Crop Improvement in Guava: An Overview

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Guava is a major fruit crop of India and popularly known as 'apple of the tropics' since it is consumed as a fresh fruit or processed into a variety of products. Efforts have been made over the past few decades to widen its genetic base by creating new variability and utilizing it for the selection of elite variety or hybrids for commercial cultivation. Attempts are still on to improve upon the existing commercial cultivars through selection of germplasm and combining the desirable traits of various genotypes through hybridization. A variety with in-built resistance to the biotic and abiotic resistance besides high yielding capacity of good quality fruit is lacking in guava. The DNA marker assisted selection has the potential to introduce and deploy favourable gene combinations for disease control along with the other agronomically important traits. The available information covering different aspects of crop improvement of guava has been reviewed.

Key words: Breeding, Crop Improvement, Genetic Diversity, Germplasm Management, Guava, Marker-Assisted Selection, Molecular Markers, *Psidium guajava* Linn

The common guava (*Psidium guajava* Linn) is mainly self pollinated, but cross pollination is also common resulting in a greater variation in the seedling population. Seed propagation, therefore, has created considerable variability from which promising genotypes were selected in different agro-climatic regions of the country (Pathak and Ojha, 1993). A proper understanding and management of variation present within the natural and other cultivated varieties as well as in the wild relatives of guava is very essential in the establishment of an efficient programme aimed at its crop improvement. The description and nomenclature of the present day guava varieties are greatly confusing and the genetic uniformity in the crop is undesirable because it tends to make the crop more vulnerable to epidemics. Hence from the germplasm maintenance and breeding point of view, the identification of duplicate accessions in different cultivar names and its elimination from the germplasm collections is yet another important task. The promising guava cultivars which are deficient in one or more traits can be improved by crossing such cultivars between the lines which possess the desired trait. A conventional breeding programme thus involves crossing the whole genome followed by selection of superior recombinants from several segregation products. Such a procedure is laborious and time consuming involving several crosses, many generations and careful phenotypic selection. Also tight linkage of desired loci with an undesired loci may make it difficult to achieve the desired objective. With the advent of DNA marker technology, several types of DNA markers and molecular breeding strategies are now available to plant breeders and geneticists helping them to overcome many of the problems faced during conventional plant breeding. The present effort outlines the history of the crop and to review the present status of guava crop improvement programmes conducted at various centres with special emphasis on the novel technologies which could be implemented in its breeding programme.

Origin and Distribution

The guava is believed to have originated in tropical America, from Mexico to Peru (Hayes, 1953), where it still occurs in the wild and forms extensive thickets. It is common throughout all warm areas of tropical America and in the West Indies (Purseglove, 1968) and was domesticated 2000 years ago (Cobley, 1976). Guava was adapted as a crop in the warmer parts of Africa and Asia including India during early 17th century soon after it was introduced by Spanish and Portuguese colonizers (Hayes, 1953; Menzel, 1985; Singh, 1985).

The common guava, *Psidium guajava* Linn, is widely distributed throughout the world and is grown mainly for its fruits in many tropical and subtropical countries. It grows in a wide range of environments from sea level up to an altitude of 1500 m (Singh, 1985) throughout Asia, South Africa, America and Australia. It exceeds the other fruit crops in productivity, adaptability and in the total vitamin content of fruits. Guava is an important fruit crop in India and stands fourth in area and production after mango, banana and citrus (Anonymous, 1985). In India, the most important guava growing states are Uttar Pradesh (UP), Bihar, Madhya Pradesh and Maharashtra.

Allahabad (UP) has the reputation of growing the best quality of guava fruits in the world (Mitra and Bose, 1990). It is cultivated on a commercial scale in many countries and India leads the world in guava production (Adsule and Kadam, 1995). The other major producers of guava are Mexico, Pakistan, Colombia, Egypt, South Africa, Venezuela, Dominican Republic, Puerto Rico, Jamaica, Kenya, Australia and Hawaii.

