2020).

Techniques used in vertical farming

Hydroponics

Hydroponics is a common system of growing plants used in most forms of vertical farming and it is slowly but steadily gaining importance. It involves the growth of plants in solutions of nutrients, rather than soil -as in traditional farming In this vertical farming method, the roots of the plants are submerged in a nutrient-rich solution which is frequently circulated and monitored.

Aeroponics

This technique involves the growing of plants in an air or mist environment, with no soil and very little water. In aeroponics, seeds or seedlings are "planted" in pieces of foam stuffed into tiny pots, which are exposed to light on one end and nutrient mist on the other. The foam holds the stem and root mass in place as the plants grow. Aeroponics is considered one of the most efficient methods of vertical farming, as it uses over 90% less water than even the most efficient hydroponics systems. And since the nutrients are held in the water, they get recycled, too. It has also been observed that the plants that are grown this way tend to take up more vitamins and minerals, which may make the plants healthier and more nutritious. The extra oxygen the plants are exposed to also results in faster growth.

Aquaponics

Another technique used in vertical farms is aquaponics. In this system, fish grow in indoor ponds and produce nutrient-rich waste that acts as a food source for the plants grown in vertical farms. The plants, in return, purify and filter the wastewater, which is recycled directly back into the fish ponds. Along with fish and plants, microbes also play an important role in converting fish waste products into useful nutrients for the plants, too.

Indoor vertical farming

Indoor vertical farming can increase crop yields, overcome limited land area and even reduce farming's impact on the environment by cutting down distance traveled in the supply chain. Indoor vertical farming can be defined as the practice of growing produce stacked one above another in a closed and controlled environment. By using growing shelves mounted vertically, it significantly reduces the amount of land space needed to grow plants compared to traditional farming methods. This type of growing is often associated with city and urban farming because of its ability to thrive in limited space.

Vertically Integrated Greenhouse (VIG)

The VIG is structured in modules that are 40 m high. Crops are cultivated in innovative plant cable lift (PCL) systems, composed of two wire cables looped around pulleys, driven by a computerized motor on the farming level. Shallow trays of plants, 2.0 m long, are suspended between the cables by swivelling clamps at each end. The PCL design is based on a well-established hydroponic method called nutrient film technique (NFT). A thin film of water runs along the bottom of each tray, delivering nutrients to the roots of leafy plants, before flowing down to the next tray. The solution is recovered at the farming level for reuse. Transpiration is limited to 10% of the flow rate by design (Sheweka and Mohamed 2012).

Advantages of vertical farming

Continuous Crop Production

Vertical farming technology can ensure crop production year-round in non-tropical regions. And the production is much more efficient than land-based farming. According to Despommier, (2010) single indoor acre of a vertical farm may produce yield equivalent to more than 30 acres of farmland, when the number of crops produced per season is taken into account.

Elimination of Herbicides and Pesticides

The controlled growing conditions in a vertical farm allow a reduction or total abandonment of the use of chemical pesticides. Some vertical farming operations use ladybugs and other biological controls when needed to deal with any infestations.

Protection from Weather-Related Variations in Crop Production

Because crops in a vertical farm are grown under a controlled environment, they are safe from extreme weather occurrences such as droughts, hail and floods.

Water Conservation and Recycling

Hydroponic growing techniques used in vertical farms use about 70% less water than normal agriculture (and aeroponic techniques, which involve the misting of plant roots, use even less water).

Eco Friendly

Growing crops indoors reduces or eliminates the use of tractors and other large farm equipment commonly used on outdoor farms, thus reducing the burning of fossil fuel. According to Despommier, (2010) deploying vertical farms on a large scale could result in a significant reduction in air pollution and in CO_2 emissions. Furthermore, carbon emissions might be reduced because crops from a vertical farm are usually shipped just a few blocks from the production facility, instead of being trucked or shipped hundreds or thousands of miles from a conventional farm to a market.

People Friendly

Some common occupational hazards that are avoided in vertical farming are accidents in operating large and dangerous farming equipment and exposure to poisonous chemicals.

Disadvantages of vertical farming

Land and Building Costs

Urban locations for vertical farms can be quite expensive. Some existing vertical farms are based in abandoned warehouses, derelict areas, or superfund sites, which can be more economical for construction.

Energy Use

Although transportation costs may be significantly less than in conventional agriculture, the energy consumption for artificial lighting and climate control in a vertical farm can add significantly to operations costs.

Controversy over Organic Certification

It is unclear if or when there will be agreement on whether crops produced in a vertical farm can be certified organic. Many agricultural specialists feel that a certified organic crop involves an entire soil ecosystem and natural system, not just the lack of pesticides and herbicides.

Limited Number of Crop Species

The current model for crops grown in vertical farms focuses on high-value, rapid-growing, small-footprint and quick-turnover crops, such as lettuce, basil and other salad items. Slower-growing vegetables, as well as grains, aren't as profitable in a commercial vertical farming system.

Pollination Needs

Crops requiring insect pollination are at a disadvantage in a vertical farm, since insects are usually excluded from the growing environment. Plants requiring pollination may need to be pollinated by hand, requiring staff time and labor.

Food and Nutritional Security through Vertical Farming

Urban food security depends on different factors: availability of food, access to food and quality of food. With urban farming, all of these factors can be improved. All cultivation methods described can have a significant contribution to communities and their families' food security. In respect to production for self-consumption, regardless of the income level, food and nutrition security can be improved by growing food in a home or community garden (Kortright and Wakefield 2011). By implementing urban horticulture in cities of the future, a greater scale of food security could be achieved. However, to gain global food security, attention has to be paid to both urban and rural agriculture. With urban horticulture alone, global food security cannot be achieved. However, urban food production on a large scale could take some pressure from rural agriculture. Urban horticulture could also help reach a certain balance between food availability in rural and urban areas. But even with a highly developed worldwide urban horticulture, rural agriculture will keep its significance concerning global food security (Dubbeling *et al*. 2010).

LANDSCAPING

Landscaping combines elements of art and science to create a functional, aesthetically pleasing extension of indoor living to the outdoors. By applying the technologies, any kind of area can be used at its maximum capacity, obtaining esthetic valences, benefic for environment and human health. Even if the price of constructing and maintaining the gardens is higher than a classical landscape it is compensated by the environmental benefits, raising the vegetation surfaces, with impact for reducing the pollution effect. The new modern concepts for landscape development are keen on using any kind of concrete or glass, turning them in real vertical gardens, being possible to overcome the development of the urban areas making a smooth transition for a healthy green urban environment.

Advances in Landscape Gardening

Computer software

Computer programs simplify the design and installation of residential and commercial landscapes, from landscape planning to planting schedules. The computer-assisted design allows clients to actually visualize what a newly-planted landscape will look like when mature. Desired alterations can be quickly and easily made before the first spadeful of dirt is turned. Interactive technology allows us to serve current and prospective clients faster and more easily and to respond fully to requests for project changes. Scheduling software keeps organized, providing options that allow we to factor in contingencies. Material deliveries, potential delays, change orders and weather all affect job completion, but we can more readily make an adjustment with interactive software. Combine a comprehensive analysis with on-site observation and testing it results enable to better plan all aspects of landscape management, from turf aeration and dethatching to seasonal fertilization and shrubbery trimming. We can respond to changing needs following severe storms and we can alert both employees and customers about potentially damaging weather events.

Lawn care technology for monitoring and control

Just as smart devices have revolutionized communication, digitally-controlled devices are now used to monitor soil moisture and control irrigation systems, analyze nutritional needs and determine fertilization schedules.

Water smart landscaping technology

Cloud-based technology drives weathermatic irrigation systems, automatically adjusting for weather variances, soil conditions and plant types. New systems have the ability to shut down when necessary and they have helped lower costs, save water and become more sustainable.

Office processing automation

Duties were simplified by computerization, new forms of automation make all business processes easier and more intuitive. The speed and convenience that automation has brought to routine tasks, as well as to corporate communication.

Battery-driven landscape technology

The detrimental effect and increasing cost of gas-powered lawn care equipment are under scrutiny by landscape companies, environmentalists and municipalities throughout the country,and there is a move toward alternative tools for the future. Although battery-powered large equipment is not yet completely viable for large-scale landscape operations, the time is probably not far off when rechargeable mowers, trimmers, blowers and a variety of smaller tools and equipment will be clean and green.

Robotic mowers

When there are large expanses of lawn with no impediments, there is little reason anymore for a human to have to walk behind a mower or sit on a riding mower. Automatic mowers equipped with sensors can be programmed to do the job quickly and efficiently with no human intervention and to return to a designated point when the mowing is completed.

Artificial intelligence and virtual reality

The overwhelming majority of landscape institutes utilize some sort of drafting program to create scale landscape plans via a computer. Architects and designers now have the ability to walk clients through the rooms of their future homes and offices virtually, without taking a single step and before a building site is even cleared. The time is not far off when landscape planners can offer a tour of a virtual public garden, a landscaped hotel pool or entertainment complex, or a newly-designed outdoor wedding venue before a single flower has been planted. One can look forward to that ability.

CONCLUSION

Horticulture is one of the activities that play the main role in supporting a human being in the world. Developing the high-tech farming systems are the results of the energy sources and new methods of farming. A single technological strategy cannot be a panacea to the ever-growing food production system. Vertical Farming has the potential way for sustainable progress to produce food or related services in urban areas. Vertical garden is a new field to investigate, regarding the insulation properties, durability aspects, maintenance, choice of plants suitable to the existing climatic conditions, materials involved, etc. Effect of the factors such as the physical structure, materials and dimensions of the panels, substrate type, composition, depth on the performance of vertical greenery systems need to be studied. Vertical farming can produce food in a climate-resilient manner, potentially emitting zero pesticides and fertilizers and with lower land and water use than conventional horticulture. Vertical farming have a wider list of benefits over the other growing methods and is a better alternative of crop growing as per the current scenario where the population is growing rapidly. Vertical farming systems currently produce a limited range of crops including fruits, vegetables and herbs, but successful implementation of vertical farming as part of mainstream horticulture will require improvements in profitability, energy efficiency, public policy and consumer acceptance.

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Review Article

Contribution of microbiology in horticulture in last 7 decades

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ABSTRACT

Horticulture is one of the fields where microbiology has played a diverse role in improving the growth, yield and quality attributes of horticultural crops. Microbial horticulture activities consider indoor and outdoor production of well-established horticultural crops, such as vegetables, fruits and berries, ornamentals, and of novelcrops in both rural and urban areas popularly regarded as urban horticulture. There is an immense need for thedevelopment and optimization of novel sustainable production systems in horticulture considering resource efficiency,particularly of water, plant nutrients, growing media and energy, as well as efficient use of space.

Keywords: AMF, biofertilizer, disease management, PGPM

Introduction

The year 2022 is marked by the completion of incredible milestone of seventy five years since the Journal "*Microbiology",* published its first articles. In 1947, the Society launched its first journal which aimed to bring together papers across fundamental microbiology and promote the original objective of the Society, which was to bring microbiologists together into a broad scientific community. Horticulture is one of the critical aspects of this broader scientific approach. Over the last seventy five years, most aspects of modern agriculture have been pursued, including systematic research in the various fields.

Horticultural sector contributes in improving land use for food, nutritional value, medicinal value, aesthetic value and nutritional security. It also promotes crop diversification, employment generation and poverty alleviation; apart from these, they also maintain ecological balance. India is the second largest producer of fruits after China and contributes 12.55% share of global fruit production. In past two decades, there is a two fold increase in area and production of fruit crops in which India has occupied first place in production of mango, banana, papaya, pomegranate, sapota and aonla. Nutrients play an important role in quality and yield production of these horticultural crops. Nutrients status of soil is the most important factor affecting the productivity of crops. Production efficiency of these crops depends upon the supply of synthetic fertilizers and agrochemicals as a quick and readily available source. However, they have adverse impacts on plant as well as soil health in long term of application.

Microbial communities play a pivotal role in the development and different physiological processes of plant. By residing in the rhizosphere zone, these microbial floras act as a credential source for nutrient availability in order to achieve sustainable plant growth and soil fertility. The rhizosphere, that is, the narrow zone surrounding and influenced by plant roots, is a hot spot for numerous organisms and is considered as one of the most complex ecosystems on Earth. the rhizosphere can be modified or reconstruct as per the need the of plant to enhance the physiological efficiency by rhizosphere engineering, rhizosphere hybridization, creating an artificial environment suitable for the plant growth-promoting microorganisms (PGPMs) to surplus a protective layer against the pathogenic microbes *i.e*., rhizosphere fortification, or by various agronomic practices. Rhizosphere hybridization is new concept to modify the rhizosphere ecology to create an optimum environment for PGPMs to show the positive effect of plant agronomy. The concept of "rhizosphere hybridization" is therefore, advocated to harness the value added benefit of nutrient-microbe synergy, besides providing dynamism to microbial consortium suiting to wide range of perennial fruits.

Root colonization is a complex process and knowledge of general ecological characteristics, such as motility, in rhizosphere microorganisms is needed to optimize the development of a variety of microorganisms that prevent plant disease attack as a bio-control agents and natural plant associated microbiota can assist in disease control and in achieving increased yield and high quality plant products in both field and greenhouse horticulture. An understanding of microbial strains relevant to plant applications is useful in the enhancement of factors such as soil nutrients, plant-pathogen resistance, crop robustness, fertilization uptake efficiency, and more. The many symbiotic relationships between plants and microbes can ultimately be exploited for greater food production necessary to feed the expanding human populace, in addition to safer farming techniques for the sake of minimizing ecological disruption.

As an integral part of the root system, Abuscular Mychorhhizal fungi (AMF) interact with other microorganisms in soil and result in increased root exudation approaching about 25% of the plant dry matter production. Roots support a multitude of microorganisms that, in concert, can have profound influence on growth and survival of the plant. AMF can alter the root exudation pattern and photosynthetic/respiratory deficiencies as well as enhance chitinolytic activity. Evidently, the interest of horticulturists in AM technology is due to the ability of AMF to increase the uptake of phosphorus and other nutrients and to increase resistance to biotic and abiotic stress. The main effects of AM inoculation in horticultural crops include: (i) enhanced seedling growth, (ii) reduced phosphate requirements, (iii) increased survival rate and development of micropropagated plantlets, (iv) increased resistance to fungal root pathogens, (v) increased resistance to abiotic stresses, (vi) earlier flowering and fruiting, (vii) increased crop uniformity, (viii) improved rooting of cuttings and (ix) increased fruit production.

Many bacteria and fungi can develop close associations with the crop plant which improves growth, immunity and overall development of the plant. Thus, understanding the action of various mechanisms exhibited by these microorganisms can show us the way to formulate the microbes to be used as biofertilizers. Continuous efforts are made to develop strategies for optimizing bioformulations. Biofertilizers can be integrated with organic manures and chemical fertilizers to enhance the soil organic carbon and maintain sustainability in the field and horticultural crops (Pathak and Kumar, 2016). *Glomus fasciculatum*, *Glomus mosseae*, *Azospirillum*, *Azotobacter* and PSB (phosphorous-solubilizing bacteria) are found useful for different horticultural crops. The use of biofertilizers particularly inoculating with *Azotobacter* could substantiate 50% nitrogen requirement of banana and produce higher yield over full doses of nitrogen application. The absorption of mobile nutrients like nitrogen also increases in association with AMF (Bora *et al*., 2016). The organically produced fruits and vegetables not only fetch much higher value in the domestic as well as international market but also devoid agrochemical residues, thereby having positive impact on human health.

PGRs allow the plant to adapt to changing environments, by mediating growth, development, and nutrient allocation (Dias, 2019).

Achievements so far

The high efficiency of *Azospirillum* for fixing nitrogen and better mobilization of fixed phosphorus by AMF even at high temperature can make these highly suited for fruits like Mosambi. AMF-treated guava trees are less prone to wilting as compared to untreated trees (Srivastava *et al*., 2001). The root colonization per cent is observed higher in *Glomus mosseae* inoculated papaya plants. Nutrient content of N, P, K and also of micronutrient such as Fe, Mn, Zn and Cu has increased due to AMF inoculation. The improvement in yield parameters in the presence of *Azospirillum* might be due to its dual nature of nitrogen fixation and production of phytohormone substances.

Various plant growth parameters of different flowers as gladiolus are positively influenced by the application of both the biofertilizers in combination with nitrogen. Biofertilizer application enhances various growth parameters at all stages of growth compared to chemical fertilizer application alone. Application of biofertilizers along with 50% recommended doses of NPK brought about results on par as 100% NPK fertilizer application with respect to chlorophyll content, floral characteristics such as days taken to 50% flowering, number and weight of flowers per plant, diameter of flowers, ten flower weight and flower yield per plant and shelf life of flowers, indicating replacement of NPK chemical fertilizers to the extent of 50% (Jayamma *et al*., 2014). Inoculation of biofertilizaers such as *Azotobacter* and PSB improve growth, flowering and yield characteristics of marigold. Similarly, growth and yield tomato was significantly higher when the biofertilizers were inoculated with combined treatment (*Azotobacter* and *Azospirillum*) compared to individual inoculation and control which could be attributed to the collective effect of biofertilizers.

Biofertilizer inoculation with strain *Pseudomonas fluorescens* strain growth promoting rhizobacteria significantly improved fruit quality as well as increased fruit yield, fruit weight, fruit length, TSS and juice volumes, while inoculation with strain Azospirillum brasilense strain increased but did not significantly improve fruit quantity and quality of

Washington navel orange (Abdelaal *et al*., 2010). Microbial population in the soil increases considerably due to use of *Azotobacter*, mycorrhiza and phosphorins in banana. The commercial yield also increased by 25–30% and saved 50% of inorganic fertilizers. Compost and biotreatment more effectively controlled Fusarium wilt disease in banana. The treatment resulted in higher total soluble sugars (TSS) to titratable acidity (TSS/TA) ratios, yield, culturable and total soil bacteria and culturable actinobacteria population (Shen *et al*., 2013).

Importantly, under stress conditions, rhizosphere communities may undergo a regular change in spatial structure and functional patterns. For instance, roots attacked by fungal pathogens excrete increased amounts of exudates, which have concentrations of organic acids that are favourable for the formation of a defensive *Pseudomonas* population. Application of *Trichoderma viride* @ 20 g/plant, once at planting and after 3 months was found effective in controlling nematodes (*P. coffeae* and

Table 1: Beneficial effects of plant growth-promoting microorganisms (PGPMs) in horticultural crops

PGPMs	Beneficial Effects	Horticultural plants
Glomus. mosseae	Growth	Tomato
Rhizobium leguminosarum	Root length, shoot height and dry weight	Pea
R. tropici	Growth	Field bean
Rhizobium spp.	Siderophore production, protein production	Pepper, tomato, lettuce, carrot
Sphingomonas	Plant height, gibberellin synthesis	Tomato
Agrobacterium	Root inoculation increased fruit yield	Strawberry
B. subtilis	Enhanced diameter of trunk	Apple
P. fluorescens	Decreased bacterial population and freeze injury	Pear
Pseudomonas chlororaphis TSAU13, *Funneliformis mosseae,*	IAA production	Cucumber, Tomato, orange
Burkholderia, Promicromonospora, Acinetobacter, Pseudomonas spp.	Gibberellin production	Cucumber
Bacillus subtilis	Cytokinin production	Lettuce
Bacillus polymyxa, Glomus intraradices, G. versiforme	Osmolyte production	Tomato, soybean,

Table 2: Use of PGPM in disease management of horticultural crop

PGPRs	Crops	Diseases
Actinoplanes spp.	Beetroot	*Pythium ultimum*
Pseudomonas fluorescens	Banana	Bunchy top virus, Panama wilt (*Fusarium oxysporum)*
	Mulberry	Leaf spot
	Mango	*Anthracnose* (*Colletotrichum gloeosporioides*)
	Apple	Grey mould (*Botrytis cinerea*)
	Peach	Brown rot (*Monilinia fructicola*)
	Pear	Fire blight (*Erwinia amylovora*)
	Strawberry	Grey mould (*B. cinerea*)
	Potato	Bacterial wilt, *Ralstonia solanacearum*, soft rot (*Erwinia carotovora*)
	Tomato	Cucumber mosaic virus, wilt (*Fusarium oxysporum* f. spp. *Lycopersici*), bactterial wilt (*R. solanacearum*)
	Brinjal	Blight (*Pythium vexans*), root rot (*Rhizoctonia solani*)
	Chilli	Powdery mildew (*Leveillula taurica*), fruit rot and dieback (*Colletotrichum capsici*), wilt (*F. oxysporum*)
	Onion	Tip blight (*Alternaria* spp.)
	Cucumber	Wilt (*Fusarium. oxysporum*), damping off (*Pythium aphanidermatum*), anthracnose (*Colletotrichum orbiculare*), angular leaf spot (*Pseudomonas syringae* pv. *Lachrymans*)
	Carnation	Wilt (*Fusarium. oxysporum* f. spp. *dianthi*)
Bacillus subtilis	Peach	Brown rot (*Monilinia fructicola*)
	Potato	inhibitory effects on the growth of *Rhizoctonia solani*
	Apple	Blue mould (*P. expansum*), grey mould (*B. cinerea*)
	Potato	Bact. wilt (*R. solanacearum*), scab (*Streptomyces)*
	Tomato	Bacterial spot and late blight, wilt (*F. oxysporum* f.spp. *Lycopersici*), damping off (*P. aphanidermatum*)
	Brinjal	Collar rot (*S. sclerotiorum*)
	French bean	Root rot (*R. solani*)
	Lettuce	Root rot (*P. ultimum*)

M. incognita), reducing the incidence of Panama wilt in Rasthali and Virupakshi. Spraying of native stain of *Pseudomonas* sp. in Robusta prevented the occurrence of crown rot disease. *Trichoderma hamatum* strains were found good root growth promoters of citrus. Biological control of guava wilt indicated the possibility of its control with *Aspergillus niger*. A progressive farmer of Chitradurga District, Karnataka State is cultivating pomegranate orchard which was severely affected by bacterial blight and he had considered uprooting the trees. Application of liquid formulation of Arka Microbial Consortium (AMC) technology from ICAR-IIHR on the pomegranate trees at fortnightly intervals on affected trees helped in alleviating the bacterial blight incidents in his orchard (IIHR, Bangaluru).

In vitro culture is a useful method to propagate endemic or endangered orchid species for conservation purposes because seeds of most of these plants are difficult to germinate. The use of competent PGPMs in micropropagation under *in vitro* and *ex vitro* conditions was analyzed and called "biotization" (Nowak, 1998). Biotization of micropropagated rice plants results in enhanced growth and higher survival rate during laboratory to land transfer. *Azospirillum barasilense* enhances the acclimatization of micro-propagated fruit rootstocks, and *Pseudomonas aureofaciens* led to a better growth of potato and strawberry at acclimatization when microshoots were inoculated before rooting. A pseudomonas strain has been also reported to promote root growth of watermelon (Nowak, 1998). Among ornamental plants, orchids dominate among the commercially micropropagated, and attract more attention.

CONCLUSION

Indeed, the use of chemical fertilizers and manures cannot be eliminated at this time without drastically decreasing food production. At the same time, the harmful environmental side-effects of fertilizer use, such as the expanding dead zones in marine systems worldwide, cannot go unabated. Hence, there is an urgent need for integrated nutrient management that targets agricultural inputs and lowers the adverse environmental impacts of agricultural fertilizers and practices. Better understanding of the interactions between microbe, fertilizer, and plants has become very crucial in the era of sustainable agriculture. The bioinoculants not only affect the fruit yield but also improve the fruit quality. The inorganic fertilizers can be supplemented with organic manures and biofertilizers. AMF is the most common inoculants in horticultural crops. However, more research work is needed in India for application of biofertilizers in fruit crops so that we may make them completely organic. It is the need of the hour that a microbiologist should work in association with a horticulturist, and this technology should be transferred to the farmer's field.

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Review Article

Seventy five Years of research and development in nutraceuticals in horticultural crops

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ABSTRACT

Nutraceuticals are food or part of food which promotes health and prevent diseases. Currently, nutraceuticals are of much interest due to its nutritive value and maintains proper functioning of the human body. Nutraceuticals have advantages in comparison to the pharmaceutically available medicines. Nutraceuitcals have been classified into traditional and nontraditional nutraceuticals on the basis of availability of food, chemical nature and mechanism of action. The global market of nutraceutical is predicted to grow upto US $734.601 by 2026. In India, the growth of nutraceutical segment is predicted to grow upto US $8.5 billion by 2022. In the initial years, Food and Drug Administration (FDA) regulated the dietary supplements under foods. The FSSAI i.e. Food Safety and Standards Authority of India, New Delhi is the first Indian regulatory system to recognize, classify and put the nutraceuticals under foods according to the Indian Food Safety and Standard Act. The horticultural crops are best source for extraction of phyto-nutrients and have been useful in decreasing the chances of various diseases. Citrus fruits in particular can be utilized as an alternative option in formulation of novel nutraceutical products. Citrus nutraceuticals if extracted efficiently can be useful in increasing the economic status of the region as a whole.

Keywords: Nutraceuticals, horticultural crops, citrus fruit, disease prevention, regulation

INTRODUCTION

The Hippocrates, known as father of modern medicine in the ancient times advised and given the principle "Let food be thy medicine, and medicine be thy food" and emphasized the relation between foods and its importance in the treatment of various diseases (Yapijakis, 2009). The term "Nutraceutical" coined by Stephen DeFelice, Founder and Chairman of the Foundation for Innovation in Medicine is derived from two different words i.e. 'nutrient' and 'pharmaceutical' in 1989 (Palthur *et al*., 2010; Chanda *et al*., 2019). Nutraceuticals include the food or part of the food which provide the required necessary supplements for body's metabolic processes and also used as medicine thereby preventing the spread of diseases (Kalra, 2003; Yapijakis, 2009). Many kinds of products emerging from industries like food, pharmaceutical, herbal and dietary supplements classified under the term of "Nutraceutical" (Gullati and Ottaway, 2006).

The world has observed the tremendous growth in the nutraceutical industry since the early 1990s and is intersection of two industries: the food industry and the pharmaceutical industry (Bagchi, 2006). It is normally a food component which not only maintains and support body metabolic functions but also antagonizes, potentiates and or otherwise modifies the metabolic functions thereby displaying the property of drugs (Doyon and Labrecque, 2008). Simply, one can say, NUTRACEUTICALS = NUTRITIVE + PHARMACEUTICAL (fortified foods, herbals, nutrients, dietary supplements) provides many medical or health benefits (Chauhan *et al*., 2013). The horticultural crops having many health promoting and disease preventing properties can be considered as a best source for extraction of phytochemicals and bioactive compounds with a potential to develop novel nutritional ingredients and supplements i.e. nutraceutical products (Mahima, 2013; Dutta et al., 2017).

Recently, the nutraceuticals has received greater consumer acceptance due to its potential nutritional and therapeutic effects. It improves health, prevent from life threatening diseases, delays ageing process and increase the life expectancy besides providing the nutritional benefits. Many studies have shown the promising results in treatment and decrease in complications from diseases like diabetes, cancer, athrosclerosis, cardiovascular, neurological and gastrointestinal disorders, etc (Nasri *et al*., 2014). In developing country like India, the nutraceuticals are not conceptualized in various terms like segments, market, export-import, manufacturing, etc. due to the lack of well defined regulatory framework (Palthur *et al*., 2009). The regulatory framework will help in providing the consumers with correct information about the health benefits. This will also serve as a guide to the manufacturers during formulation, labeling, claims, etc. which one should follow before launching the new product in the existing market (Palthur *et al*., 2010).

In the present review, an attempt has been made to present the concept of nutraceuticals, demand and market trend, highlights of horticultural crops and citrus fruits in particular for development of novel nutraceuticals. A further emphasis on the role of nutracueticals for disease prevention, its regulatory framework and an insight into the current trend and future prospects of nutraceuticals has been discussed.

NUTRACEUTICALS CATEGORIES

Nutraceuticals are categorized on the basis of food availability, chemical nature and mechanism of action.

I. Classification based on Food availability

II. Classification based on chemical nature

III. Classification based on mechanism of action

I. Classification based on Food availability

Traditional nutraceuticals

This category includes nutraceutical products obtained directly from natural source with no change in form. These include many natural products like lycopene from tomato, omega-3 fatty acids from salmon, etc and confer numerous health benefits (Jha, *et al*., 2021; Chanda *et al*., 2019). The traditional nutraceuticals are further divided into different classes on the basis of:

a. Chemical constituents

i. Nutrients

ii. Herbals

iii. Phytochemicals

b. Probiotic microorganisms

c. Nutraceutical enzymes

a. Chemical constituents

i. Nutrients

Carbohydrate, vitamins, minerals, amino acids, fatty acids, antioxidants are the primary and secondary metabolites with established nutritional properties are included under nutrients. Antioxidant comprises important segment in the nutraceutical market that retards the damage caused by the oxidative reactions (Devi and Rehman, 2002; Sagar *et al*., 2004). These bioactive and functional nutrients play a major role in prevention of many diseases. Fruits and vegetables are the common source for many of the nutrients like vitamins, dietary fibre, minerals, phytocemicals for day-to-day life (Subbiah, 2007).

ii. Herbals

The herbal nutraceuticals are well known from around thousands of years in the ancient history due to its analgesic, anti-inflammatory, astringent, anti-pyretic and anti-arthritic properties. Compounds like flavonoids, tannins; salicin, terpenoids, many micro- and macro- nutrients make are included in herbals. Herbals are well known in playing an important role in enhancement of life and disease prevention (Pandey *et al*., 2011; Chanda *et al*., 2019).

iii. Phytochemicals

Phytochemicals are the naturally occurring substances present in plants which are responsible for imparting characteristic color, texture, smell, and flavor, etc. Some of the commonly found phytochemicals present in plants include lyopene in tomatoes, flavonoids and limonoids in citrus fruits, tannins, carotenoids in vegetables, phenolic compounds, etc (Berger and Shenkin, 2006; Jha *et al*., 2021).

b. Probiotic microorganisms

Probiotics are the foods containing live microorganisms which when consumed in an acceptable limit; exert a beneficial effect on the host body. These are popularly known as ‘Friendly bacteria’ (Mohammad and Imran, 2019). The term ‘Probiotic’ is coined by the scientist ‘Metchnikoff’ (Chanda *et al*., 2019). Probiotics are responsible for microbial stability, healthy digestion, and absorption of nutrients and increase the immunity thereby preventing the growth of harmful microorganisms (Ghani *et al*., 2019). Various probiotics are presently available in the market which counteract the pathogens and protects human body from diseases (Jha *et al*., 2021).

c. Nutraceutical enzymes

These enzymes are proteinaceous in nature derived from plant, animal and microbial sources. These are essential part of life which acts as a biocatalyst and increases the metabolic processes and fastens the reaction. Nutraceutical enzymes have found useful in treatment of many medical problems like constipation or diarrhoea or ulcerative colitis, etc (Chanda *et al*., 2019; Jha *et al*., 2021).

Non-traditional nutraceuticals

These include the foods enriched prepared through biotechnology and enriched with some supplements to improve the human health (Chanda *et al*., 2019). There are classified as:

a. Fortified nutraceuticals

b. Recombinant nutraceuticals

a. Fortified nutraceuticals

These are nutraceuticals obtained through agriculture breeding or by incorporation of nutrients to the main ingredients present in foods. Examples include- calcium, iron fortified flour; minerals added to cereals; fortified milk; etc (Jha *et al*., 2021).

b. Recombinant nutraceuticals

Recombinant nutraceuticals are produced through fermentation process of food and involves the extraction of bioactive components such as enzymes for providing of nutrients at appropriate level. Examples include- Cheese, bread, yogurt, etc. (Chanda *et al*., 2019).

II. Classification based on chemical nature

These classification schemes include wide variety of primary and secondary metabolites such as carbohydrates, amino acids, proteins, fatty acids, phenolic compounds, isoprenoid derivates, minerals, etc. (Chanda *et al*., 2019).

III. Classification based on mechanism of action

Nutraceuticals according to this scheme of classification are categorized on the basis of antimicrobial, anti-inflammatory, and antioxidant properties (Chanda *et al*., 2019).

DEMAND AND MARKET TREND

The nutraceuticals were accepted long back in the 1980's when physicians acknowledged the clinical benefits of calcium, fibre, fish oil and published in the mass media (Pandey *et al*., 2010). The modern day lifestyle adapted in the 21st century has led to the development of many disorders. The principle factors for many diseases are eating unhealthy food, lack of physical exercises/ activities, mental stress, incorrect body posture, etc. Consumer acceptance towards nutraceuticals has increased due to health awareness and better life expectancy (Sharma and Majumdar, 2009). Herbal/natural products, functional foods and dietary supplements are the main segments. The global nutraceutical market identified in the year 2017 was US $379.061 and the market is expected to grow upto US $734.601 by 2026. In India, according to the Associated Chambers of Commerce and Industry of India (ASSOCHAM), the growth of nutraceutical segment is predicted to grow upto US $8.5 billion by 2022 which was US $2.8 billion in 2015 (Sachdeva *et al*., 2020).

HORTICULTURAL CROPS

India with its diverse climatic conditions and geographic location is favorable for growing many horticultural crops of fruits, ornamental crops, vegetables, etc in different parts of the country. Horticultural sector is one among the fast growing sectors in agriculture and play a very important role in country's economy by increasing the income of the poor and is also found useful in establishments of agro-food industries thereby generating employment opportunities. India has emerged as one of the leading producer in fruits of mango, banana and citrus and is second largest in the world in production of fruits and vegetables (Agarwal *et al*., 2016). Nutrition is of utmost importance since ancient times (Dutta *et al*., 2021). The horticultural sector has gained importance in the recent years as it is recognized as emerging source for many nutraceutical products besides providing the basic nutritive value (Ashok *et al*., 2020). Many research studies have stated that fruits, vegetables, spices, medicinal plants, tuber crops are found to be the rich source of many vitamins, minerals, proteins, carbohydrates required for balanced diet and healthy lifestyle (Kulshretha, 2018). Table 1 depicts the nutraceuticals reported from the horticultural crops. These are considered as protective foods which play an important role in prevention and treatment of various diseases and provided nutritional security to the people (Agrawal *et al*., 2016; Ashok *et al*., 2020).

CITRUS FRUITS AS NUTRACEUTICAL

Citrus fruits are one among the widely grown horticultural crops which belongs to the family *Rutaceae.* The countries leading in the production of citrus are Brazil, China, United States, Mexico, India and Spain (Marti *et al*., 2009; Fejzic and Cavar, 2014). The genus citrus consists of varying fruits of different sizes as well as shapes. The most common and the commercially grown citrus varieties include mandarin (*C. reticulata* Blanco), lime (*C. aurantifolia* Christm.), sweet orange (*C. sinensis* L. Osbeck), grapefruit (*C. paradisi* Osbeck), lemon (*C. limon* L. Brn. F.), (Kumar *et al*., 2019; Zarina and Tan, 2013). Citrus fruits are famous for its enormous health advantages attributed to the presence of several bioactive compounds like flavonoids, phenols, limonoids, antioxidants, carotenoids, ascorbic acid, etc.

Table 1: Nutraceuticals reported from the horticultural crops

S.No.	Horticultural crops source	Phytochemicals present	Health benefits
Fruit crops			
1.	Apple	Flavonoids, polyphenols, carbohydrates	Anti-ageing, improve pulmonary function, weight management, bone health and gastrointestinal health
2.	Banana	Carbohydrates, dietary fibre, vitamins, minerals	Nutritive, smoothens the stomach, astringent
3.	Bael	Vitamins, minerals, flavonoids, phenolic acids	Astringent, laxative, stomachic
4.	Citrus	Flavonoids, limonoids, carotenoids, ascorbic acid	Anti-oxidant, anti-cancerous, rich source of vitamin C
5.	Guava	Ascorbic acid, minerals, antioxidants	Anti-bacterial, laxative
6.	Mango	Ascorbic acid, β-carotene, minerals, polyphenols	Laxative, diuretic, improves digestion
7.	Pineapple	Flavonoids, phenols, minerals, vitamins, micronutrients, dietary fibre	Vermicide, wound healing, anti-diabetic, anti-oxidant
8.	Papaya	Carotenoids, polyphenols, ascorbic acid	Laxative, digestive, anti-inflammatory, anti-pyretic
9.	Pomegranate	Phenolic acids, tannins, minerals, vitamins, flavonoids	Coolant, anti-inflammatory, anti-oxidant, prevents haemorrhoids
10.	Plum	Flavonoids, phenolic acids	Coolant, anti-oxidant, preserve bone density
	Vegetable crops		
1.	Brocolli	Polyphenols, sulphoraphane, quercetin, carotenoids	Anti-oxidant, anti-cancerous
2.	Beet	Ascorbic acid, carotenoids, phenolic acids, flavonoids	Effective in tuberculosis, constipation, obesity, tumors
3.	Beans	Phenolic acids, flavonoids, lignans, dietary fibre	Effective in cancer, anaemia; maintains cholesterol level
4.	Cabbage	Phenolic acids, flavonoids, β-carotene, anthocyanins	Anti-oxidant, anti-cancerous, analgesic
5.	Carrot	β-carotene, active oligosaccharides, phenolics, ascorbic acid, antioxidants	Anti-oxidant, anti-cancerous, relieves constipation, maintain cholesterol level
6.	Coriander	Linalool, flavonoids, phenolic acids, glycosides, terpenoids, tannin, saponin, steroids, alkaloids	Effective in diarrhoea, constipation, indigestion, anti diabetic
7.	Drum stick	Quercetin, vitamins, minerals, phenolics, carotenoids, tocopherols,	Effective in diabetes, hypertension polyunsaturated fatty acids
8.	Garlic	Flavonoids, allicin	Anti-cancer, anti-viral, anti-bacterial, anti-allergic
9.	Ginger	Terpenes, phenolic compounds, flavonoids, tannin, saponin, carbohydrate	Anti-oxidant, anti-bacterial
10.	Potato	Phenolics, flavonoids, carotenoids, anthocyanins	Effective in skin diseases, cancer, dyspepsia

(Mahima *et al*., 2013; Dutta *et al*., 2017; Arya *et al*., 2019)

(Marti *et al*., 2009; Zarina and Tan, 2013). The color of the fruit is due to carotenoids present; vitamin C also known as ascorbic acid is a powerful natural antioxidant and together with other antioxidants scavenge oxidative free radicals and reduces the risk of diseases like atherosclerosis, heart diseases and cancer (Wang *et al*., 2007; Almeida *et al*., 2011); the flavanone glycoside namely hesperidin and naringin, imparts characteristic taste are predominantly found in the citrus fruits. The highest flavonoids content are known to accumulate during the initial developmental stages of fruit (Kumar *et al*., 2021). Limonoids present in citrus fruits have anti-bacterial, anti-fungal and antioxidant properties (Russo *et al*., 2016). Phenolic compounds scavenge reactive oxygen radicals, exhibit anti-inflammatory and anti-bacterial activities respectively (Gasecka *et al*., 2020). Citrus fruits can be potential utilized as a rich source of nutraceuticals owing to the presence of inherent phytochemicals with many beneficial health effects. The nutraceutical compounds if extracted effectively can contribute in increasing the economic status of the region as a whole (Dutta et al., 2017).