The Plant and its Importance

The guavas belong to the genus *Psidium* (family – Myrtaceae) which comprises approximately 153 species of trees and shrubs and about 20 species have edible fruits (Hayes, 1953; Iyer and Subramanyan, 1987; Yadav, 1990). Out of these, the common guava *Psidium guajava* is commercially and economically utilized so far. The plant is a shallow rooted shrub or a small tree up to 33 feet with spreading branches close to the ground with an attractive 'bony' appearance of the trunk. Young twigs are quadrangular and downy with opposite decussate with short-petioled leaves. The flowers are characteristic by a prominent tuft of around 250 abundantly incurred white stamens of various size. The guava trees produce a large number of fruits which vary between genotypes in colour, size, flavour and has a characteristic musky odour. The guava fruit is a rich source of vitamin C – contains four to five times higher than in citrus fruits; vitamin A, vitamin B_2 (riboflavin), thiamin, niacin and minerals like calcium, phosphorus and iron. The fruit pulp is a commercial source of pectin and oil from its seeds. Ripe guavas are eaten out of hand and are processed into innumerable products. Guava shells, concentrated pulp, paste, jelly, jam, juice powder and confectionaries are a few among them. The guava fruits are often referred as 'apple of the tropics' (Rangacharlu, 1954; Menzel, 1985). The wood is valued for engravings, useful as tool handles and in making implements. The leaves, bark and immature fruits are rich in tannin and are used for dyeing. The roots, bark, leaves and immature fruits can be used in local medicine.

Related Species of Common Guava

The important cultivated species related to common guava are Brazilian guava or Guisaro (*Psidium guinese* Sw); Cattley guava or Strawberry Guava (*P. cattleanum* Sibne), Costa Rican guava (*P. friedrichsthalianum* Ndz), Para guava (*P. acutangulaum* DC), *P. littorale, P. longipes, P. montanum, P. microphyllum, P. sartorianum, P. quidanense* and the other genus *Myrcaria floribunda* Berg, the Rumberry or guavaberry (Mortan, 1987).

Species like *Psidium araca, P. cattleianum, P. corecium, P. cujavillus, P. cumini, P. friedrichsthalianum, P. guinese, P. molle, P. quidanense* and phillipine guava are reported to be tolerant or resistant to the wilt disease (Edward and Shankar 1964; OmPrakash and Mishra, 1993; Rawal, 1993).

Genetic Diversity among Cultivars

Genetic variation and its assessment in the existing germplasm of guava is an essential component to its improvement. Plant breeders need the sources of genetic diversity to draw upon when required, to breed for better nutritive value, adaptability and resistance for biotic and abiotic stresses. Among the cultivated genotypes of common guava, extensive genetic diversity exists in different countries (Teaotia, 1967; Pandey, 1968; Purseglove, 1968). Diversity exists in tree size, flowering and fruiting characteristics, yield, qualitative fruit characters like size, shape, skin colour, texture and colour of flesh, flavour, aroma, ascorbic acid content of fruit, pulp to seed ratio, seed characteristics, post-harvest characteristics and susceptibility to pests and diseases (Mortan, 1987). A list of germplasm collections of different agroclimatic regions of the world is given in Table 1.

The germplasm evaluation studies have successfully identified some promising genotypes which have economic potential in early flowering and maturity, yield, qualitative fruit characteristics, post harvest and fruit processing characteristics and tolerance or resistance to biotic stresses (Pathak and Ojha, 1993; Subramanyan and Iyer, 1993).

Genetics and Breeding

The cultivated guava is a diploid species (basic chromosome number is 11; 2n =22) with a high bearing capacity. However, it has a disadvantage of high seed content. A natural as well as an artificial triploid species 2n = 3x = 33 produces seedless fruits but they are almost shy bearers (Kumar and Ranade, 1952; Sharma and Majumdar, 1957; Raman *et al.* 1969, 1971). Naithani and Srivastava (1966) reported natural autotetraploids in the genus. Ramkumar (1973) induced tetraploidy in Allahabad Safeda variety by treating shoot tip with 0.1 % aqueous solution of colchicine. Ploidy levels higher than this are not reported in guava. Studies on the inheritance pattern of important traits in guava have indicated that the flesh colour of fruits and the seed size are linked characters; Red pulp colour is dominant

Table 1. Local and introduced cultivars, selections, breeding lines and hybrids of guava grown in different agro climatic regions of the world