NUTRACEUTICALS IN DISEASES

Nutraceuticals play a very important role in minimizing the chances for the cause of the disease. Nutraceuticals also helps in delaying the process of ageing, improving health and increasing the life of the people (Jha *et al*., 2021; Dutta *et al*., 2018). The modern human diet and stressful lifestyle has led to the occurrence of allergic disorders, cardiovascular diseases, diabetes, cancer, Alzheimer’s disease, eye disorders, heart attack, lung cancer, obesity, Parkinson’s disease, obesity, gastrointestinal disease, osteoarthritis, etc. and are some of the major health issues faced today (Chintale *et al*., 2013; Verma and Mishra, 2016; Parveen and Bhagrav, 2020). Many studies have shown that the consumption of horticultural crops (fruits and vegetables) have been useful in decreasing the chances of various diseases of esophagus, stomach, lung, endometrial, oral cavity, pancreas, pharynx, and colon, etc (Bradbury *et al*., 2014). The variety of phytochemicals namely, flavonoids, dietary fibre, â- carotene, folic acid, D-limonene, lycopene, phytosterols, vitamin-C and vitamin-E, saponins, carotenoids, antioxidants, etc. help to boost one's immune system and to protect from diseases (Sachdeva *et al.*, 2020).

REGULATIONS OF NUTRACEUTICALS

A nutraceutical product, fortified food or dietary supplement which provides health benefits needs to comply with all the regulatory rules and regulations pertaining to safety, efficacy, and quality testing and marketing (Pandey *et al.*, 2010). In India, the nutraceuticals are not conceptualized in terms of market, its export-import, manufacturing process, distribution, packaging, labeling, etc. (Palthur *et al.*, 2009). With growing interest among consumers for nutraceuticals, there is current need to frame the quality standards regarding the nutraceutical products (Jha *et al.*, 2021). For many years, Food and Drug Administration (FDA) regulated the dietary supplements under foods for consumer acceptance and safety (Chauhan *et al.*, 2013). The FSSAI i.e. Food Safety and Standards Authority of India situated in New Delhi is the first Indian regulatory system to recognize, classify and to put the nutraceuticals under foods according to the Indian Food Safety and Standard Act (FSSAI, 2009). The act was drafted with two main purposes- to introduce a single statute relating to food and to provide scientific development to the food processing industry. This initiative will help in providing the consumers with correct information about the health benefits. In this way, manufacturers will be aware of all the guidelines or standards for formulation, labeling, claims, etc. to be follow before the product is launch into the market (Palthur *et al.*, 2010). Different officers of FSSAI are like Food Analyst, Food safety Officer, etc. are present in different checkpoints to evaluate the nutraceutical product starting from the raw material and ascertain the products quality and standard in every aspect of the Act (Jha *et al.*, 2021).

CURRENT TREND AND FUTURE PROSPECTS

Increasing awareness among the world population about the fitness, exercise and healthy life has led to the increased consumption of functional or fortified foods to meet the increasing demand. Nutraceuticals in this context has become one of the important parts in people diet for nutrition (Petrovska, 2012; Mohammad and Imran, 2019). In the day-to-day life, consumers are facing mental stress, low energy issues, metabolic disorders, oxidative stress, etc. and are concern are of keen interest to combat and get relieve with all the problems. In the market of nutarceuticals, there are various formulations presently available like plant bioactive, herbals, nutrients, vitamins, dietary supplements and with the due course of time the list of products has increased to a great extent (van der Zanden Lotte, 2014; Fleisher, 2018). Several studies have been reported to warrant the use of nutraceutical to improve health and treat diseases caused due to deficiency of nutrients and other bioactive compounds (Sapkale *et al.*, 2013). The nutraceutical industry seems to play an important role and its growth in the market will lead to growth various food, pharmaceutical, healthcare and agricultural industries. The problem of hunger in the world can be tackle by assessing the potentials of nutraceuticals. The development of new medications is costly, time consuming and having risk factors as compared to the drugs available in the market. Therefore, many pharmaceuticals companies are stepping towards nutraceuticals (Pandey *et al.*, 2010). Countries namely USA, China, Germany are taking lead for investing in the nutraceutical research and development and is coming up with innovative products and gaining the attention of the people through the aid of social and print media (Pandey *et al.*, 2010; van der Zanden Lotte, 2014). New technological interventions in the field of real time cellular imaging techniques, nutirgenomics, encapsulation, enzyme nutraceuticals, new drug delivery systems, pharmacokinetics study, toxicity profiling has emerged and have positive impact in the health care management. To sum-up, we can conclude that the nutraceutical industry will give rise to products with high efficacy and acceptance rate and will shape our near future with next-generation nutraceuticals (Jha *et al.*, 2021).

CONCLUSION

Products from natural source have long been known for its therapeutic and nutritive value since years. In today's lifestyle, nutraceuticals are an alternative source to the medicines to not only prevent but also to cure many life-threatening diseases. Citrus fruits are grown worldwide and help to boost immunity; can be utilized due to its anti-cancer, anti-oxidant, anti-microbial properties and can prove good source which can be explored for extraction of nutraceuticals. Regulatory bodies and concerned professionals play major role at different steps of manufacturing, quality maintenance, packaging, safety, etc. Different officials namely Health professionals, nutritionists, biotechnologists, toxicologist and industrialist should strategically work together to plan appropriate regulation to provide the ultimate health and therapeutic benefits to mankind with purity, efficacy, and safety. The nutraceutical industry is growing at a much faster rate than expected as compared to many other food and pharmaceutical industries. Citrus nutraceutical is a powerful and an alternative natural source useful in maintaining health and to act against many acute and chronic diseases, thereby promoting optimal health, longevity, and quality of life.

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Review Article

Seventy five years of research in processing and product pevelopment in plantation crops - coconut, arecanut and cocoa

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ABSTRACT

Coconut and arecanut are the major plantation crops and their cultivation has deep root in the culture and history of India. Cocoa is an understory crop of coconut and arecanut and is of recent origin to India. In order to enhance the production of coconut and arecanut in India number of committees and organizations were set up both during pre-independence and post-independence periods. These institutional mechanisms suggested research needs to enhance the productivity, better management of pest and diseases and marketing. However, it was rarely felt that there is a need for research on advanced processing and product diversification in India. During 1990s there was sufficient area expansion and steady increase in productivity that resulted in market glut leading to price crash thereby emphasized the need for value addition and product diversification so as to stabilize the price for the produce. Though value addition of plantation crop products is at its nascent stage in India, the recent innovations and the value chains systems developed can transform the farmers into entrepreneurs and can easily increase their income. There are well established organizations for research (ICAR-Central Plantation Crops Research Institute and State Agricultural universities), various developmental agencies [Coconut Development Board (CDB), Directorate of Arecanut and Spices Development (DASD)], funding sources (like central and state government schemes, NABARD etc.) and to implement these value chains, farmer producer organizations are being established in each producing states. In this review we present the research developments during the last 75 years on value added products and product diversification of coconut, arecanut and cocoa which can be effortlessly taken up as a cottage or small scale industries.

Keywords: value addition; plantation crops; food processing; machineries; industrial uses

INTRODUCTION

Palms are among the best known and most extensively cultivated plant species native to tropical and subtropical regions of the world. Some of the palm trees native to India are coconut (*Cocos nucifera* L.), palmyra (*Borassus flabellifer* L.), date (*Phoenix dactylifera* L.), fish tail (kithul) (*Caryota urens* L.), pejibaye (*Bactris gasipaes* L.), arecanut (*Areca catechu* L.), sago (*Cycas revolute* Thunb.), royal (*Roystonea regia* (Kunth) O.F.Cook, oil palm (*Elaeis guineensis* Jacq.), fox tail (*Wodyetia bifurcate* A.K.Irvine), doum (*Hyphaene thebaica* (L.) Mart.) *and* aren palm (*Arenga pinnata* (Wurmb) Merr.). Most of these palms have been extensively used by humans for various purposes since time immemorial. The palms with the greatest importance in Indian commerce are the coconut and areca nut, both are primarily cultivated in south Indian coastal and hilly interiors. Coconut is the main source of vegetable oil and fat, while arecanut is a stimulant but both possess a huge repertoire of biochemicals such as polyphenols, antioxidants, minerals and vitamins. In coconut the husk of the fruit is the source of coir, used for ropes and mats; the hard inner fruit layer (endocarp) is used as fuel and to make charcoal, cups, bottles, and trinkets; coconut "juice" or "water" (liquid endosperm) is a tasty beverage; the flesh (solid endosperm) is eaten raw or dried to form copra, a source of oil (widely used for food preparation and industrial purposes) and oil cake (cattle feed); the flesh may also be grated, mixed with water, and pressed to obtain coconut milk, used in food preparation and as a substitute for cow's milk. The sap obtained from tapping the inflorescence, or flower stalk, is drunken unfermented (*Kalparasa® neera*) or fermented (toddy) and is a source of sugar, vitamins, antioxidants and minerals. Trunks are used in construction and furniture making, and leaves are used in a variety of ways in domestic economies. The nut of arecanut tree is used chiefly for chewing, which gives kind of pleasure for the chewers. Areca tree provides fodder for cattle, edible fruits, building materials, fuels and fibres. Cocoa is used to make chocolate milk, cakes, chocolate bars, chips and other confectionary items.

The evolution of research in plantation crops such as coconut, arecanut and cocoa has immense roots in the culture and history of the region where these crops are grown. Furthermore, the research and developmental facets of these plantation crops cannot be witnessed as a standalone aspect considering the intricate relationships these crops weave in the social fabric of the regions where it is cultivated. In 1950s the area under coconut and arecanut was only 6 lakh ha and 1 lakh ha, respectively with a corresponding production of 3281 million nuts and 80000 tonnes. Hence, the research priority during the period was to increase the productivity to meet the domestic demand for consumption. With the coordinated efforts of the research, the productivity of both coconut and arecanut started showing steady increase since 1990s which in combination with area expansion resulted in an initial steady and later glut in production (Fig.1). At present 22,000 million nuts of coconut is produced from 2.1 m ha area with an average productivity of above 10500 nuts /ha. The enhanced productivity during 1990s and the accompanying price crash had necessitated the need for value addition and by product utilization to increase the income from per unit area.

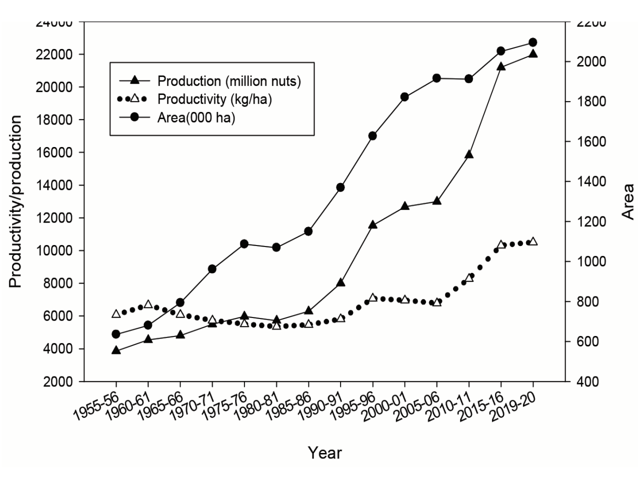


Fig.1: Area production and productivity of coconut (Source: https://coconutboard.nic.in/statistics.aspx)

A glimpse of traditional products of coconut at the global scale in the year 1993 reveals that coconut kernel-based products, oleochemicals, raw materials for soap industry etc. were dominant. However, in the year 2018 it was observed that more than 100 diverse products are made available for the consumers (ICC Secretariat Presentation, Coconut for a better future, Vanuatu coconut summit-2019, Santo, Vanuatu). In order to promote research on plantation crops Central Plantation Crops Research Institute (CPCRI) was established in 1970 and the Central Coconut Research Station (CCRS) Kayamkulam and Central Arecanut Research Station (CARS) at Vittal, Karnataka were designated as Regional Stations. To further strengthen developmental activities Coconut Development Board (CDB) under the Ministry of Agriculture was established in 1981. A centrally sponsored scheme "Technology Mission on Coconut (TMOC)" was initiated in 2002 to encourage the production of value added products and their export. CDB had taken initiatives in the formation of Coconut Producer Societies (CPS), Coconut Producers Federation (CPF) and Coconut Producers Company by mobilization of small and marginal coconut farmers in contiguous areas.

Areca nut/betel nut *(Areca catechu* L.) is an important commercial crop cultivated through tropical India, East Africa, Far East Asia, and South Pacific. India is the major producer and consumer of arecanut in the world. The present global production of areca nut is about 1.214 million tonnes from an area of 0.958 million ha. India ranks first in both area and production. In India, areca nut is cultivated in an area of 473 thousand ha with an annual production of 703 thousand tones (Fig.2). Karnataka is the major producer as the state shares 59.32 % of crop followed by other major producers such as Kerala, Assam and West Bengal (Fig. 2). Although, the production of areca nut is localized in a few states, the commercial products are widely distributed across the country and are being consumed by all classes of people. Areca nut industry forms the economic backbone of nearly six million people in India and for many of them it is the sole means of livelihood. Compared to coconut the research progress on value addition and product development of arecanut is meager as a result even today more than 95% of the arecanut produced goes for chewing.

Since 1970 research in arecanut is conducted by the ICAR-Central Plantation Crops Research Institute at its Regional Station at Vittal and Research Centres at Kidu (both in the Dakshina Kannada district of Karnataka), Mohitnagar (West Bengal) and Kahikuchi (Assam) while the developmental portfolio rests with the Directorate of Arecanut and Spices Development (DASD), Kozhikode in Kerala. In fact, comprehensive R&D efforts in arecanut started as early as 1947 with the establishment of an ad-hoc arecanut committee by the ICAR to study the problems of arecanut industry and subsequently, the Central Arecanut Research

Station (CARS) was established at Vittal in 1956. Consequent to the establishment of the CPCRI in 1970, the CARS became the Regional Station of the Institute. Government of Karnataka and Kerala set up Central Arecanut Marketing and Processing Cooperative Limited (CAMPCO) in July 1973, for procurement of the bulk of the produce, for proper storage and timely release of produce coinciding with the demand. An expert committee constituted in 2001 to look into the market glut and the consequent unprecedented fall in prices and a great farmer distress recommended technical and financial assistance for the entrepreneurs to encourage / promote alternate uses of arecanut by-products such as arecanut stem, leaf sheath etc. for making disposable plates and cups, caps, umbrellas, curios and other products derived from arecanut. National Horticulture Board (NHB) was advised to fund for such projects.

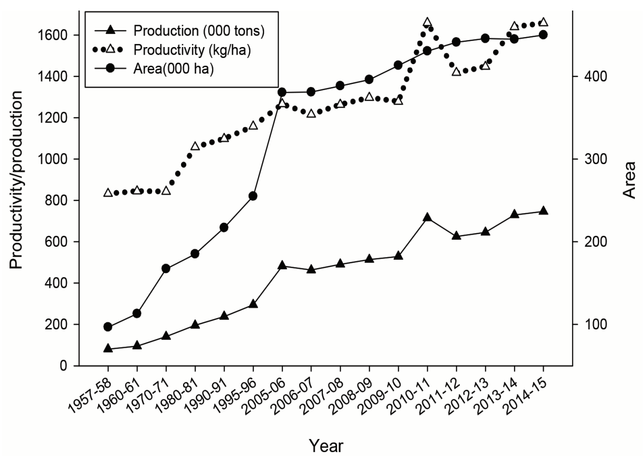


Fig. 2: Area, production and productivity of arecanut in India

Cocoa entered in India way back in 1798 and tropical diversified congenial climate in India especially in the southern part provided immense scope for its cultivation (Malhotra *et al*., 2016). However, the cultivation on a commercial scale began only in 1970 and hence, cocoa cultivation in India is of recent origin. Since 1964, CPCRI has been continuously engaged in research on various facets of cocoa cultivation. The real commercialization phase of India's cocoa economy commenced post Independence in 1965, when the Cadbury India Private Limited started the direct involvement in promotion of the crop. At first, *Criollo* beans were cultivated and later when *Forastero* cocoa plants were brought in from West Africa, these *Criollo* trees were removed to avoid cross pollination. In the early 1970s, global cocoa prices soared and many plantations in Kerala began cultivating the trees. But, when the prices suddenly dropped within a decade or two, most of the cocoa planters moved to rubber and other crops. Central Arecanut Marketing and Processing Co-operative (CAMPCO), during 1990's started procuring, processing and marketing cocoa products. From the year 2006 onwards, the domestic cocoa prices have become attractive with steady increase, and by the end of 2009, the prices have reached record high in comparison to the previous 31 years. In recent times, cocoa is fast spreding in states of Andhra Pradesh and Tamil Nadu. In the global production scenario, India is a very small player with the production share of a meagre 0.3%. It is mainly cultivated in four major southern states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh.

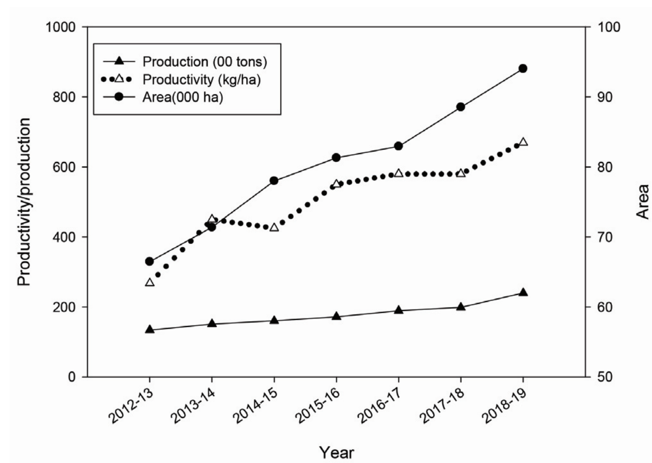


Fig. 3: Area production and productivity of cocoa
(*Source*: www.dccd.gov.in)

The cocoa industry in the country has expanded to a considerable extent in recent years, with a production of 27,072 MT tonnes of cocoa from an area of 1,03,376 ha with an average productivity of 669 Kg/ha and contributing more than Rs.2,000 million annually to the national GDP (DCCD, 2021). Although the per capita cocoa consumption in India (0.04 kg/head) is meagre in comparison with major cocoa consumers, the consumption has been steadily increasing over the last 10-15 years, reflecting the increasing purchasing power of the expanding middle class segment in India. Taking into consideration, the present day consumption patterns and growth of confectionery industry in India at around 15-20 %, the demand for cocoa is likely to increase in coming years. The demand for cocoa by 2050 is projected at 212 thousand tonnes against the estimated supply of 121 thousand tonnes.

This review compiles the major value added and diversified products and processing machineries developed during the last 75 years for coconut, arecanut and cocoa in India.

ADVANCES IN COCONUT PROCESSING

Even though India is a leading producer of coconut in the world scenario, the country has not attained a desired product diversification. Coconut processing is confined to handful of sectors such as copra production, coconut oil extraction and desiccated coconut powder preparation in food industry. Besides, coir and coir-based products form another important component of coconut processing. Among the food processing sector, approximately 40% of coconut is utilized for culinary and religious purposes whereas 35 % is used for oil extraction via copra production and very miniscule proportion (6%) is being utilized in the manufacture of value added products (1% virgin coconut oil, 1% as coconut milk or cream, and 4% as desiccated coconut), 17% is consumed as tender nuts and 2% for coconuts are utilized in seedling production.

Unlike India, other Asian countries like Philippines, Indonesia and Vietnam etc., have ushered in an era of coconut product diversification utilizing state-of-the-art technologies available in food processing sector. The changes in food habits and introduction of cheaper edible oil alternatives including oil palm and soybean have led to the decline in use of coconut oil in food and edible oil sectors. Thus, a prime reason for sharp decline in the price of coconut and its products could be attributed to the greater dependence of this sector on the price of coconut oil which in turn is influenced by the international supply of other vegetable oils. In this context, diversification of coconut food products and processing technologies has an immense potential to achieve remuneration and to enhance the export of coconut based products.

Coconut serves as the basic raw material for a series of agro-processing activities and sustains the lively hood of over 10 million people in the country. Copra, Coconut Oil, Desiccated Coconut, Coconut Cream, Coconut Milk Powder, Virgin coconut oil, Coconut chips etc. are few among the products using coconut kernel as the raw material. Many of the unit operations involved in coconut processing was done manually till recently. These unit operations involved in the production process were all quite cumbersome and involves a lot of drudgery, especially for the women folk. The unfavourable benefit-cost ratio due to the high labour involvement was the major reason that prevented entrepreneurs from taking up the coconut processing technology. Research and development by private entrepreneurs and institutions in public sector led to the development of a series of machineries that could reduce the drudgery and made the coconut processing industry more competitive.

Tree Climber

Climbing the coconut palm is an essential operation for various activities such as harvesting, cleaning, pollinating, sap collection and other research and plant protection-related activities. Due to the its cylindrical structure and unbranched, single stem manually climbing on coconut is very difficult. Kushwaha and Singh (2015) reported that amongst the various models tested *Chemperi* model (pedal type) climbing device was found most suitable, for which CPCRI introduced a safety attachment device (Fig. 4). This safety attachment had eliminated the risk of falling down. Further, robotic type climber has also been developed and tested but were not successful up till now.

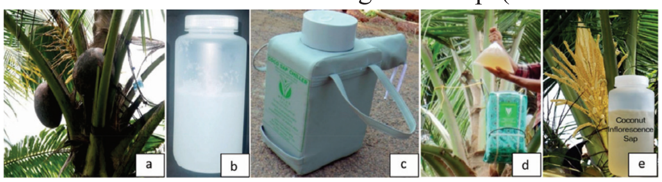
Fig. 4: Safety attachment device for coconut tree climbers

Invention on sap collection and its value addition

Coconut sap, normally called as *neera* is the phloem sap from the unopened coconut spadix. It is a very good health drink, rich in sugars, protein, amino acids, minerals, antioxidants, and vitamins. ICAR-CPCRI developed '**Coco sap chiller'** collects fresh, hygienic and unfermented sap (Fig.5) (Hebbar *et al* 2015b) and is called as Kalparasa®. Coco-sap chiller is a light weight HDPE insulated portable device which is directly connected to the coconut and the ice cubes placed inside the box keeps the inner temperature low and thus collects the sap in its original form (Hebbar *et al* 2015a; 2015b) (Fig.5).

Fig. 5: Coco-sap chiller developed by ICAR-CPCRI for the collection of unfermented coconut inflorescence sap.

Kalparasa collected by coco-sap chiller under low temperature can be sold as fresh juice in local market with the adherence to quality standards prescribed by CPCRI. pH of the fresh sap is 7±0.5. pH > 7 is ideal for promotion to health drink. Other quality parameters easily judged are degrees Brix around 14; color golden brown; and taste sweet and delicious (Fig. 6.). The collected sap can be stored for any length of time under sub-zero temperature. The sap gets freezed and just before use it is thawed to get the original liquid form. Dispensers are used to keep it cool in kiosks or *neera* hub for selling fresh sap (Hebbar *et al*

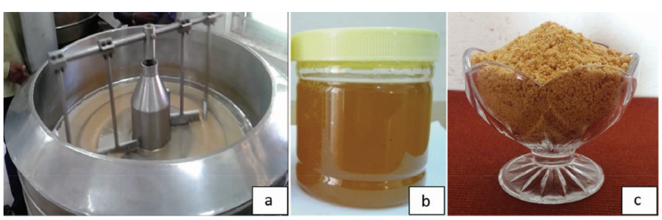


2018).

Fig. 6: Comparison of collection of coconut inflorescence sap by traditional method and coco-sap chiller method (a) Earthen pot connected to the unopened inflorescence to collect the sap; (b) Coconut sap collected by traditional method. (c) Coco-sap chiller; (d) Coco-sap chiller connected to the unopened inflorescence and (e) Coconut sap collected by coco-sap chiller method

Kalparasa-product diversification and value addition

The hygienic, zero-alcoholic sap collected by CPCRI method is easy to process in a natural way without the use of chemicals into various value added products which fetches premium prices both in domestic and international markets. Very good quality coconut sugar, jaggery, nectar or syrup



can be produced in double jacketed cookers with temperature regulation and stirring facility (Fig. 7.).

Fig. 7: Coconut sap concentrate and sugar are prepared by evaporating the moisture from the fresh sap. (a) Specially designed double jacketed cooker; (b) coconut sap concentrate and (c) coconut sugar

Coconut sugar is the best natural sweetener which possesses several health benefits - contains all essential amino acids required for protein synthesis; considerable amount of minerals like calcium, magnesium, zinc, iron and copper; rich in electrolytes like sodium and potassium; abundant in dietary fibers which normalizes bowel movements and digestion; rich source of phenolics which are potent and important contributors in reducing oxidative stress due to their antioxidant activity (Hebbar *et al* 2020). Moreover its glycemic index is low and is in the range of 35 to 54 Gi/ serving and eating a low glycemic index diet reduces the risk of chronic diseases such as Type 2 diabetes.

From the coconut sugar, products like Kalpa Bar a coconut sugar based chocolate purely from plant based ingredients without milk is prepared. (Fig. 8.). Kalpa Drinking Chocolate is an instantised blend of low GI coconut sugar, crafted from fine cocoa powder formulated to produce the

delicious drinking chocolate. The product is soluble instantly in hot or cold milk releasing the chocolate aroma. Fresh Kalparasa based milk sweets are prepared in West Bengal (Hebbar *et al* 2017) (Fig. 8).

Fig. 8: Second line of products from *Kalparasa* and coconut sugar

CPCRI, Kasaragod has developed the complete production to consumption value chain from Kalparasa collection to either it to be sold as health drink or to be processed into value added products *viz*., coconut sugar, jaggery, concentrate, syrup etc (Hebbar *et al* 2018). Also developed on campus training module for a minimum period of two to three days for those entrepreneurs who wish to collect Kalparasa and market it as juice or process into value added products. The technology has been commercialized to more than 55 entrepreneurs/ Coconut producer

Companies in almost all the coconut growing states and two patents and a trade mark have been granted (Hebbar 2021; Hebbar and Augustine 2021). The characterization of sap and its value added products for complete nutrient profile (Hebbar *et al*., 2020) along with the documentation of technology know-how enabled the technology buyer to form FPOs and facilitated to obtain FSSAI certification for their products. Few of the start ups in Pollachi, TN and few firms in Karnataka had produced coconut sugar and selling in malls and online markets like Amazon, FlipKarts, India mart etc. Institute could also establish linkage with Industries for the manufacture of cocosap chiller and for the production of dark chocolate and drinking chocolate using coconut sugar.

Tender Coconut Processing

Tender nuts are predominantly utilized as such as nutritious beverages. The nutritional and therapeutic value of tender coconut water has resulted in increased consumption and demand globally. Although technologies are available for the processing of tender coconut water into packaged soft drinks, consumer preference is for the natural taste of tender coconut. ICAR-CPCRI developed tender coconut punch and Cutter in 2012 (Patent: 233744) which is safe to pierce the tender coconut and to cut open it after drinking the water inside (Manikantan *et al*., 2018) over the traditional way of cutting using lengthy knife (Pandiselvam *et al*., 2020a). ICAR-CPCRI in 2021 has developed an automatic cutting machine that is working based on the concept of conversion of rotary motion to linear motion which has further simplified this process. Further, tender coconuts are used in the production of different value added products such as snowball, chips, and frozen coconut delicacy. These tender coconut based products warrants harvest of the nuts at specific maturity stage. However, no tools/gadgets are commercially available to identify the maturity of the tender coconut.

Snow Ball Tender Coconut (SBTC) is a product developed from tender coconut having 8-9 months maturity. It is nothing but the soft white ball obtained after neatly removing the outer shell. The main unit operation in the snow ball tender nut making is to take a groove around the shell on its middle (Manikantan *et al*., 2018). Then, the white kernel is scooped out from the tender nut without shell with the water inside intact.

The bulky nature of tender coconut can be reduced by trimming out the husk to leave it as two-third of the original weight (Pandiselvam *et al*., 2020a) without damaging the shell (Pandiselvam *et al*., 2020b). A minimum of 20–35% of the coconut weight can be reduced by performing trimming operation (Pandiselvam *et al*., 2019; Pandiselvam *et al*., 2021a). This not only ensures considerable reduction in the ratio of weight/volume of the nut but also results in an attractive look (diamond/pentagonal shape). ICAR-CPCRI has developed a linear actuator-based trimming machine for tender coconuts (Fig. 9). Nevertheless, browning and mold development in the nuts following the trimming process requires to be controlled with careful use of chemical solution without contaminating the kernel and the water (Pandiselvam *et al*., 2020a). An image processing-based automatic tender coconut trimming machine is required to be developed for large scale production of trimmed tender coconuts.

Fig. 9: Trimming Machine for the production of minimally processed tender nuts

The bottled tender coconut water has a great demand in worldwide. The CDB and Defence Food Research Laboratory (DFRL), Mysore has developed a technology for processing and packing of tender coconut water either in pouches and aluminum containers with a shelf life of 6 months (extendible upto 12 months under refrigerated conditions). The thermal treatments applied for the preservation of tender coconut water has a negative impact on the quality and flavor profile (Pandiselvam *et al*., 2021b). In this context, different non-thermal food processing technologies such as ozone, cold plasma, ultraviolet, high-pressure processing, pulsed light, and ultrasound are being attempted to extend the shelf life of tender coconut water (Prithviraj *et al*., 2021). However, the limitations of non-thermal technologies such as the high initial investment and non-availability of commercial scale equipments restrict their practical utility in industries.

Processing of Matured Coconut

De-husking is the first post harvest operation in any coconut processing industry. Traditionally coconut is dehusked manually using a spike. 'Keramitra', the coconut dehusking machine developed by KAU is a very popular device in the households. However, it's extremely low output is a major constraint. A power-operated semi automatic coconut de-husking machine has been designed and fabricated at ICAR-CPCRI (Deo *et al*., 2020a).The machine has a capacity to de-husk 200 coconuts per hour.

Shell remover has two concentrically rotating multi pointed circular blades and a stationary pointed blade on which coconut would be placed firmly are the major components of the shell removing machine (Deo *et al*., 2020b). The machine has a capacity to remove the shell of 150 coconuts per hour. **Testa remover** can remove testa of about 75 coconuts per hour. Two **gratings machines** were developed by ICAR-CPCRI to enhance the grating efficiency. First one is of single user and the second one is of multi user (four grating blades) type. The motorized coconut grating machines developed scrapes off the deshelled coconut flesh into fine gratings with the help of stainless steel blade. The single user machine has a capacity of 60 nuts/h and the multi user has a capacity 240 nuts/h.

Pulveriser is very important for the production of desiccated coconut powder and coconut milk. The coconut kernel pieces are fed into the hopper manually. The machine has a capacity of 250 nuts/h. Four different **milk extractors** are developed at ICAR-CPCRI to enhance the milk extraction efficiency. Two are manually operated and two are hydro-pneumatic. The grated coconuts are kept in a perforated cylinder and by rotating the handle provided at the top of the screw the gratings are pressed. In the first machine the whole pressing process is done manually by rotating the handle. In the second machine an additional hydraulic jack is provided at the bottom (Manikantan *et al*., 2018). Two hydro pneumatic coconut milk extractors of different capacities were also developed to enhance the extraction efficiency of coconut milk. The operation of both the machines is completely automated using a programmable logical controller. They are useful for large scale extraction of coconut milk in coconut milk processing industries and virgin coconut oil production centres. The smaller machine could handle 250 nuts/h where as the bigger machine can handle 500 nuts/h. Two screw type coconut milk expellers, single and double screw, with different capacities have been developed to extract coconut milk. The screw type expellers have the maximum extraction efficiency among different types of coconut milk extractors. The single screw expeller has a capacity of 300 coconuts per hour and the double screw has capacity of 1000 coconuts per hour (Manikantan *et al*., 2015). Various post-harvest machineries for the processing of coconut have been developed (Fig. 11)

Value Added Products from Coconut kernel

Wet coconut kernel is generally utilized in households either in the grated form and as a milk or cream obtained by squeezing the gratings with or without the addition of water. To increase the shelf life of matured kernels to 4-6 months, small pieces of the kernels are preserved in hot syrup exhausted at 80 °C, sealed and processed. Alternatively the kernels are preserved in a 50 °C Brix syrup with 0.01% sodium metabisulphite as a preservative. Tender nuts are preserved in jelly-like consistency using refined sugar, packed and sealed in cans. Earlier, the preservation methodology utilized a mixture of butylated hydroxy anisole (0.1%) and propionic acid (1000 ppm) coupled with modified atomosphere package system, or vacuum packaging. Even freeze-drying of coconut slices preserves the inherent flavor but cost of production escalates.

Matured coconut is mainly used for oil extraction and virgin coconut oil (VCO)-produced from freshly grated coconut endosperm milk- is a premium value added product with immense nutritional potential. A number of VCO production processes being followed in India and elsewhere cause variations in the physicochemical properties, which in turn potentially affect the nutritional and medicinal properties of VCO. ICAR-CPCRI has standardized the protocol and commercialized the technique to producing virgin coconut oil by hot and fermentation processing methods (**Fig.10)**. Two types of VCO cookers (differing in their fuel sources-LPG/biogas or agricultural waste) were developed at CPCRI to extract the VCO by hot processing (Mathew *et al*., 2014). VCO cooker developed by the ICAR-CPCRI consists of a double jacketed vessel filled with thermic fluid of capacity of 125 litre. However, a VCO cooker of any capacity can be fabricated by scaling up the design (Mathew *et al*., 2014). Alternatively microbial fermentation process is also followed to recover oil from the skim milk and fermented curd. Screw pressing or hydraulic pressing of pulverized meat is also followed to extract VCO (Marina *et al*. 2009). The technologies developed for wet processing to recover oil are a) Krauss Maffei process developed in Germany utilizes centrifugation process to separate cream and water phases followed by processing of cream into oil with a recovery of about 89%. Further improvement in this process by CFTRI had led to enhancement in the oil recovery to 93%. Also the water phase or coconut honey is utilized for the preparation of processed foods such as infant protein food and cereal flakes (NIIR Board of Consultants and Engineers 2012). The physical and biochemical properties of VCO from the hot process (VCO-

Hot), fermentation (VCO-Fer), expelled from dried gratings (VCO-EDG), centrifugation (VCO-Cen), and conventionally prepared copra coconut oil (CCO) and the required quality standards were documented (Ramesh *et al*. 2020).

Fig. 10: Virgin coconut oil (VCO) developed by ICAR-CPCRI

Edible coconut flour

Coconut meat gratings, when partially defatted, forms an excellent source of nutritious ingredient for use in household, bakery or confectionary preparations. Relatively low fat content along with high proportion of protein, minerals and sugars, and as a rich source of dietary fibre, the product has appreciable acceptance among the consumers. CFTRI, Mysore, and National Institute for Interdisciplinary Science and Technology (NIIST-CSIR), Trivandrum, India has developed a process for the manufacture of edible flour. Coconut flour has relatively low digestible carbohydrate and high fibre contents (Banzon *et al*. 1990) and hence at least 5% of wheat flour and non-fat dry milk powder in school nutrition programmes without compromising the baking qualities and food value (Balakrishnamurthi 1979). Other value added products developed are nutribars, porridge, traditional sweets (*laddoo*, *halwa*), noodles, extrudates, pasta, muffin cakes and ready-to-eat food items such as coconut pickle and coconut chutney powder at ICAR-CPCRI and other national research organizations.

Desiccated coconut powder (DCP)

It is white kernel of coconut of particle size less than 5 mm, processed to retain moisture content (<3%) following comminution and desiccation. DCP has demand all over the world as an important ingredient for fillings in various confectionary products such as chocolates, candies etc and in related food industries. Besides Sri Lanka, East Asian countries such as The Philippines, Malaysia, Indonesia, and others such as Fiji, Tonga, Côte d'Ivoire, Brazil and India are producers of DCP. The major consumers are North America, Western Europe and Middle East.

Coconut chips (also a patented technology of the CPCRI) are a ready-to-eat, snowy white crisp and healthy non fried snack prepared from 8 to 9 month old fresh kernel through osmotic dehydration in a forced hot air electrical dryer at 70-80°C for 5-6 h to less than 3% moisture content. The kernels undergo paring, blanching, slicing and osmotic dehydration to prepare ready to eat chips. Kernels are sliced using a slicing machine.

Extrudate-based products: Co-products of coconut processing industries such as coconut milk residue (CMR), virgin coconut oil cake, deoiled copra are obtained from VCO, coconut milk powder, coconut milk yogurt and flavored coconut milk based processing industries. Besides, rich source of dietary fiber and polyphenols, they are presently either underutilized as animal feed or thrown as waste (Manikantan *et al*., 2015). It was observed that 25% corn flour, 15% CMR flour, 220 rpm screw speed and 140 °C temperature gave an optimized product of 0.956 desirability (Pandiselvam *et al*., 2018). Coconut haustorium-based extrudates i.e., incorporation of 20% coconut haustorium in rice (50%) and maize (30%) based extrudates resulted in healthy and nutritious products (Arivalagan *et al*., 2018).

Coconut-milk based products

Coconut milk from the kernel is processed to obtain milk concentrate, coconut cream and milk powder. In addition to its use in household culinary preparations, coconut milk is an excellent and nutritious substitute for dairy cream, preparation of white cheese, and yoghurts. Further, coconut milk is preserved either as a dehydrated whole milk, canned milk or cream in many countries including Philippines, Thailand, Indonesia, Western Samoa, Sri Lanka and Malaysia. The processing technology for preservation of coconut milk in India involves Pasteurisation at 75 °C to 80 °C for 10 min, addition of preservatives such as nisin, sodium metabisulfite along with the stabilizers such as carboxy methyl cellulose (CMC) and guar gum (Arumugham *et al*. 1993). The coconut cream serves as a fat source of skimmed dairy milk and infant milk powders.

Bottled coconut milk after treatment with 0.1% benzoic acid, and thermal treatment (117 °C for 3 min.) followed by cooling is a substitute for cow's milk widely used in many countries. Coconut milk is also marketed in the form of dry powder following dehydration utilizing spray dry process along with the addition of maltodextrin or casein (Muralidharan and Jayashree 2011). Alternatively, coconut syrup is produced using the homogenized coconut milk with the addition of sugar and citric acid (0.05%) or sodium phosphate (0.25%) in a steam cooking process to attain TSS of ~65%. This syrup is used in confectionary preparations or consumed as an instant drink when mixed with water or as bread spread (Sangamithra *et al*. 2013). Coconut honey could be produced by steam boiling the coconut milk mixed with 90% of sugars (60% of brown sugar and 30% of glucose) to achieve a thick consistency, golden brown colour product with nutty flavor that serves as an excellent base for soft drink preparation (Muralidharan and Jayashree, 2011). Coconut cheese is a nutritious product, which can be produced at house hold level units, by heating the skimmed milk with vinegar to coagulate the proteins followed by mixing with cream and kneading with salt (Ghosh 2015).

Coconut skim milk is a protein-rich soluble component of coconut milk obtained by separating the cream using a separator devised by Texas A&M University, US. It serves as an important ingredient of various products namely spray-dried powder, coconut honey, coconut jam, fermented beverage concentrate, sweetened condensed milk and as a source of casein.