Country & Cultivar	Pulp colour	Country & Cultivar	Pulp colour	Country & Cultivar	Pulp colour	Country & Cultivar	Pulp colour	Country & Cultivar	Pulp colour
Bangladesh		**Florida (Contd)**		**India (Contd)**		**India (Contd)**		**India (Contd)**	
Deshipeyara	n.a.	Red Indian	R	Allahabad-Safada	W	Hybrid 1	W	Wickramasekara	R
Kazipeyara	n.a.	Red land	W			Hybrid 16-1	W	WhiteSupreme-xRuby	W
Sarupakatti	n.a.	Ruby	R	Allababad-Surkha	W	Hybrid 45	n.a.		
Mukundhupuri	n.a.	Supreme	W		n.	Hybrid 53	n.a.	**Malaysia**	
Brazil		**France**		Am Sophri	n.a.	Hybrid 84	n.a.	Gu 4	n.a.
Brune Branca	n.a.	Acid Speer	PY	Anakapalle	R	Hybrid 105	n.a.	Gu 5	n.a.
IAC – 4	n.a.	Beaumont	P	Aneuploid-82	n.a.	Hybrid 161	n.a.	Gu 7	n.a.
IMC	n.a.	Elisabeth	P	Apple Colour	n.a.	Indonesian-Seedless	n.a.	HongKong Pink	n.a.
PB	n.a.	Large White	W	Arka Amulya	n.a.			Jambu Biji	n.a.
PV	n.a.	Patricia	PO	Arka Mridula	W	Kafroe	R	**Miami**	
Rica	n.a.	Pink Indian	R	AS 1	n.a.	Karela	W	Miami Red	R
TL	n.a.	Red Hybrid	R	AS 2	n.a.	Kohir Safada	W	Miami White	W
California		RedxSupreme-xRuby	DP	AS 3	n.a.	Kothrud	R	**New South Wales**	
Detwiler	n.a.			Banarasi	R	Lalit	n.a.	GA 11-56	n.a.
Hart	PY	RedxSupreme-XRubyxWhite	CW	Banarasi-Surkha	W	Lal Seiba	R	1050	n.a.
Red Indian	R					Lucknow-24	n.a.	**Puerto Rico**	
Rolfs	P	Stone	DP	Bangalore	W	Lucknow-42	W	Corozal Mixta	n.a.
Turnbull	n.a.	Supreme	P	Bariampur	n.a.	Lucknow-46	n.a.	Corriente	n.a.
Webber	PY	SupremexRuby	W	Beaumont G35	P	Lucknow-49	W	Seedling 57-6-79	n.a.
White Indian	W	**Hawaii**		Behat Coconut	W	Madhuri-am	n.a.	**Queensland**	
Coloumbia		Allahabad-Safada	W	BHR – 3	n.a.	Mirzapuri	W	GA9-39-R1T2	n.a.
Agrio	n.a.			BHR – 5	n.a.	M25988	n.a.	GA11-56R1T1	n.a.
D-13	n.a.	Apple	n.a.	Chakaiya	n.a.	Nagpur Seedless	n.a.	GA11-56R5T2	n.a.
D-14	n.a.	Beaumont	P	China Surkha	R	Nasik	W	GA11-564T1	n.a.
Puerto Rico	n.a.	Burma	n.a.	Chittidar	W	Navalur	n.a.	GA11-56T3	n.a.
Red	n.a.	HongKong Pink	P	CHN	n.a.	Oakey Pink	n.a.	GA11-56T7	n.a.
Rojo Africano	n.a.	HongKongWhite	W	Dharbar	W	Patillo	n.a.	**South Africa**	
Trujillo 2	n.a.	Indonesian-seedless	W	Dharidar	n.a.	Portugal	n.a.	Dimple	n.a.
White	n.a.			Dharwar	W	Redfleshed	R	Fan Retief	n.a.
Cuba		Indonesian-White	W	Dholka	R	Rewa 72	n.a.	Frank Malherbe	n.a.
Belic L-97	n.a.			EthridgeSelection	n.a.	Safeda	W	Fredene	n.a.
Belic L-207	n.a.	Ka Hua Kula	DP	FloridaSeedling	n.a.	Safrior Payere	n.a.	Fredericka	n.a.
EEA 18-40	n.a.	Lucknow-49	W	FS 1	n.a.	Sangam	n.a.	Jonelle	n.a.
Egypt		No. 6362	n.a.	FS 2	n.a.	SeedlessTriploid	W	Weiheim	n.a.
Bassateen-Edfina	W	No. 6363	W	Gwalior 27	n.a.	Seedless-Triploid Poona	W	**Taiwan**	
		No.7198	DP	Habshi	W			Chung Shangpa	n.a.
Bassateen-El-sabahia	n.a.	No.7199	n.a.	Hapi	R	Sindh	W	Laiapa	n.a.
Florida		**India**		Harijha	n.a.	Smooth Green	W	Peipa	n.a.
Blitch	LP	ABD 3	n.a.	Hasijaka	R	Super Acid	R	**Trinidad**	
Patillo	P	AC 10	n.a.	HybridRed-Supreme	R	Tathen White	n.a.	Cayenne	n.a.
		Allahabad	W			Verdie	n.a.		