Frozen coconut delicacy: In view of increased demand for non-dairy products from ever increasing strict vegetarian and lactose intolerant population, ICAR-CPCRI has come out with a coconut based "Frozen Coconut Delicacy", which is composed of coconut milk, coconut sugar/refined sugar, tender coconut water and pulp (Beegum *et al*., 2021). It is a premium product which is completely natural and healthy. It is enriched with vitamins, minerals and healthy fatty acids. Due to lauric acid rich coconut milk and potassium rich tender coconut water, this will be a functional and nutraceutical food.

Products from mature coconut water

Coconut water from mature nuts is considered a waste produce in copra or desiccated coconut powder industries. **Coconut water concentrate (CWC)** is concentrated by adopting reverse osmosis technique and utilized by the end user industries such as food and beverage, hospitals, fermentation industries and research laboratories receive the product. Fresh coconut water, after the removal of solids and oil, could also be frozen or concentrated and canned as **frozen coconut water** for further use in the production of carbonated or non-carbonated beverages. Another product is **coconut vinegar** which enjoys preference as a preservative in pickling industry and as a flavouring agent for foodstuffs. **Coconut honey** is produced by evaporating the water followed by addition of golden syrup to form a nutty-flavoured sweetener that could

Fig. 11: Post-harvest machineries for processing of coconut and production of value added products

be an additive to breakfast food, and a soft drinks additive. **Nata de coco** is another flavoured delicacy in food industry and Philippines is one of the largest producers of nata de coco.

ARECANUT PROCESSING, VALUE ADDITION AND PRODUCT DIVERSIFICATION

In India, arecanut is marketed as unhusked, whole fruit, dehusked and dried nut, boiled and dried whole kernel or their cuts. Nearly 20% of total areca production in the country is consumed as ripe fruit and the rest in the form of whole nut and processed forms (Chowdappa *et al*., 2020). Market of semi ripe, fully ripe or fermented arecanut has enjoyed considerable value in Assam, Kerala and West Bengal. In Kerala, about 25% of the produce is marketed after harvest either at semi-ripe or fully ripe or fermented arecanut. About 70% of the production is converted into processed arecanut. In Assam 90% of the crop is consumed locally in the form of semi ripe, fully ripe or fermented arecanut (Mula *et al*., 2015). The remaining 10% of the production are converted into processed arecanut. Bulk of the production in Maharashtra is in the form of ripe nut. In Goa, it is harvested only when they are ripened. About 92% of the production is converted into *Chali* and the remaining consumed as fresh nut or preserved in water for use in the off-season (Bhat *et al*., 2017).

Arecanut dehusking is a labour intensive process as the nuts are to be cut into longitudinal sections or *choor* and transverse sections called *kottai* depending upon their maturity stages. However, rotary drum type mechanical dehuskers are available which has a capacity of 30kg/h (Kiran *et al*., 2014). A semi-mechanical dehusker developed by Gandhi Krishi Vigyan Kendra (GKVK), Bangalore has the capacity of 160 kg per day reducing the drudgery to great extent. Similarly some of the local inventions of semi mechanized peeling machines have greatly assisted in reducing the drudgery involved in manual processing of arecanuts.

The boiled arecanuts are currently dried in open sun drying process for 8-10 days. Though metallic fabricated trays are used for drying the nuts, artificial dryers are also utilized when adequate sun light is not available. To expedite the process of drying, a solar-cum-biomass dryer was designed by Tamil Nadu Agricultural University which could reduce the moisture content of the nuts from 40% to 11% in 15 hours besides maintaining the quality parameters of the arecanut when compared to open sun drying process. Similarly, ICAR-CPCRI has developed solar and agricultural waste fired dryers capable of processing 50 Kg/batch and 150 kg/batch arecanuts, respectively.

The entire processing of raw arecanut deshuking, cutting, boiling and drying could be performed in a reliable and safe manner by adopting a recently developed Automatic Arecanut Processing Unit developed by Kumar *et al*., (2019).

Grading

Processed arecanut is sorted into different quality grades at the farm level before marketing. For example, farmers bringing nuts to Shimoga regulated market, grade the processed nuts in to three types, namely '*Hasa*', '*Bette*' and '*Gorabalu*'. The farmers producing *Chali* also undertake the grading at the farm level. For example, the farmers in the coastal districts classify *Chali* into '*Old Supari*', '*New Supari*' and so on. These grade specifications and designations are based on several quality attributes to meet the market demand to prepare value added end products in important centers spread across India (Fig. 12 and Fig. 13).

1.Mora 2. Moti 3. Sevardhan 4. Jam 5. Jeeni 6. Lindi

Fig. 12. Commercial grades of areca nut *chali*

Fig. 13: Some of the grades of processed arecanut

Moisture content and water activity (a_w) for safe storage

Appropriate moisture content for safe storage of arecanut is imperative hence a study conducted in ICAR-CPCRI sourced arecanut samples from different places during dry and rainy seasons, processed (red) and *chali* and their sub-types. It revealed that the arecanut samples showed mean water activity a_w of < 0.71 (corresponding moisture content of <11.3%) which is safe and unlikely to cause nut deterioration during storage, that includes discoloration, musty odors, dry matter loss, tissue disintegration, nutritional and processing quality losses, and mycotoxin accumulation, due to fungal contamination. Hence, the arecanut growers, processing industries, quality standard organization like FSSAI must ensure a_w of <0.71 for dried arecanut samples for its safe storage as well as safe for mastication (Hebbar *et al*., 2021).

As masticatory

The practice of chewing betel leaves after meals was mentioned in the Charaka and Sushruta Samhitas and Kashyapa Bhojanakalpa (75 AD to 300 CE) (Prakash, 1961). During c.730 to 1200 CE, chewing betel leaves with some spices after meals was a common custom. In 1654 CE, Niccolao Manucci referred to the habit of betel chewing and the use of *paan* by royals. Basavaraja, the King of Keladi, enumerated various locations for the best betel leaves and areca nuts in his treatise, *Shivatathvaratnakara* in c. 1700 CE (Desai, 1980).

Arecanut is either consumed alone or as a betel quid wherein betel leaf, slaked lime and others such as tobacco, catechu, spices and sweetness are included (Mathew *et al*., 2014). In general a betel quid contains betel leaf, arecanut and slaked lime and may contain others like cardamom, saffron, clove, aniseed, turmeric, mustard or sweeteners. The different modes of consumption of arecanut are: (a) arecanut alone, (b) arecanut with betel leaf and any other ingredients except tobacco, and (c) arecanut with betel leaf and any other ingredients including tobacco. A variety of processed and packaged arecanut products are available such as (a) *pakku* or supari – processed, flavoured and packaged arecanut, (b) *pan masala* – a preparation of arecanut, catechu, cardamom, lime and variety of perfuming and flavouring materials, (c) *gutka* – it is a variant of *pan masala*, which in addition to these ingredients contain flavoured chewing tobacco. *Pan masala* and *gutkha* are often sweetened (Anonymous, 2004). The rise of commercial pan masala and gutka about three decades ago caused an exponential growth in the sales of smokeless tobacco along with arecanut products besides developing export-oriented markets (Sushma and Sharang, 2005). It could be attributed to the portable, convenient and cheap packaging which further increased the shelf life of these products (Mathew *et al*., 2014).

Medicinal and pharmaceutical uses

Arecanut has greater importance in the ancient system of medicines such as Ayurveda, Unani and Homeopathy. The seeds of arecanut have been widely used in clinical practices in China and other south and Southeast Asian countries. Since time immemorial, arecanut is being used for chewing as it is believed to have lots of medicinal properties. The potential and proven pharmacological uses of arecanut, applications in traditional medicine, are reviewed by Peng *et al*., (2015). WHO has enumerated multiple beneficial effects of consumption of arecanut. Chewing arecanut sweetens the breath, removes bad taste from the mouth, strengthens the gums and checks perspiration. It has potent antioxidant, anti-inflammatory and analgesic, antiulcer, hypolipidemic, antidiabetic and neuroprotective properties. It is also traditionally used in a number of ailments for its laxative, digestive, carminative, antiulser, antidiarrhoeal, anthelmintic, antimalarial, antihypertension, diuretic, prohealing, antibacterial, hypoglycaemic, antiheartburn properties (Arivalagan *et al*., 2020; Amudhan *et al*. 2012).

Biochemical composition

Arecanut is characterized with diverse biochemicals namely nitrogenous compounds, vitamins, minerals, phenolics [including simple phenolics, condensed tannins, hydrolyzable tannins, no tannin flavans (e.g., catechin, epicatechin)], flavonoids, triterpenes, fatty acids (Peng *et al.,* 2015) and alkaloids such as arecoline, arecaidine, guvacoline, and guvacine, arecatemine A to C of pharmacological importance (Tang *et al.,* 2017). Alkaloids are characteristic components of *A. catechu*, and arecoline, with a content of 0.3–0.6%, is the main alkaloid. The predominant alkaloids are of the pyridine type and include arecoline, arecaidine, guavacoline, guavacine, arecolidine, ethyl N-methyl-l,2,5,6-tetrahy- dro-pyridine-3-carboxylate, methylnicotinate, ethylnicotinate, methyl N-methylpiperidine-3-carboxylate, ethyl N-methylpiperidine-3-carboxylate, nicotine isoguvacine), and homoarecoline. Tannins are another characteristic component of *A. catechu,* and the main types are condensed tannins (also called proanthocyanidins). Tannins are one of the main constituents that contribute to the perception of the taste of food (astringency and bitterness perception). Further many triterpenes and steroids have been reported.

The biochemical composition of marketed arecanut depends on the maturity of the nut since processed arecanut are made from both green and ripe nuts. Tender arecanut comprise around 30-37% of tannins, hence the tannins obtained as a byproduct(Shivasankar and Govindarajan, 1963). It has multiple utilities such as in drying leather, clothes, and rope, in the preparation of black writing ink, as an adhesive used in manufacture of plywood, and as food colourant (Swain *et al*., 2016). The arecanut lipid obtained from the nut (~10-12%) could be blend with cocoa, following the refining process, to develop confectionary products. Also, it can form a reasonable substitute for hydrogenated fat of plant origin used in the preparation of sweets. The furfural and xylose obtained from the arecanut husk fibre is relatively a good source for multiple industrial applications. The mineral matter contains calcium (0.05%) phosphorus (0. 13%) and iron (1.5 mg/ 100 g). Arecoline has been a proven muscarinic cholinergic receptor agonist and hence it improves the conditions of Alzheimer presenile dementia. The development of arecoline-loaded transdermal patch with potential pharmacological effect suggests the untapped potential of arecanut (Wu *et al*., 2014)

Effect on human health

There are numerous reports to show that arecanut chewing might cause cancer. However, in a recent Interactive Workshop entitled 'Arecanut and Human Health' conducted at ICAR-CPCRI involving large number of medical practitioners were of the opinion that reports on the effects of arecanut consumption on human health are only observational and not based on any systematic scientific studies (Chowdappa *et al.,* 2018). The adverse effects reported in association with arecanut chewing might be due to several other factors such as small sample size, the role of other ingredients used in the preparation of betel quid, the quality of arecanuts (including contaminations and adulterations) used for making different preparations of chewing products, etc. Further, a survey conducted by ICAR-CPCRI during 2020 in traditional arecanut chewing belts of Karnataka and Kerala, further revealed that there was no significant difference in health of chewers and non chewers (Jose *et al*., 2020).

In addition, studies have showed that at lower concentration (1.5 to 5 g/ kg body weight) arecanut found to arrest the growth and multiplication of several human cancer cells such as MCP-7 breast cancer cells, SGC-7901 gastric cancer cells and SMMC-7721 liver cancer cells (Anajwala *et al*., 2010; Xing *et al*., 2010). Certain studies carried out on both normal as well as immune suppressed laboratory mice for two years confirmed that the extracts of arecanut and betel quid without tobacco were not carcinogenic (Garg *et al*., 2014). It was also reported that the betel quid ingredients from several Asian countries also did not induce any carcinogenic activity (Dunham and Herrold, 1962). In another study, consuming arecoline, the main alkaloid principle of arecanut, at a dose of 100mg/kg body weight per day was reported to be safe to Wistar albino rat (Wei *et al*., 2015).

The antioxidant activity of arecanut might play active role in repairing DNA damage in cancer cells. The methanol extract of eight month old arecanut husk showed a dose dependent inhibition of comet formation (Phaechamud *et al*., 2009). In a recent study at the Winship Cancer Institute of Emory University, Atlanta, USA, the arecoline hydrobromide found to arrest the growth of cancer cells. It was reported that the arecoline hydrobromide inhibited the activity of the enzyme ACAT1 (acetyl-C0A acetyltransferase) which lead to attenuation of cancer cell proliferation and tumor growth in mice (Fan *et al*., 2016).

All these reports confirm that arecanut in its pure form and at right dose is not dangerous but has got a plethora of medicinal properties including curing ulcers, wounds and even cancer. Most of its folklore medicinal properties are now validated by scientific evidences but still others need to be validated. Detailed studies on the nature of active principle(s) responsible for all these properties and clinical trials on them are warranted to utilize such plant products effectively and profitably as these palms are available in plenty in most of the South and Southeast Asian Countries.

Agri-business oppurtunities

Several value-added technologies are available for arecanut by-product utilization such as making eco-friendly disposable plates and bowls from areca leaf sheath, leaf sheath fodder, oyster mushroom production from leaf and bunch wastes (Fig. 14) and vermicomposting. But only very few commercial (small-scale) ventures are operating at present. About 3.5 billion arecanut leaves and leaf sheaths are produced every year and have the potential to facilitate production of 0.3 billion kg of mushroom and Rs.7 billion worth areca leaf sheath plates and bowls (Patil *et al*., 2019). Analysis of carboxy methylcellulose coated arecanut leaf sheath could be utilized as a suitable transparent packaging material (Disanayake *et al*., 2021). Vermicomposting of arecanut leaf wastes per hectare can generate a net income of Rs. 20,000 and this can be taken up as a microenterprise, instead of the prevailing unscientific dumping of wastes in the plantations.

Fig.14: Utilization of leaf sheath for production of disposable plates and mushroom

Bio-softened arecanut husk fibres can be exploited commercially for the production of furnishing fabrics, textiles etc. by blending with cotton, viscose and polyester (Rajan *et al*., 2005). It is also utilized in the preparation of reinforcing material having potential applications in construction, automobile and aerospace industries (Muralidhar *et al*., 2019). But, efforts of developing commercially-viable technologies for products like tooth brush, paper boards, plyboards, hardboards and plastics from arecanut husk mixed with conventional raw materials has to be taken up in collaboration with industrial R&D institutions. From a long term perspective, the fact remains that, in spite of early leads, not much progress has so far been made in taking them forward in to developing commercially-viable products/processes/business enterprises, which can change the destiny of this crop. Unfortunately, the only small consolation is the development of few small-scale industrial units making plates and cups from arecanut leaf.

COCOA PROCESSING

Cocoa or cacao is popularly known as 'food of god'. The cocoa beans, the economic part of cocoa are derived from the mature cocoa pods and processed to get the end products such as chocolate, cocoa butter and cocoa powder. Cocoa butter is also used in moisturizing creams and soaps while cocoa powder is often used as chocolate flavouring. Cocoa is considered as a functional food because of its richness in terms of flavonoids, polyphenols and antioxidant properties.

Post harvest quality of beans

The pre-harvest factors including genotypes, growing conditions or agro techniques, seasons, pollination, fertilization, pre and post harvest handling etc. influence the bean quality such as bean size, flavor etc. Bean size with respect to bean indices, moisture content, shelling percentage, nib or kernel recovery and fat contents add value to the marketable bean. Elite clones and hybrids are developed with rich bean qualities. Clones rich in polyphenols, procyanidins, fat, antioxidant properties etc. have been identified. Fatty acid profiles obtained from clones and hybrids are high in stearic acid. In the recent years, flavour improvement has been given importance in order to develop specialty chocolates with a blend of Criollo and Forastero beans. Bean size is highly varying with genotypes, changes in climate and processing which are to be taken care of in order to maintain the quality of the cocoa beans.

Harvesting

Traditionally, farmers harvest cocoa using wooden mallet or poles and sickles. During 1980s, CPCRI, regional station Vittal has developed a cocoa harvesting tool to harvest the pods even from more than 2 m height (Fig.15). It eliminated the use of a ladder for climbing the tree and also performs the function of a sickle or knife used for harvesting pods which are at the lower branches and main stem (CPCRI, 1980).

(a) (b)

Fig. 15. Cocoa harvesting using a) cocoa harvester b) sickle (Source: Apshara and Hubballi, 2013)

Primary processing: Fermentation and drying

Fermentation

Fermentation and drying of beans are the primary processing operations which require utmost care. Fermentation, drying and roasting are critical steps influencing the characteristic chocolate flavour. Despite the large scale cocoa plantations in the country, the process of fermentation suffers from many drawbacks. Even today, majority of the cocoa farmers sell the wet beans to the collection centers established by manufacturing firms. From 1980s onwards, CAMPCO has been procuring fruits/ pods instead of wet beans.

Mechanization in fermentation

The primary and secondary processing facilities were created at KAU during 1995 under the KAU- Cooperative Cocoa Research Project (CCRP) (Peter, 2002). Attempts were made in India to develop small scale methods of fermentation such as mini box, mini basket, tray and heap methods using bean lots substantially smaller than those required for the standard methods. Later, small scale fermentation methods were standardized by KAU. The efficacy of some of the methods was also studied based on the pH of the beans and cut test (Kumaran *et al*., 1981; Premalatha, 1983). For large scale fermentation, farmers follow heap, tray and box methods. Similar kind of small scale fermentation is practiced in ICAR-CPCRI, Vittal. The effect of fermentation methods on the quality of different accessions were also studied at Vittal (Amudhan and Apshara, 2015). The studies on the biochemical changes occurring during fermentation was well explored in international publications and in India. Of late in 2020, KCAET, Tavannur under KAU has developed a cocoa bean fermentor (Srikanth *et al*., 2019) which needs to be popularized among the farming community (Fig.16). Generally fermentation completes within 5-7 days depending on season.

Fig. 16: Cocoa bean fermentor developed at KAU

Drying

The beans after fermentation are generally dried under sun which is the simplest and most popular method followed in most of the cocoa producing countries. In India, beans are dried on raised ground or on concrete floor and exposed to sun for about 4-12 days depending on the climatic condition. CPCRI has developed a small scale electrical drier of 40 kg bean capacity mainly to dry the bean during monsoon season which is the main harvest season for cocoa (CPCRI, 1980). Of late, cross flow electrical dryer is commercially available for drying of cocoa beans. Temperature in the drier is maintained at 70°C as quick drying results in increased acidity in beans. The moisture content of well dried beans is around 6-7%. Interrupted drying with short period of drying followed by longer resting period showed better migration of moisture to the surface during the rest period which resulted in good quality as mentioned by Asopa and Narayan, (1990).

Following drying, the beans are sorted manually or mechanically to remove flat, slate, shriveled, broken and clumped beans and other extraneous materials and packaged in polythene lined (150 – 200 gauge) gunny bags or jute bags. The International Standard recommends that the samples should amount to not less than 300 beans for every tonne of cocoa. For bagged cocoa, samples should be taken from not less than 30% of the bags, and for bulk cocoa there should be not less than 5 samplings per tonne. Bean counts are another measure of quality that producing countries often use, though there is no internationally accepted bean size classification (Fig.17).

Fig. 17: Appearance of bean during fermentation process

Secondary processing

Secondary processing involves the conversion of dried beans to chocolates and other products. The steps involved in secondary processing are cleaning, roasting, kibbling/ bean breaking, winnowing and grinding. Secondary processing is mainly done in big factories of Cadbury or CAMPCO. A small scale cocoa butter extractor was designed in India by way back in 1982 (Ganesan, 1982). Cocoa butter recovery is ranges from 50-58% (Peter, 2003) and fat content in the left over cake is ranges from 11-25%.

Bean to bar chocolate: Cocoa is an understory crop of coconut. A small farmer who grows both coconut and cocoa can prepare the chocolate using the well fermented, dried cocoa beans and coconut sugar with or without cocoa butter as a cottage industry and refered to as 'Bean to bar' chocolate and thus directly benefits the farming community (Fig.19). Lately, chocolate production with palm sugar has emerged as a healthy alternative and accords multiple health benefits due to low glycemic index (GI) of natural sugars. Dark chocolate with coconut sugar production protocol was optimized at ICAR-CPCRI. Due to higher proportion of cocoa and presence of natural sugar, bean to bar chocolates have high polyphenols, flavonoids, antioxidants and minerals.

Fig. 19: Bean to bite dark chocolate

Home level chocolate processing studies undertaken by the Kerala Agricultural University opened up way to utilize cocoa in the homesteads, ensuring women empowerment, improve income from unit area of land and make available farm fresh and natural chocolates at comparatively affordable prices (Suma and Minimol, 2018).

By-products utilization

Cocoa pod husk constitutes 70-80% of the pod weight which is generally discarded after collection of beans. Pod husk is utilized for pulp and paper production (Daud *et al*., 2013). Mucilage is utilized for making fruit wine. Cocoa sweating is also used for making alcohol and vinegar. Cocoa shell is another by-product of cocoa (12-25% recovery from beans). Both cocoa shell and cocoa husk contain phytochemical compounds which are potential to inhibit the growth of pathogenic bacteria in food products (Kayaputri *et al*., 2020). Cocoa butter extracted from discarded cocoa beans, with little or no commercial value, can be used in the production of toilet soap and body pomade.

CONCLUSION

Though mechanization could reduce drudgery involved in all unit operations in coconut processing involvement of human labour could not be avoided. This human intervention in each processing operations make the production line rather slow and costly. Automation of these unit operations from de husking to the final product would be the future strategy for coconut industry and research institutions. In arecanut the effects of arecanut on human health are found to depend on the dose of arecanut and mode of administration. At a normal or lower dose either areca nut extract or the arecoline is found to be safe. The off-target effects of areca nut and other chewing products containing areca nut might be due to their high doses or application in unusual manner like injection, direct exposure to cultured cells or due to several other factors such as contaminations and adulteration, the effect of other ingredients of betel quid or pan masala and the food habits of individuals etc. Hence, the future research objectives shall explore the metabolic profile of arecanut in order to identify novel biomolecules offering immense health benefits. A non-thermal based commercially viable technologies need to be optimized for the shelf life extension of coconut beverages. In cocoa domestic supply chain of cocoa in India is still in rudimentary stages. CAMPCO and Cadbury India Ltd (now Mondelez India) are the major procuring agencies in India, who are directly procuring the cocoa beans from farmers. The value share of the producer / farmer is a meager 32% because most of the farmers sell the produce as wet beans, even without doing minimal processing. Drying yards, primary processing facilities, and storage facilities are lacking in the case of most of the cocoa farmers. Since the stringent food safety standards and trace back systems are evolving in international arena, it is a real challenge to establish robust procuring system in the upstream end of the cocoa value chain in the country. Focus is needed to establish village level primary processing units and capacity building for fermentation and drying of cocoa beans with the formation of strong farmer aggregates, women SHG's and rural youths.

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Research Article

Assessment of seed spice squashes from dill, fennel and coriander

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ABSTRACT

Spice seeds are important source of fibre, vitamins, minerals and phenolics. These contain pleasant aroma and used mostly in culinary purposes. Squashes were developed from dill, fennel and coriander using aonla juice as base material. The squashes were prepared using water extracts of 5 per cent coarsely ground seed spice powders mixed in aonla juice. The prepared squashes were stored at low temperature (10±2°C) for one year. Among the samples, coriander squash contained highest amount of ascorbic acid (73.3 mg/100 ml) and phenolics (735 mg/100 ml) at zero day. During storage, both ascorbic acid and phenolics decreased in all the samples. The reducing sugar content initially was 13.2-13.5 per cent, which increased to 24.1-24.4 per cent after one year of storage. All the squashes were organoleptically acceptable, scoring between 7.5 and 8.2 on hedonic scale during sensory evaluation. The squashes retained high acceptability obtaining 7.2-8.3 scores till the end of storage. No microbial contamination was observed in any of the samples at any stage of storage. It was inferred from the study that good quality squashes could be prepared from dill, fennel or coriander using aonla juice as base material.

Keywords: Seed spices,dill, fennel, coriander, squash

INTRODUCTION

India is the largest producer of spices contributing 70% of global spice production. The world production of all spices stood at 22.04 lakh tonnes in 2012. Total area of land under spice cultivation in India was 7,40,990 hectares accounting for 14,96,990 tonnes during 2012 according to FAO statistics (Yogesh and Mokshapathy, 2014). The major seed spices produced in India are coriander, cumin, fenugreek and fennel. The minor seed spices are ajwain, celery, dill, nigella, caraway, etc. It is observed that about 70% of the total trade in spice consists of whole spices. The rest is made up by spice oleoresins and oils, curry powder, ground spices and spice mixes in bulk as well as consumer packs. The consumption of spices is increasing steadily with the improvement in living standard of the countries all over the world. Since the seed spices are vital adjuncts to food and drugs, the quality and purity have to be of the highest level and production/ processing cost to be lowest. Keeping in view importance and value of seed spices, it is necessary to process these spices in to novel value added products.

Dill (*Anethum graveolens)*, fennel (*Foeniculum vulgare*) and coriander (*Coriandrum sativum*) are important seed spices of India. These have pleasant, aromatic and spicy flavor and hence used widely in culinary and medicinal purposes since time immemorial. The spices possess rich amounts of fibre, vitamins, minerals and phenolics. These spices act as antioxidants and increase the flavour and storability of the products.They also exhibit antimicrobial properties with carminative effect and aid digestion through the stimulation of appetite (Griffin,1992). Dill is used for some gastrointestinal ailments such as flatulence, indigestion, stomachache and colic. The fruit has an antispasmodic effect on the smooth muscle of the gastrointestinal tract with regard to central nervous system. Dill has been used to alleviate tiredness from disturbed nights and strengthen brain. (Heamalatha *et al.,* 2011). Fennel seeds are used as anti-inflammatory, analgesic, carminative, diuretic and antispasmodic agents (Farooq *et al*., 2009). Coriander has been reported to have a number of possible medicinal attributes including antispasmodic, carminative and stomachic properties. Additionally, coriander has been advocated as an anti-diabetic remedy. It is also helpful in reducing level of cholesterol by stimulating bile forming function of liver (Dhanapakiam *et al.,* 2008).

Spice seed extract alone may not suitable for beverage preparation due to lack of any pulp or juice in it that can provide body to the product. Hence, there appears a need for addition of some base material in the form of pulp or juice of any fruit. However, most fruit juices have taste and flavor of their own and therefore are not suitable for selection as base material since they can interfere taste and flavor of spice seeds in the product. Aonla (*Emblica officinalis*) juice could be an ideal base material for this purpose. It is more preferable due to its inert sensory properties especially absence of any color and flavor. Moreover, it can further add nutraceutical properties to the product as aonla is a rich source of vitamin-C and polyphenols.

In the present investigation, squashes from spice seeds, viz., dill, fennel and coriander were prepared using aonla juice as base material.

MATERIALS AND METHODS

Seed spices were cleaned and washed gently in tap water to remove adhered dust. These were dried under sun and ground coarsely in mixie grinder. The spice seed powder @ 5 per cent of the product to be prepared was soaked in four times of clean water for one hour and filtered through muslin cloth with gentle squeezing to obtain water extract. Healthy aonla fruits were washed thoroughly in tap water and crushed in fruit mill to obtain coarse pulp. The pulp was then wrapped in thick cloth and subjected to a pressure of 1500-2000 kg / square inch in a hydraulic press to obtain clear aonla juice. The collected juice was pasteurized at 90^0C for 1 minute and used as base material for seed spice extract.A syrup was prepared by heating a mixture of 60 per cent refined sugar and 20 per cent aonla juice in water using a stainless steel container. As soon as syrup starts boiling, spice extract was added to it and continued heating for further two minutes. The container was removed from flame and syrup cooled down slightly. It was then added with calculated amount of citric acid to achieve final acidity of the squash at 1.1 per cent. The product was preserved with addition of 0.5 per cent potassium metabisulphite and filled hot in clean, pre-sterilized glass bottles. The crown corked bottles were stored at low temperature (10±2^{o}C) for one year.

The prepared squashes were analyzed at different intervals for various biochemical and sensory parameters. The total soluble solids of beverages were recorded by using hand refractometer (Erma, Japan). Titratable acidity, ascorbic acid and total phenolics were determined as per the methods described by Ranganna (2000). Ascorbic acid content of beverage was measured by titrating samples against dye (2, 6-dichloro phenol indophenol) solution, while total phenolics were estimated spectrophotometrically using Folin-Ciocalteau's reagent.The types of phenolic compounds present in seed spice squashes were identified by High Performance Liquid Chromatography (HPLC) using protocol of Basha *et al.*, 2004. The reducing sugars were determined by Folin and Wu method while total antioxidants by FRAP method developed by Benzie and Strain. The microbial examination of beverage was carried out as per method detailed by Speck. The organoleptic evaluation of beverage was carried out on the basis of colour, acidity, aroma and taste by a panel of semi-skilled .,1965, using a 9-point Hedonic scale as prescribed by Amerine *et al,* (1965). The experiment was laid out in a Completely Randomized Design (CRD) along with three replicates for each treatment. The data was analyzed statistically using software OPSTAT developed by OP Sheoran of CCSHAU, Hisar, India.

RESULTS AND DISCUSSION

The total soluble solids of squashes ranged between 50 to 56 ^{o}B initially, which increased slightly or moderately during storage (Table 1). Break down of insoluble solid compounds in to soluble forms is attributed to increase in TSS of squashes. Addition of spices resulted into increase in the total acidity of the product to the range of 1.52-1.96 per cent. Acids present in the spices might impart such increase. During storage, a sharp decline was observed in the acid content of the product up to six months of storage when it came down to 0.92 per cent in all the sample (Table 1). Rapid break down of acidic compounds of squash might be responsible for this decrease. The ascorbic acid content was highest (73.3 mg/100 ml) in coriander squash, while minimum (63.1 mg/100 ml) in dill squash. There was a regular decrease in ascorbic acid content during storage (Fig. 1). This reduction might be due to oxidation of asco acid into dehydroascorbic acid by oxygen (Sethi *et al.,*1980). Coriander squash contained maximum phenolics (735 mg/100 ml), followed by dill (685 mg/100 ml) and fennel (679 mg/100 ml) squash. The values decreased continuously till the end of storage (Fig. 3). HPLC analysis revealed presence of gallic acid (0.1-0.5 mg/100 ml), catechin (0.15-2.0 mg/100 ml), epi-catechin (0.1-2.0 mg/100 ml), caffeic acid (0.05-1.0 mg/100 ml), p-coumeric acid (0.01-0.5 mg/100 ml) and kaempferol (0.05-1.5 mg/100 ml) as the major phenolics in spice seed squashes. Initially, reducing sugar content was around 13 per cent in all the samples. It increased with the period of storage to reach a value of around 24 per cent after 12 months of storage (Fig. 4). The increase is attributable to the hydrolysis of sucrose in glucose and fructose by the acid present in the beverages (Garg *et al*., 2012) or gradual inversion of non-reducing sugars into reducing sugars in acidic medium (Malav et al., 2014). All three squashes were found to be highly acceptable during sensory evaluation based on colour, flavor and taste. The samples obtained scores between 7.5

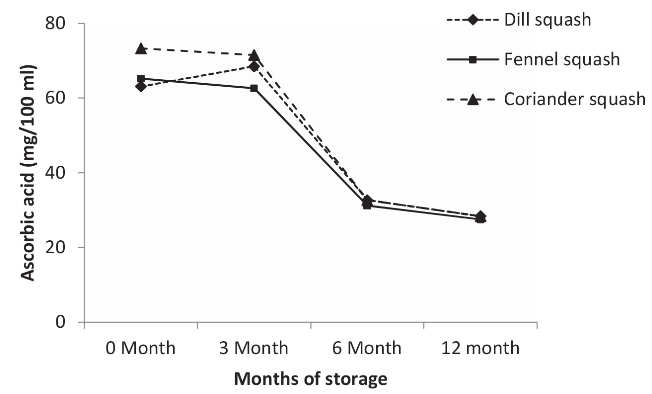
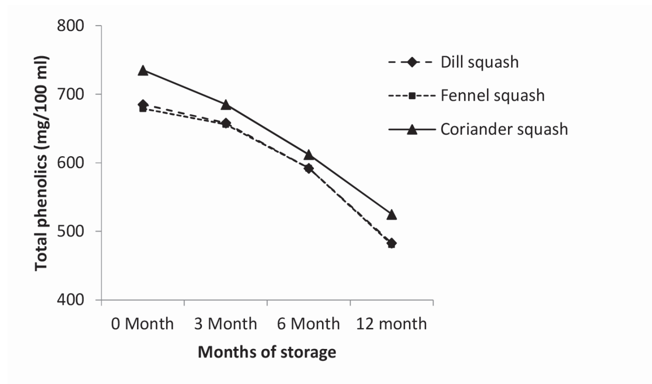
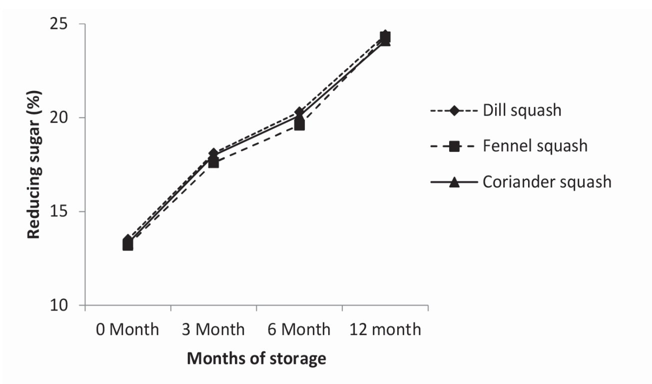


Fig. 1: Changes in ascorbic acid content of aonla based spice seed squashes during storage



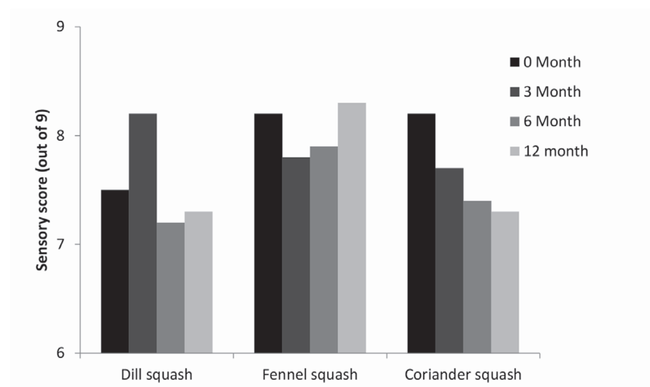
[CD at 5% : Treatment (T) : 12.903 Period (P) : 14.899 T X P : 25.807]

Fig. 2: Changes in total phenolic content of aonla based spice seed squashes during storage



[CD at 5% : Treatment (T) : 0.354 Period (P) : 0.408 T X P : 0.707]

Fig. 3: Changes in reducing sugar content of aonla based spice seed squashes during storage



[CD at 5% : Treatment (T) : NS Period (P) : 0.455 T X P : NS]

Fig. 4: Changes in sensory scores of aonla based spice seed squashes during storage

to 8.2 out of 9 at zero day. During storage, sensory scores of the product exhibited though no specific trend, achieved good acceptable level every time. Samples obtained 7.3-8.3 scores after 12 months of storage. All the samples were found to be free from any microbial contamination during storage. All the squashes prepared have the medicinal properties of respective seed spice. Dill seed oil contains medicinally important monoterpenes viz. carvone and limonene as main constituents (Meena et al., 2019). Dill squash samples were found to contain 70 mg/100 ml carvone and 15 mg/100 ml limonene. The aromatic property of fennel is because of the essence. There are more than 30 types of terpene compounds in the essential oil of fennel, the most important of them are transanethole, fenshon and limonene (Kooti et al., 2015). Fennel squash samples had 40 mg/100 ml transanethole, 1.0 mg/100 ml fenshon and 2.5 mg/100 ml limonene. The volatile oil of coriander is rich in beneficial phytonutrients, including carvone, geraniol, limonene, borneol, camphor, elemol and linalool (Rajehwari and Andallu,2015). Coriander squash was found to have 0.35 mg/100 ml geraniol,1.2 mg/100 ml camphor and 21 mg/100 ml linalool.

Table 1: Changes in TSS and titratable acidity of aonla based seed spice squashes during storage

	TSS (° Brix)			
Sample	0 Month	3 Month	6 Month	12 month
Dill squash	54.5	54.0	55.0	55.0
Fennel squash	50.0	50.5	52.5	52.3
Coriander squash	56.0	56.0	57.5	57.7
[CD at 5% : Treatment (T) : 0.232 Period (P) : 0.267 T X P : 0.463]				
	Titratable acidity (%)			
Dill squash	1.72	1.45	0.92	0.93
Fennel squash	1.52	1.09	0.92	0.97
Coriander squash	1.96	1.16	0.92	0.93

[CD at 5% : Treatment (T) : 0.020 Period (P) : 0.023 T X P : 0.040]

It may, therefore, be inferred from the data that good quality of squashes could be prepared from spice seeds viz. dill, fennel and coriander using aonla juice as base material. The product could be stored for one year at low temperature without any microbial spoilage and with least deterioration in the quality.

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Research Article

Identification of CMS-S male-sterile cytoplasm among the bunching onion (*Allium fistulosum* L.) collections

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ABSTRACT

The bunching onion (*Allium fistulosum* L.) species collections were assessed for identification of male-sterile trait among the germplasm, as a resultant identified a male sterile line, phenotypically and which was confirmed by the *orf725* gene and *orf501* gene-specific markers conferred linkage for male sterility cytoplasm of S and normal (N) cytoplasm. The manifestation of the male-sterile trait in bunching onion genotypes could be attributed to the *ms* genes expression. Phenotypically male-sterile plants produce flowers, does produce pollen grains which were lacking in the anthers. The anthers are slightly green at an immature stage, and yellowish trans-lucent at the mature stage, without pollen grains spores inside the anther sac, matured anthers were shrivelled, empty and fused anther sacs. Soon, the male-sterile line will be used as parental material in hybridization for heterosis breeding to boost bunching onion.

Keywords: Bunching onion; Male sterility; *orf725*; *orf501*; S/N cytoplasm; Heterosis

INTRODUCTION

Bunching onion (*Allium fistulosum* L.) commonly named Welsh onion, the term comes from the German language *welsche*, means foreign (Inden and Asahira, 1990). It fits to section *Cepa* of genus *Allium* of the family *Alliaceae.* It is a popular condiment having properties such as hunger stimulation, better digestion, and antimicrobial capabilities. It is also resistant to diseases such as *Fusarium* basal rot, onion leaf blight, and pink root disease; hence it is a valuable genetic resource (Ohara *et al.*, 2005; Yamashita, Takatori and Tashiro, 2005). The European countries have more demand for Welsh onion since it is a little-known Far Eastern vegetable. As a result, producers may be inquiring more about commercial production from the research experts for breeding directions and major plant breeding activities (Padula, Xia and Ho³ubowicz, 2022).