Source: Mortan (1987)
W – White, CW – Creamy White, PY – Pale Yellow, L – Light Pink, P – Pink, PO – Pinkish Orange (Salmon fleshed), DP – Deep Pink, R – Red, n.a. – information not available.

to white which are governed monogenically and bold seeds are found to be dominant over soft seeds and are also governed monogenically (Subramanyan and Iyer, 1982). The systematic breeding work done for the crop improvement in guava was reviewed by Subramanyan and Iyer (1993).

In India, guava improvement programme was initiated during 1907 at Ganesh Khind Fruit Experimental Station, Pune (Phadnis, 1970) with objectives to develop dwarf, as well as high yielding, good post harvest characteristics in fruits and to evolve resistant lines to biotic and abiotic stresses. As a result, many varieties and hybrids of agronomic and commercial importance have been evolved through selection and hybridization. Most of the popular varieties existing today are developed from selections from the seedling progenies of open pollinated seeds. Out of 600 seedlings selected from the different regions of the country, Lucknow 49 was identified (Cheema and Deshmukh, 1927) as a promising strain evolved from the open pollinated seedlings of Allahabad Safeda. This strain had distinguishing characters like spreading growth habit, large globose fruits with white flesh, high TSS content, sugar:acid ratio and yield (Cheema *et al.* 1954). After successful field trials at Saharanpur (Singh, 1953) and Kodur (Rangacharulu, 1954) the variety is now renamed as Sardar and recommended for large-scale commercial cultivation. The work initiated by Singh (1953) at Horticultural Research Station, Saharanpur led to the evolution of superior selection known as S-1 which had good fruit shape, less number of seeds, sweet taste and high yield (Singh, 1959).

A large germplasm of guava was established and evaluated for morphological features, fruit quality and yield at Central Institute of Horticulture for Northern Plains, Lucknow where after the evaluation of 20 varieties, Lucknow-49 was found to be the best (Chadha *et al.* 1981). In Karnataka, 16 high performing seedlings were selected from a variety named after a village *viz.*, Navalur which was hardy, drought tolerant and canker resistant (Hulamani *et al.* 1981). Similarly, three superior strains viz., ABD 3, BHR 3 and BHR 5 were identified from twelve strains collected from Aurangabad and Bhir Districts of Maharashtra (Thonte and Chakrawar, 1981). At Narendra Dev University of Agriculture and Technology, Faizabad, three seedlings of Allahabad Safeda (AS_1, AS_2 and AS_3) and two seedlings of Faizabad Selection (FS_1 and FS_2) were found to be promising out of 23 strains evaluated with respect to the fruit quality and yield (Pathak and Dwivedi, 1988). Apart from this, surveys conducted in Gujarat and Rajasthan also resulted in the identification of few outstanding trees of desirable attributes (Anonymous, 1988). Similarly from Indian Institute of Horticulture, Bangalore, two varieties *viz.*, Arka Mridula (Selection 8) and Arka Amulya were released (Iyer and Subramanyan, 1988) from open pollinated seedlings of Allahabad Safeda. They are heavy yielders, dwarf plant type, fruits white fleshed with high sugar and TSS content, soft seeded and with good keeping quality. Allahabad Surkha, a red skinned guava variety was obtained by chance selection of Allahabad Safeda.