In *Allium*, by the establishment of CMS-S male sterility system, hybrid seed production of common onion has first been commercially feasible (Jones, 1936; JONES, 1943; Jones and Mann, 1963), CMS-T (Berninger, 1965; Schweisguth, 1973), CMS*ga* cytoplasm from *A. galanthum* species (Havey, 1999). The CMS*ga* cytoplasm was introduced into the bunching onion by continuous backcrosses and cytoplasm cause male sterility in bunching onion (Yamashita, Arita and Tashiro, 1999; Yamashita *et al.*, 2010). Despite of CMS importance in breeding of bunching onions, genetic studies elucidating its male sterility cytoplasms identification and their diversification among the breeding populations are limited. Interspecific hybridization to introduce alien cytoplasm into bunching onions is time-consuming and labour-intensive; but by the utilization of molecular methods, identifying innate male-sterile plants in open-pollinated populations could be simple.

CMS systems are employed to develop hybrid seeds in a cost-effective manner; in the bunching onions, CMS is an essential feature for future F_1 hybrid seed production. The identification, introduction and introgression of various CMS cytoplasms to increase cytoplasmic diversity across genotypes has the potential value to minimize vulnerability to cytoplasm-specific diseases (Yamashita *et al.*, 2010). A male-sterile plant was obtained in the "Zhang Qiu" cultivar (*A. fistulosum* L. var. *giganteum*), in which the stamens of the male-sterile plants were abortive and completely sterile. Their filaments were shorter than those of normal plants and could be easily distinguished. A part formed complete male sterile plants, there were a few semi-male sterile plants (Qipei, Youying and Qi, 1987). Several bunching onion accessions (135) was evaluated to identify CMS resources, male-sterile plants among the accessions ranged from 1.7 to 24.5%, and microscopic analysis of CMS plants microspores revealed the degradation of microspores without mitotic division, confirming male sterility (Yamashita *et al.*, 2010).

Open-pollinated cultivars are primarily in normal (N) fertile cytoplasm; certain cultivars either possess both N and sterile (S) cytoplasm, or exclusively S cytoplasm (Havey and Bark, 1994). S-cytoplasm is an alien cytoplasm witnessed in onion (Havey, 1993), it is the most common source of cytoplasmic-genic male sterility (CMS), identification of the cytoplasm from 4 to 8 years phenotypically based on the segregation pattern. Thus, molecular characterization of N- and S-cytoplasms by polymerase chain reaction is way ahead to confirm the cytoplasmic male sterility within a cropping season, thus significantly reducing the investment and time required to identify male sterile plants in any population (Havey, 1995). The chimeric gene *orf*725 has a sequence of *cox*I gene (52 end) with *orf*A501 (32 end), it could able to distinguish normal cytoplasm, CMS-S and CMS-T types. As a result, a molecular marker based on *orf*725 and *cox*I gene was developed to segregate three cytoplasmic loci in simple PCR (Kim *et al.*, 2009).

Male-sterile and maintainer lines of Welsh onion were compared for polymorphism between S and N cytoplasm by RAPD (S13_2800 and S200_2400) technique, and they were confirmed linking to sterility and fertility through individual identification, which was useful in marker-assisted selection (Shupeng, Xiangdong and Lijuan, 2004). The practicability and productivity of utilizing marker-assisted selection for male-sterile lines in Welsh onion could distinguish between N and S cytoplasm in between and among welsh onion cultivars. It showed that the cytoplasmic markers could precisely identify cytoplasmic types individually, performed by one generation of a cross and two generations of test crosses and self-crosses, markers could assist and accelerate sterile and maintainer lines selection with less labour and cost (Gai and Meng, 2010).

Cytoplasmic male sterility exists widely in most natural populations of welsh onion, which makes it possible to breed out many male sterile lines for heterosis utilization. Unfortunately, the breeding of cytoplasmic male sterility in welsh onion has little progress due to the limitation of its biological characteristic and traditional selection approach (Gai and Meng, 2010). CMS mainly exploited heterosis several vegetable crops, but exploitation of CMS system remains lacking in the Welsh onion (Liu *et al.*, 2016). Hence, the study was carried out to identification of male sterility in Welsh onion for the exploitation of heterosis for foliage yield.

MATERIALS AND METHODS

Germplasm materials

The experimental materials of *Allium fistulosum* L. species collection were maintained in the germplasm maintenance block, as active germplasms, these species are perennial; the passport data has been presented in Table 2. The germplasm was examined for male sterility traits during the flowering *rabi* season of the year 2020-21.

Screening of genotypes for phenotypic male-sterile trait

Flowers in the umbel were phenotypically tested using clear black tuff paper cards, with each card rubbing against the individual umbel of the plant for pollen adherence. Fertile pollen clung to the card and could be seen with the naked eye in case of fertile, whereas no pollen clung seen in male-sterile plant flowers swabs cards (Manjunathagowda and Anjanappa, 2020).

Screening of genotypes with molecular markers

The genomic DNA of bunching onion plants was extracted from fresh tissues of leaves CTAB method (Murray and Thompson, 1980) with slight modifications. PCR was performed in a 10 µL reaction mixture containing DNA 0.05 µg as a template, 10× PCR buffer of 1 µL, 0.2 µL each forward and reverse primer, and dNTPs (10 mM each), and *Taq* polymerase of 0.1 µL. the thermal cycle was with an initial denaturation at 94°C for 5 min, then 40 cycles of 94 °C for 30 sec, 65°C for 30 sec, and 72 °C for 90 sec, and final 10 min extension at 72°C for *orf*725 marker(Kim *et al.*, 2009), and *orf*501 marker (Engelke, Terefe and Tatlioglu, 2003) and PCR product was visualized at one per cent agarose gel with 1kb plus DNA ladder.

RESULTS AND DISCUSSION

Identification of male-sterile plant phenotypically and their characterization

Bunching onion collections were examined for male sterility trait, in which flowers in the umbel were phenotypically tested using clear black tuff paper cards, with each card rubbing against the individual umbel of the plant, in the case of male fertile plants the pollen grains have adhered to the black card, whereas in the male-sterile plant did not find any pollen grains clung on black card. The pollen clung to the card could be seen with the naked eye for the confirmation of male fertility. Pollen clung was subjected for pollen viability assay by acetocarmine dye, with colored pollen being fertile, whereas in incase of male-sterile plant pollen was absent.

Table 1: Gene specific markers used for the confirmation of cytoplasm among the Bunching onions.

Genes	Marker name	Primer Sequence	Cytoplasm	Amplicons	Reference
*orf*725 gene +*cox*I gene	MK-F	CATAGGCGGGCTCACAGGAATA	CMS-S	C" 600 bp	(Kim *et al.*, 2009)
	MK-R1	AATCCTAGTGTCCGGGGTTTCT			
*cox*I gene	MK-F	CATAGGCGGGCTCACAGGAATA	Normal (N)	C" 850 bp	
	MK-R2	CAGCGAACTTTCATTCTTTCGC			
*orf*A501 gene	*orf*A501-F	ATGGCTCGCCTTGAAAGAGAGC	CMS-S	C"500 bp + C"300 bp	(Engelke and Tatlioglu, 2002)
	*orf*A501-R	CCAAGCATTTGGCGCTGAC			

Table 2: Source of collection with passport data of Bunching onions

Genotype	Accessions / Germplasm lines	Source	Flowering	Growth	Status	Bulbing
Allium fistulosum L.	EC328491, Russian line	NBPGR, New Delhi	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	CGN16418, Greece-Netherland line	NBPGR, New Delhi	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Taiwan line - 1	WVC, Taiwan	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Open pollinated population - 5	DOGR, Pune	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	EC461748	NBPGR, New Delhi	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Open pollinated population - 4	DOGR, Pune	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	EC321643	NBPGR, New Delhi	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Open pollinated population - 3	DOGR, Pune	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	NGB14619	NGRC, Nordgen, Sweden	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Taiwan line - 2	WVC, Taiwan	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	All-646	NBPGR, New Delhi	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Open pollinated population - 1	DOGR, Pune	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	All-750	Georgia, Germany	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	Open pollinated population - 2	DOGR, Pune	Rabi	Perennial	Wild	No bulb
Allium fistulosum L.	EC609483	NBPGR, New Delhi	Rabi	Perennial	Wild	No bulb

The male fertile plants produce inflorescence umbel with prominent anther in the flower (Figure 1), at immature stage anther were light green yellowish, as on maturity of anthers, turn to the bright yellow color, the matured anther filled with powdery and dusty pollen grains, usually feel by hand by finger touch. Male sterile flower anthers are yellowish-green when immature, but turn brown as they mature, resulting in visually deformed, shriveled, irregularly shaped, brown colored anthers that lack pollen grains when felt by hand as well as on black card; the anthers are viewed as empty without pollen grains in the anther sac, and the anther sac was fused without pollen grains (Figure 1).

Identification of male-sterile traits using orf725 and orf501 gene-based markers

The genomic DNA of bunching onion collections were subjected for molecular markers *orf*725 gene and *orfA*501 gene markers linked to the cytoplasm to confirm the cytoplasm responsible for the induction of male sterility (Table 1). The markers were distinguished the male-sterile cytoplasm namely CMS–S from normal (N) cytoplasm, and the identified lines were regarded to be the CMS-S cytoplasm in *Allium fistulosum* species, *orf*725 gene marker amplification was noted C"600 bp and *orfA*501 gene marker was amplified at 500 bp and 300 bp in the species *Allium fistulosum* species population-3 maintained by open-pollinated, whereas other species were amplified at C"850 bp were found have normal (N) cytoplasm in *Allium fistulosum* species, the marker validated results are presented in Figure 2.

DISCUSSION

Male sterility and fertility were assessed by physically flicking their inflorescences and observing anther morphology, colour, shape and pollen shedding, as well as pollen stainability of male sterile and male fertile plants, was followed to confirm male sterility in Bunching onion. Male sterile plants have pale yellow anthers that were slenderer than the anthers from the male fertile plants (Yamashita *et al.*, 2010). Anthers are translucent and light green (Pathak, 1994), Anthers were shriveled in the male-sterile plant of onion (Manjunathagowda and Anjanappa, 2020; Manjunathagowda *et al.*, 2021). The anthers were empty, fused in the anther sacs (Manjunathagowda and Anjanappa, 2020). Similarly, in the finding, the male-sterile plant produced flowers were brown-yellowish deformed, shriveled, irregularly shaped anthers that lack pollen grains (Figure 1).

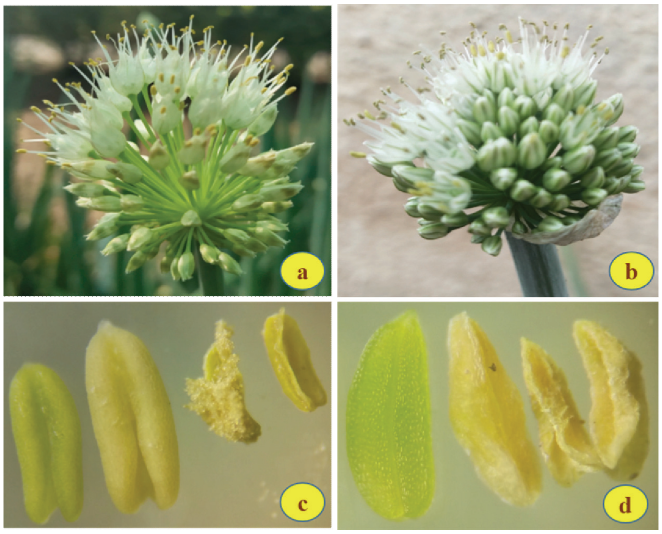

Fig. 1: Male fertile and male sterile phenotypes of Bunching onions

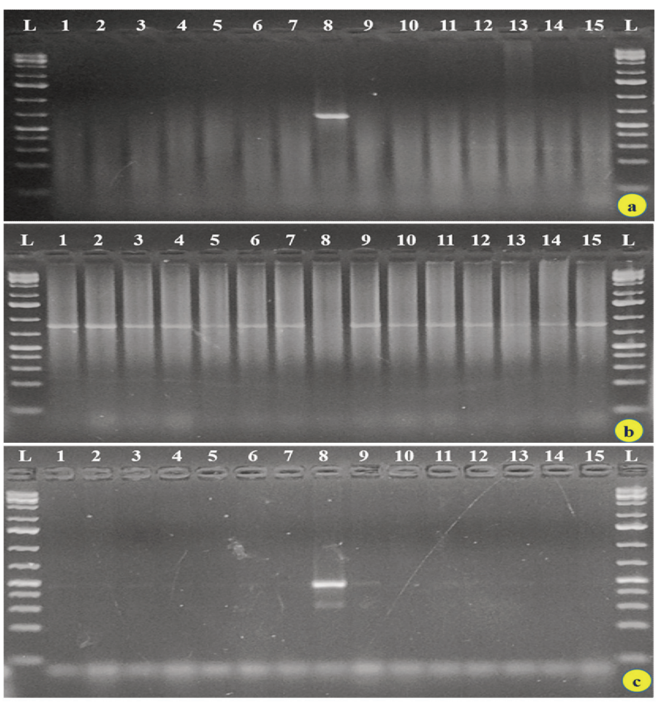

Fig. 2: Marker assisted selection of cytoplasm using gene specific markers and confirmation of cytoplasm among the Bunching onions, a) *orf*725 and *cox*I based genotyping to confirm the CMS-S cytoplasm, b) *cox*I gene specific marker genotyping for Normal (N) cytoplasm confirmation, c) *orf*501 gene marker amplification to confirm CMS-S cytoplasm

The potential of markers to differentiate cytoplasms was proven in the research among bunching onions to corroborate the male sterility inducing cytoplasm linked marker. The genes specific markers to the CMS-S and the N cytoplasm in simple PCR reactions could easily distinguish S and N cytoplasm across the populations (Figure 2).

A unique chimeric gene with a 52 end of *cox*I gene sequence and a 32 end with *orfA*501 gene sequence of chive was obtained and designated as *orf*725 gene, the marker could distinguish the three cytoplasm types among the onion populations by a simple PCR, it could be due to the *orf*725 and *cox*I genes different stoichiometry among three cytoplasmic onion plants (Kim *et al.*, 2009). The marker is effectively used in *Allium cepa* for genotyping of the onion population for identification CMS-S and normal (N) cytoplasm (Manjunathagowda and Anjanappa, 2020). The marker has been deployed among the Bunching onion (*A. fistulosum* L.) population, it could easily be transferred among the tested population, and aid in the isolation of CMS-S and normal (N) cytoplasms among *A. fistulosum* species (Figure 2). It is the most reliable and economically feasible marker for genotyping of the population for the identification of cytoplasms (S/T/N), this marker will be a potential marker in the marker-assisted selection of cytoplasm in the onion breeding program.

An insertion consisting of one *atp6* homologous potion and one part of unknown origin, which was selectively amplified in the sterility inducing cytoplasm of CMS_1, was interrupted by an *atp9* homologous section on its end. As a result, it was used to differentiate CMS_1 cytoplasm type from the other cytoplasm types found in chives. The chimerical marker sequence generates a hypothetical open reading frame of 501 bp, which will be called *orfA*501, and from which CMS_1 may have originated (Engelke and Tatlioglu, 2002). The chimerical mitochondrial (CMS_1-specific) sequence of *Allium schoenoprasum* was employed and developed simple PCR based marker using *the orf*501 gene, and it could distinguish cytoplasms (CMS-S/T and N), male-sterile phenotypes from the male fertile phenotypes in *A. cepa* (Engelke, Terefe and Tatlioglu, 2003). Hence, the same marker was used in the study, the marker can transfer among *A. fistulosum,* and the marker could be able to differentiate among the male fertile and male-sterile phenotypes (Figure 2).

The combination of both primer systems allows differentiating of the cytoplasm types. The CMS-S cytoplasm is characterized by the amplification at C”600 bp and C”850 bp in normal (N) cytoplasm by *orf*725 marker, and 500 bp and 300 bp fragment of the *orfA*501 marker, whereas the same marker had failed to amplify from other than CMS-S cytoplasmic plants. Thus, these markers could be potential markers for the identification of CMS-S cytoplasm among Bunching onions.

CONCLUSION

The identification of male sterile lines in bunching onion could aid in the heterosis breeding for the improvement of yield, the new sterile lines could aid to reduce the efforts and complexity in crossing and breeding programme. The male sterility inducing cytoplasms identified by the PCR markers (*orf*725 and *orfA*501) among the diverse populations, the confirmed CMS plants used in the future breeding for the development of F_1 hybrids of bunching onions and the marker system might help to check on the F1-hybrid character of varieties. Furthermore, the identification of the cytoplasm type also helps to classify the genetic nature of sterile plants, which spontaneously occur in open-pollinated varieties. It was interesting to note that the marker of *orf*725 and *orfA*501 genes were transferred in Bunching onions (*Allium fistulosum* L.), where *orfA*501 gene marker was developed to amplify in CMS_1 in chives (*A. schenoprasum* L.), and *orf*725 gene marker was developed to confirmed cytoplasms of S/T/N in the onion (*A. cepa* L.).

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Research Article

Seasonal variations for oil content and fatty acid composition in oil palm hybrids

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ABSTRACT

Oil content and fatty acid composition in three different sources of oil palm hybrids *viz*., Malaysia, Deli x Ghana and Deli x Nigeria were analyzed during two seasons,rainyand summer. Seasonal variations in fruit weights (4.9 – 13.6 g), oil content (69.3 – 81 %) and moisture (30.2–43.9%) were observed among hybrids. The fruit weight and mesocarp contents were higher in all the hybrids during summer compared to that of rainy months, while oil content was high during rainy months in the oil palm hybrids studied. The oil to dry mesocarp content was high in Deli x Ghana hybrid followed by Malaysian and Deli x Nigeria hybrid sources. Saturated fatty acids like myristic acid (0.67 – 1.32 %) and palmitic acid (41.9 – 49.6 %) showed higher levels during summer season, while stearic acid (3.67 – 4.86 %) increased during rainy season. Palmitic acid levels were high in oil palm hybrids belonging to Malaysian source followed by Deli x Nigeria and Deli x Ghana sources. Unsaturated fatty acids like oleic (36.5 – 44.1 %), linoleic (5.58 – 8.57 %) and linolenic (0.22 – 0.56 %) increased during summer and decreased during rainy months. Oleic acid levels were high in oil palm hybrids belonging to Malaysian source followed by Deli x Ghana and Deli x Nigeria sources. The study confirms that oil content and fatty acid composition is influenced by temperature and rainfall during rainy and summer months.

Keywords: Fatty acid composition, mesocarp oil, moisture, monounsaturated fatty acids (MUFA), oil palm, poly-unsaturated fatty acids (PUFA), saturated fatty acids (SFA).

INTRODUCTION

The demand for vegetable oil is increasing at a rapid pace in India due to increased per capita consumption and growing population. A huge gap of 15.20 million tonnes exists between the demand and supply of vegetable oils, necessitating imports that constitute almost three-fourths of consumption. Oil palm (*Elaeis guineensis*Jacq.), a perennial crop with a production potential of 6-8 tonnes of oil/ha/year could play a critical role in meeting the vegetable oil requirements in India. Different committees constituted by Indian Council of Agricultural Research and Department of Agriculture and Farmers welfare, Government of India have identified potential area of 2.80 million ha in 22 Indian Provinces and an area of 4.30 lakh ha has been brought under oil palm cultivation till date (ICAR/DAC&FW Report, 2020).

The fruit development in oil palm is known to be influenced by genetic and environmental factors. Fruit development starts approximately two weeks after anthesis (WAA) and oil deposition in endosperm is almost completed by 16 WAA (Oo*et al.,* 1984, Suresh and Behera, 2020; Suresh *et al*., 2021). The performance of palm oil can be accessed on the basis of oil producing capacity of the palm. After the sterilization of bunches, fruits are stripped off and crude oil palm is generally extracted through a screw press. Regarding environmental factors, water deficits in oil palm causes early closure of stomata, which decreases photosynthesis leading to decreased yields (Suresh and Nagamani 2006, Suresh *et al*. 2010). Breeders aim to select good dura palms for developing high yielding tenera varieties with the main objective to increase unsaturated fatty acid content of oil palm (Arasu *et al*., 1987).