Crop improvement programme in guava through hybridization was initiated at Indian Agricultural Research Institute(IARI), New Delhi, Andhra Pradesh Agricultural University Station at Sangareddy and at Indian Institute of Horticultural Research, Bangalore. The seeded diploid variety of Allahabad Safeda was crossed with a seedless triploid at IARI, New Delhi and a series of aneuploids were produced (Majumder and Mukherjee, 1972 a, b; Mukherjee, 1977) with dwarf tree growth habit, normal shape and size of fruits with few seeds. Nijar (1977) suggested that aneuploidy breeding may be profitable in fruit trees where high seed content of fruits is a defect. Crosses were made and a tetrasomic species namely, Aneuploid-82 was developed with normal size and shape of fruit, few seeds and with tremendous scope to be utilized as root stock. The hybrids Safed Jam and Kohir Safed were released from A.P. University Station, Sangareddy (Mitra and Bose, 1985) and Hybrid-1 and Hybrid 16-1 were released from IIHR, Bangalore (Subramanyan and Iyer, 1988). At Rajendra Agricultural University, Sabour, F_1 hybrid seedlings were raised from crosses between Chittidar x Apple Colour, Chittidar x Sardar, Chittidar x Redflesh, Chittidar x Allahabad Safeda; Sardar x Allahabad Safeda, Sardar x Chittidar; Apple Colour x Sardar; Allahabad Safeda x Apple Colour, Allahabad Safeda x Sardar (Singh and Hoda, 1988). Ghosh *et al.* (1998) mentioned the characteristics of a few more promising guava hybrids *viz.*, Hybrid-45, 53, 58, 84, 105 and 161 at IIHR., Bangalore. A brief breeding and selection programme was initiated at Institute for Tropical and Subtropical Crops, South Africa to develop a wilt resistant cultivar along with other desirable characters suitable for processing, canning and fresh market (Preez and Du-Preez, 1996). At Taiwan

Agricultural Research Institute, Kohsinag, Wan-WuChang *et al.* (1999) have selected the crosses between R4 x Pepia and R1 x Pepia resistant against *Myxosporium* wilt in guava.

Attempts were made through grafting in guava with major objective of developing root stocks with resistance to guava wilt. The wild *Psidium* species can be utilized as root stocks for regulation of vigour, bearing, fruit quality and resistance to pest and diseases (Mitra and Bose, 1990). The Chinese guava (*Psidium friedrichsthalianum*) is a compatible root stock and has been reported to be resistant to wilt disease. Its dwarfing effect would be used in commercial plantings (Edward and Shankar, 1964). Allahabad Safeda trees grafted on *P. pumilum* had a dwarfing influence and on *P. cujavillis* produced the largest trees but non uniform and rough skinned fruits. Fruits from trees of Florida seedling stock had the highest total acidity (Teaotia and Phogat, 1970). Singh *et al.* (1976) observed that fruits of Allahabad Safeda contained higher sugar content on *P. pumilum* while higher ascorbic acid content was recorded in those grafted on *P. cujavillis*. In the attempts made for the interspecific hybridization in guava with a major objective of developing root stocks for wilt resistance, it was observed that *P. guajava* and *P. chinensis* are crossable. Similarly *P. chinensis* when used as female parent with *P. molle*, the cross was compatible where as the cross between *P. guajava* as female parent and *P. molle* was incompatible (Subramanyan and Iyer, 1982). However cross incompatibility exists between several cultivars of superior traits. Seth (1960) reported varietal cross incompatibility since neither fruit nor seed set was obtained when crosses were made between Behat Coconut and Lucknow 49; S-1 and Behat Coconut; Behat Coconut and Apple Colour; and Apple Colour and S-1.

Biotechnology Applications in Crop Improvement

The advent of plant molecular biology techniques related to DNA based markers provide powerful and reliable tools for a variety of purposes including variation within the crop germplasm, tagging of genes for agronomically important traits and genome mapping. A variety of molecular markers have been developed for these purposes. Some of the DNA markers currently in use are RFLPs, RAPDs, SCARs, DAF, Minisatellites, Microsatellites or SSRs, ISSRs, AFLPs, S-SAPs, REMAP and IRAPs. The role of DNA markers in crop improvement has been reviewed by many authors (Joshi *et al.* 1999; Kumar, 1999; Thomas and Raman, 2000).

The molecular markers are specially advantageous for improving agronomic traits in perennial fruit crops that are otherwise time consuming and difficult to tag the genes conferring resistance to pathogens, insects, nematodes, tolerance to abiotic stresses, quality parameters and quantitative traits. By using Marker Assisted Selection (MAS), the breeder could select molecular markers that are tightly linked to resistant genes for identifying resistant genotypes. Unfortunately, information on these aspects assisted by molecular marker aided studies is lacking in guava. Hence the task of developing molecular marker based genetic map is challenging and important in the crop improvement of guava.

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