Among all the palm oil products, crude palm oil and refined palm oil are the most commonly traded commodities (Nursulihatimarsyila *et al*., 2012). Chow and Ho (2002) studied the chemical composition of oil droplets of palm sludge oil and reported that composition of major lipids of palm sludge oil is similar to that of commercial palm oil. Palm oil is cholesterol and trans-fat free. It is composed mainly of triglycerides of fatty acid with a balanced composition of saturated and un-saturated fatty acids which are classified as saturated (SFA), monounsaturated (MUFA) and poly-unsaturated (PUFA) fatty acids. The glycerol molecules in triacylglycerols are esterified with fatty acids. Unsaturated fatty acids have a lower melting point compared to that of SFAs of similar chain length (Chayanoot *et al*., 2005). Palm oil rich in oleic, palmitic and lauric acids are considered as high quality raw material, which is used for biodiesel and cooking oil (Bamgboye and Hansen, 2008). During fruit ripening process, bunch maturity and palm oil development are the correct indicesfor monitoring harvest time and recommendation to evaluate the palm oil performance in food industries (Suresh *et al*., 2021; Suresh and Behera, 2020). It is rich in Vitamin E (Tocopherol and Tocotrienol) and pro-vitamin A (β-carotene), which acts as powerful antioxidants (Corley and Tinker, 2003).

As there has been limited study on this aspect under irrigated conditions, the present study was undertaken to understand the variations in oil content and fatty acid composition in three commercially grown tenera oil palm hybrids grown in India during rainy and summer months.

MATERIALS AND METHODS

Three adult oil palm tenera hybrids *viz*., Malaysia, Deli x Ghana and Deli x Nigeria planted at ICAR-Indian Institute of Oil Palm Research, Pedavegi, West Godavari district, Andhra Pradesh, India were taken up for the present study. Pedavegi is located at 16°8'N, 81°11'E with a mean sea level of 13.4 m. Standard agronomical practices were followed. The fruitlets were collected during the final weeks of bunch maturity during rainy (August-October) and summer (March-May) seasons at which higher percentage of oil was reached and they were analyzed for fatty acid composition.Simultaneously, weather parameters such as temperature, rainfall and humidity were recorded from nearly located automatic weather station.

Table 1: Accumulated rainfall and temperature (6 months before harvesting) during rainy and summer seasons

Season	Harvested months	Accumulated rainfall (mm)	Accumulated temperature (°C)
	August	151.8	5796
Rainy	September	206.3	5814
	October	106.0	5832
	Mean	154.7	5814
	SD	50.2	18.0
	March	0	6138
Summer	April	26.5	6444
	May	6.0	7038
	Mean	10.8	6534
	SD	13.9	457.6

The mean temperature (°C) recorded during summer and rainy season was 36.3 and 32.3 respectively. The average rainfall (mm) recorded during summer and rainy season was 10.8 and 154.7 respectively.The accumulated rainfall and temperature within 6 months before harvesting of both seasons were calculated for studying its relationship with fruit weight, oil yield and fatty acid composition in different hybrids (Table 1).

Oil and moisture percentage in mesocarp

Few fruits from fully matured bunches were collected randomly and were scrapped and dried in oven over night at 105 °C or in a microwave oven (Yanez*et al*., 2000). The samples were packed in whattman filter paper thimbles and weighed. The oil content was estimated in dry mesocarp samples by using petroleum ether at 60-80 °C in a soxhlet extractor according to Blaak (1963).Oil percentage in dry mesocarp samples were analyzed based on oil to dry mesocarp ratio (Said *et al*., 1983). For estimating moisture content, the fruitlets were scrapped and oven dried over night at 105 °C until they attained constant weight. By taking the initial and final weight of mesocarp,moisture content present in mesocarpwas estimated. Triplicates of samples were taken to minimize the sample error.

Fatty acid composition

Oil was converted to fatty acid methyl esters (FAME) by adding 5 ml of sodium methoxide (0.1N in methanol)for analyzing fatty acid composition as per Morrison and Smith, (1964). The aqueous layer was collected and was directly injected (1 µl) into a gas chromatography (Model GC 17A, Shimadzu Corporation, Kyoto, Japan). It was equipped with flame ionization detector (FID) and a polar capillary column BPX 70 (60m x 0.25 mm x 0.25 µm). The column, injector and detector (FID) were set at 180, 230 and 25 °C. Column flow was kept at 1.5 ml min^{-1}.

Few fruits from fully matured bunches were collected randomly to estimate the fatty acid composition. After the moisture estimation, mesocarp sample was dried and powdered. Approximately 500 mg sample was ground in mortar and pestle, derivatized to methyl ester by adding 0.5N sodium methoxide solution and transferred it into screw capped boiling tubes and incubated for about 10 – 15 min in a water bath at 60-70°C. The sample was allowed to cool and 2-3 drops of BF_3 (Boron tri fluoride) was added as a catalyst and incubated for 5 min in water bath at 60 - 70°C. Fatty acid methyl esters were later extracted by adding 1 ml of hexane to form a hexane layer at the top. The upper transparent layer was pipetted out into microfuge tube and anhydrous sodium sulphate was added to remove moisture present in sample. Sample was later transferred into another microfuge tube leaving anhydrous sodium sulphate. Finally the solution obtained was injected (1µl) with the help of syringe through injector port for analyzing fatty acid composition. Standards under similar conditions as that of fatty acid methyl esters were identified by means of their retention times. The samples were compared with those of standard fatty acid methyl esters purchased from Sigma-Aldrich Chemicals Pvt. Ltd., India.

RESULTS AND DISCUSSION

The fruit weight in three oil palm hybrids ranged from 4.9 to 13.6 g.The highest fruit weight was recorded in Malaysian hybrid source, while lowest content was in Deli x Nigeria during both the seasons (Table 2). In all the three hybrids, highest fruit weights were attained in bunches harvested during summer and decreased during rainy months. Fruits per bunch showed positive correlation with hours of sunshine and a negative correlation with high precipitation received five or six months prior to harvest (Alvarado and Sterling, 1998). Bunches developed during rainy season are likely to be exposed to more precipitation resulting in poor fruit set and development,where as bunches that developed during summer are exposed to low precipitation thus have better fruit setting and development (Mhanhmad *et al*., 2011). Fruit to fruit variability was also observed in all the hybrids under study. However, the maximum fruit weight was attained during summermonths.

The oil content in hybrids ranged from 69.3 to 81.0 % and highest content was recorded in Deli x Ghana hybrid, while lower values were observed in Deli x Nigeria in both seasons (Table 2). The main difference observed was that, oil contents in all oil palm hybrids attained high levels during rainy season and lower values were observed during summer months. In Benin, Ochs and Daniel (1976) observed that oil to mesocarp tend to get decreased in bunches harvested two months after the period of greatest moisture deficit. Moisture percentage in fruitlets ranged from 30.2 to 43.9 % and highest moisture content was found in Deli x Nigeria hybrid and lowest in Deli x Ghana (Table 2), which confirm to the findings of Suresh *et al*. (2013) in another study. An inverse relationship was observed between oil content and moisture content among hybrids. Oil content in mesocarp is determined principally by degree of bunch ripeness and by other external factors related to hereditary variation caused by the genetic variation of the material planted, as well as by climatic factors like sunlight and water deficit in the weeks prior to bunch ripening (Siregar, 1976; Azis, 1985 and Henson, 1993).

Among the three saturated fatty acids (SFA), myristic and palmitic acids increased during summer season, while stearic acid increased during rainy months. Myristic acid in hybrids ranged from 0.67 to 1.32 % in which Deli x Ghana showed highest value during summer season while lower values were observed in Malaysian hybrid during rainy season (Table 3). Palmitic acid ranged from 41.9 to 49.6 % and Malaysian hybrid recorded highest and lowest contents during summerand rainyseasons. Stearic acid ranged from 3.67 to 4.86 % in which Deli x Ghana recorded highest content, while the lowest value was recorded in Malaysian hybrid.

Table 2: Seasonal variations in fruit weight (g), oil/dry mesocarp (%) and moisture in mesocarp (%) in oil palm hybrids

Parameter	Season	Oil palm hybrid sources		
		Malaysia	Deli X Ghana	Deli X Nigeria
Fruit weight	Rainy	9.8 ± 0.5	6.1 ± 4.9	4.9 ± 0.4
(g)	Summer	13.6 ± 1.6	8.9 ± 1.2	5.4 ± 2.1
Oil /dry mesocarp	Rainy	80.2 ± 3.0	81.0 ± 1.9	72.7 ± 2.2
(%)	Summer	73.7 ± 5.4	78.2 ± 2.4	69.3 ± 9.3
Mesocarp content	Rainy	32.9 ± 5.9	30.2 ± 1.2	35.2 ± 1.3
(%)	Summer	34.1 ± 2.3	31.2 ± 7.0	43.9 ± 2.4

Table 3: Fatty acid composition (FAC), % in mesocarp oil in oil palm hybrids during rainy and summer seasons

Fatty acid composition	Oil palm hybrid sources					
	Malaysia		Deli X Ghana		Deli X Nigeria	
	Rainy	Summer	Rainy	Summer	Rainy	Summer
Myristic (C14) %	0.67 ± 0.2	1.21 ± 0.2	0.95 ±0.4	1.32 ±0.2	0.84 ±0.3	0.89 ± 0.2
Palmitic (C16) %	41.94 ±1.0	49.63 ±2.4	44.37 ±5.1	48.37 ±5.7	43.64 ±5.3	44.42 ±3.2
Stearic (C18) %	4.37 ± 1.7	3.67 ± 1.8	4.86 ±0.8	4.39 ± 1.2	4.84 ± 1.2	4.32 ±0.9
Oleic (C18:1) %	44.10 ± 0.8	36.54 ± 3.1	40.88 ± 5.5	39.4 ± 6.4	42.19 ± 4.2	41.63 ± 4.0
Linoleic (C18:2) %	8.57 ± 1.4	8.13 ± 1.0	8.50 ± 1.2	6.20 ± 1.1	8.12 ± 2.5	5.58 ± 1.1
Linolenic (C18:3) %	0.35 ± 0.2	0.27 ± 0.1	0.56 ±0.1	0.22 ± 0.1	0.38 ± 0.2	0.34 ± 0.1

Unsaturated fatty acids like mono un saturated fatty acid (MUFA) and poly unsaturated fatty acid (PUFA) decreased during summer season and increased during rainy season. The range of oleic acid (MUFA), linoleic and linelonic acid (PUFA) was in the order of 36.54 to 44.1 %, 5.58 to 8.57 % and 0.22 to 0.56 %. The oleic acid content was highest and lowest in Malaysian hybrid and linelonic acid values were highest and lowest in Deli x Ghana during both seasons. Linoleic acid was highest in Malaysia during rainy season and lowest in Deli x Ghana during summer season. Similar results were obtained by Tang (2000), Sambanthamurthi*et al*. (2000) and Berger (1996). Oleic acid was the dominant unsaturated fatty acid presented in mesocarp,which conform to the results of Mhanhmad *et al*. (2011).

Before the maturity of fruit bunches in oil palm *i.e*., at the initial growth stages, temperature and rainfall do influence fatty acid composition or may be due to genetic differences. But there is no evidence that environmental factors affect oil composition in other crops, with more saturated fatty acids being produced at higher temperatures (Lehrian *et al*., 1980). According to Ekpa *et al*. (1994) seasonal variations in oil content of oil palm was observed regularly and revealed variations in fatty acid content. Similarly, Loncin and Jacobsberg (1963, 1965) found no differences of fatty acid composition between grove palms and plantation palms in Congo.

To conclude, oil palm tenera hybrids showed high response to accumulated rainfall and temperature in terms of oil yield and fatty acid composition during rainy and summer months. Based on the findings of our study, oil content and fatty acid compositions in oil palm are not only influenced genetically but also by environmental factors like temperature and rainfall. However, there may be some geographical differences also. This information on seasonal variations in oil content and fatty acid composition would be very useful to breeders for improving oil yield and oil quality in oil palm.

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Book Review

COUNSELING STUDENTS: Fundamentals and Skills for Improving Personality and Performance
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I am pleasantly happy.to review and write on book entitled **Counseling Students - Fundamental and Skills for Improving Personality and Performance**, written by Hon'ble Vice Chancellor, GBPUAT, Dr. Tej Partap, and Dr. M.S. Vignesh. I was keen to review their book because counseling has been my passion from very beginning of my career, which I applied, when I was the Dean of the prestigious GBPUAT, Pantnagar, in 2004-05, and continued as Vice Chancellor at RAU, Pusa, Bihar, and beyond. I continue to meet students, whenever I get an opportunity and use the word to make them cartelised in their mind for self realization through Indian philosophy. In my opinion, this book has given a thrust on counseling for developing personality with self realization. When I think of teacher, my mind reflects to Lord Krishna, whose, teaching made his student Arjun, to fight the battle, as his Karma. The teachers have to be like Krishna and provide tips to the student to be successful in the career and life, which is focused on fundamental of personality, communication and leadership. This book has also quoted verse of Gita and ancient literature. In most of education institutions, it is believed that teacher can be a counselor without training. This is misleading. This book in its first part has clearly explained the difference between counseling and guidance. Counseling catalyses the mind of the counselee to enable him take any decision independently. It is also to be noted that very few faculty will have clear notion that advice is not counseling and what is done in their institution by most of the faculty members. It is just advising students i.e. sharing/ dictating their view points. This book is written in two parts. Part-1 has seven chapters dealing with counseling of students, while Part-2 has nine chapters dealing with counseling eco-system, diversity, process and technique of counseling.

The reading of this makes us to believe that counseling has to be an essential part of educational institutions. There is a difference between guiding and counseling like difference between proficiency and efficiency. Proficiency refers to acquiring mastery over knowledge or subject, while, efficiency signifies application of such acquired knowledge into one's practical situation. Absence of efficiency and over emphasis on proficiency invariably results in the creation of dependent personalities. This is the present scenario that the current education system is experiencing. It has come to a situation that, Higher the degree of education greater the rate of dependency. There are bands of highly qualified and meritorious students with ninety plus percent marks, and desperately searching for jobs. Many of them are just prepared to accept whatever the profession is given to them. Current educational system, to a great extent, do not have inbuilt or structural mechanism to develop human personalities, an emphasis is primarily on intelligence. Even after a decade of schooling, majority of the students fail to identify their goals and destinations and this is called identity crisis. In fact when students experience conflict between their needs and goals, and these are not resolved to their satisfaction, they will then experience tension and anxiety. Thus the Holi Geeta says, do the duty honestly and leave the results on God and have no expectations. This relives from anxiety and tension.

While reading, it was observed that this book has attempted to address many issues about student counseling. The information compiled in this book is an excellent source of knowledge for professionals as well as non-professionals, who want to enhance their counseling capabilities so that, they can help others in their surroundings. The first part of the book provides a holistic view of the need and essence of counseling. It provides a basic framework for understanding the nature and scope of counseling and outlines practical aspects that can guide best counseling practices. It begins by describing the importance of educational counseling and exploring the needs and challenges faced by school and university-going students. The seven chapters under Part A 'Students counseling perspectives and issues' cover very crucial elements of students counseling, personality management, career counseling, motivation, stress management, parenting practices and building leadership qualities. This will not only help students but also provide a holistic approach to parents and mentors regarding concepts and approaches of student's counseling.

One of the biggest concerns and confusion in student life is about the right career choices. However, most educational institutions lack any system for providing such support to students. The fourth chapter of the book discusses the nature and scope of career counseling. It outlines a framework for creating career development guidelines and standards that can be used not only by professional counselors but also by teachers and professors to help students make the right career choices based on their aptitude, interests, and aspirations. A big challenge among many students is a lack of motivation and control of the mind. As a result, they lack pro-activeness, easily get discouraged by failures, and crumble under stressful situations in life. To help such students, it is essential to understand their personality traits and help them develop the right motivation and ability to control their minds. Discussions on motivational counseling and methods of mind training for managing stressful situations are very insightful additions that will be extremely helpful for both counselor and counselee. Sixth chapter captures the problem associated with 'helicopter parenting' or 'over parenting' that is generally not given much attention. It is a must-read for parents to ensure that their over involvement with their children does not smother their growth and well-being. The last chapter of the first part is dedicated to counseling at the workplace that every working individual will relate to. It beautifully describes the subtilities of human behavior and various behavioral issues that negatively affect the productivity of an individual at the workplace. It will be beneficial in counseling the employee to ensure their increased productivity and better individual growth.

The diversity and complexity of the counseling process is explained in understandable ways in the second part of the book. It describes various counseling techniques suitable for students with varying backgrounds and needs. It elaborates on various definitions and concepts associated with counseling process and issues related to each of those. The eight chapters of second part, Part -B 'counseling ecosystem, process and techniques' has in-depth explanation of counseling categories, training counselors, counseling process, counseling techniques and behavior and emotional problems. There is also a chapter giving insights regarding counseling of students with special needs, troubled family environments and family concerns with respect to marriage. This part of the book is very helpful for trainers, parents and teachers to understand the process and ways of customized counseling for tackling youths surrounded by diverse social problems. It outlines various approaches that can make counseling more effective, which is especially useful for those who wish to understand various aspects of counseling in detail. The book has appropriately described sensible suggestions to eliminate the ever prevailing and yet ignored problem of truancy, delinquency, disobedience, fear, anxiety, suicidal tendencies and uncooperativeness amongst students in a constructive way. This self-assessment narrative provides all-inclusive modules and models for assessment, clientele based moral and ethical components of counseling, the research-based prescriptions for counselor trait acquisition, mind management, stress management and even the employee satisfaction in an institution with a motive of managerial and leadership development.

The book is like a manual for counselors and teachers, a guide for students and informative to general readers. It can be used as a guide for academic discussions and will also be very useful for practical purposes of counseling in everyday life. The book will be of immense use for all those stakeholders who connect with students at various levels and work with them with different mandates of teaching, training, counseling, norming, inculcating discipline, managing and rearing. It is a wonderful and insightful publication, seems to be an interesting material for leisure reading as well as a précised text book to be referred again and again. The simplicity and elegance with which everything is explained will ensure that not only professional counselors but even non-professionals will find it easy to absorb and assimilate. With my personal experience and passion for counseling, it can be said that this book will go a long way in enhancing the counseling capabilities of individuals working in educational institutions that will catalyse a change in positive direction.

I find this book highly informative and can help even teacher to do counseling to some extent by acquiring the knowledge. In the current National Education Policy (NEP)-2020 much emphasis has been given counseling of student as course curricula in higher Education. Thus the initiative of authors, Dr. Tej Partap and Dr Vignesh for writing this most relevant and useful reference book is highly appreciable. They have put in extraordinary efforts to bring out this excellent piece of literary work. I am sure all will be benefited who read this book, and would like to keep in personal library for reference. Finally, I recommend this book for all the stakeholders who are concerned with the education ecosystem.

-- Dr. H.P. Singh
Chairman, Confederation of Horticulture Associations of India (CHAI)

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Before submission, manuscripts must be reviewed by two reviewers and revised appropriately, with the names of the reviewers included on the manuscript submission form. Manuscripts must be in IJIH style. A manuscript number will be assigned to each new or resubmitted manuscript, refer to this number in all subsequent correspondence. Submitted manuscripts that do not confirm to standards will be returned to authors for correction. Manuscripts submitted for publication are reviewed by Editors who solicits at least two additional peer reviews. The purpose of the reviews is to assure readers that competent, independent professionals have found the published papers acceptable. Some revision is usually necessary after the reviews, and final acceptance generally depends on satisfactory revision. A manuscript will be considered withdrawn if the author will not respond within 2 months to a request for revision. Decision of Editor-in-Chief will be final for acceptance or rejection.

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