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Improvement of custard apple (*Annona squamosa* L.)

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Abstract

Immense prospects exist to develop desirable cultivars of annonaceous fruits by conventional breeding techniques. There is greater scope to exploit inter-specific variation than intra-species variation. Edible *Annona* species exhibit morphological affinity to one another but each one is unique and distinct for fruit shape, size, skin surface, pulp colour, texture, flavour and taste. Some species like *Annona squamosa* exhibit narrow genetic variation. However, several interesting traits are available in one or the other allied *Annona* species. Because there are no serious barriers in inter-specific hybridization between *A. squamosa, A. cherimola* and *A. reticulata* gene transfer across species boundaries is possible. Gene exchange among them should result in interesting novel recombinants at times most esteemed ones like the popular atemoya.

Key words: *Annona* species, cytogenetics, flower biology, improvement, varieties

Introduction

The Annonaceae or custard apple family comprises about 120 genera and more than 2000 species (Leboeuf *et al*., 1982). The genus Annona is the most economically important one, containing 120 species. The major commercial species throughout the world are: the cherimoya (*Annona cherimola*), sweetsop (*Annona squamosa*) and atemoya (a hybrid of *Annona squamosa* and *Annona cherimola*). The sweetsop species name '*squamosa*' refers to the knobby appearance of the fruit. Sweetsop is a small tropical tree originating in the New World tropics, probably Central America. This species is the most widely grown in the tropical regions of the America, Africa, Asia and the Pacific. Sweetsop is also named sugar apple and has many other regional names, such as Custard apple (India), anon (Spanish), ata (Portuguese), noi-na (Thailand), stis (The Philippines) and fan-li-chi (Taiwan). Sweetsop is the mostly grown Annona species. The fruit is frequently found in village markets but has not shown much potential for large commercial cultivation due to the small fruit size, frequent cracking at maturity and poor shelf life. The perishable nature and supply shortages make marketing localized or air shipment essential. Fruit is usually harvested from July to October and can be extended to March if summer pruning is conducted. In India, the peak of production occurs later between August to November and in Thailand, Florida and the Caribbean between July and September. Taiwan's peak of production occurs between July and March. Sweetsop is a good source of carbohydrate, potassium, calcium, phosphorus and ascorbic acid. The fruit is usually consumed fresh and also can be used to make juices, shakes and ice creams.

Cytogenetics and breeding

Understanding cytology of a crop is useful in planning breeding programme. The chromosome number of *Annona squamosa* is 2n=14. Cross-pollination between species is conducted primarily to determine compatibility for increasing fruit set. Inter and intraspecific cross combinations among *Annona squamosa, A. atemoya, A. reticulata, A. glabra, A. cherimola* and *A. muricata* were investigated by Kumar and Jalikop (2000).They reported that *A. squamosa* was the most effective pollen parent of *A. atemoya* and *A. cherimola*. However, *A. squamosa* was not an effective female parent with *A. atemoya*, whereas *A. cherimola* was compatible with both *A. squamosa* and *A. cherimola*. *A. atemoya* can be crossed freely with *A. reticulata, A. glabra* and *A. cherimola, A. atemoya* is the only hybrid that has gained importance and it has inherited the glabrate leaf character of *A. squamosa* and a leaf size almost as large as that of *A. cherimola*. Flowering and fruiting seasons are similar to those of sweetsop. Skin, pulp and seed characters of both parents are inherited in varying degrees by each plant. A desirable hybrid would be between the cherimoya and soursop that combines the larger fruit size and acidity of the soursop and the cherimoya's sweetness, flavour and texture. Attempts to cross the soursop with cherimoya, ilama, bullock's heart or sweetsop have not been successful and may reflect a considerable genetic distance of soursop from the other species (Paull and Duarte, 2011). Jalikop (2010a) investigated the inheritance of foliage characteristics in trispecies hybrids of atemoya (*A. cherimola* x *A. squamosa*) and *A. reticulata*. Segregation for leaf colour (green or dark green), leaf angle (erect or drooping), leaf apex shape (rounded or pointed) and time of leaf fall (early or late or intermediate) into discreet phenotypic classes revealed that their inheritance followed simple Mendelian genetics. Duplicate dominant gene interaction

governed the leaf colour and leaf position. Individuals with single or both the dominant genes (A-B-, A-bb, aaB-) produce green colour leaves and those with recessive genes (aabb) dark colour leaves. Likewise erect leaf individuals are C-D-, C-dd, ccD- and drooping leaves are ccdd. A single gene determined shape of leaf apex that was either rounded (Rr) or pointed (rr). Segregation of progenies for leaf fall into early, intermediate and late suggested that co-dominant alleles were responsible for time of leaf fall. The pattern of segregation of tree and fruit traits in trispecies hybrids *(A. cherimola* Mill. x *A. squamosa* L.) and *A. reticulata* L. have been investigated by Jalikop (2010b) with the objective of salvaging useful genes from the three edible annonas and determining the extent of variation in the progeny. The heterogenous nature of *Annona* species and simultaneous segregation of three distant genomes resulted in a tremendous heterogeneity in the progenies and thus demonstrated that A. reticulata is potentially a valuable source of a variety of novel traits. However, the F1 trihybrids exhibited reduced fertility with pronounced undesirable traits of *A. reticulata* , and the survival of F2 trees was poor, with those that did survive being extremely weak and failing to flower or set fruit. Consequently, backcrossing may be more suitable approach than advancing trihybrid generation for transferring desirable genes from *A. reticulata*. Backcrossing F1 progeny of [(*A. cherimola x A. squamosa*) x *A. reticulata*] to *A. squamosa*, a highly fertile species, is expected to yield productive introgressions in which the contribution of the A. squamosa genome will be extended from 25 to 62.5% in F1BC1 generation.

Problems in breeding

Wester (1913) was the first scientist to realize the possibilities for genetic improvement of annonas and initiated breeding programmes in Florida and in the Philippines. The long reproductive cycles, higher levels of heterozygosity and the costs associated with evaluating large populations of crosses limits breeding programmes. Existing commercial cultivars show considerable variation in growth, fruit set, fruit size and quality. No single variety has all the desirable characteristics. The length of the juvenile period varies, with earliest production occurring in 2 years and full production in 5–6 years. This juvenile period is extremely variable with scions on seedling rootstocks. The seedling rootstocks are derived from extremely heterogeneous, open-pollinated seeds; hence it is difficult to fix specific characters in a short period. Breeding programmes have focused on selections from seedling populations. Seedling rootstocks of annonas are generally derived from heterogeneous open-pollinated plants; hence, it is often difficult to fix specific characters in a short period. Early maturity, better fruit appearance and long post-harvest life for tropical annonas, and in the subtropics, greater cold tolerance, are objectives for cherimoya breeding (Nakasone and Paull, 1998).

Varietal wealth

Arka Sahan

It is a progeny of Island gem (*Annona atemoya* Hort.) x Mammoth (*A. squomosa* L.). Arka Sahan fruits come to harvest in September-October and mature fruits (210 g) take about 6-7 days to ripe. The skin has a waxy bloom, light green in colour, moderately thick (0.5 cm) with large, flat eyes. The creamy white colour flesh is juicy with mild pleasant aroma and tender with scarce seeds (9/100 g) and large segments. The edible pulp is remarkable for its sweetness with 22.8% total sugars and measures more than 30°B as against 24°B in Mammoth. A 100 g pulp of Arka Sahan contains 2.49 g of crude protein, 42.29 mg P and 225 mg Ca against 1.33 g, 17.05 mg and 159 mg respectively in Mammoth. On an average, 12 tonnes of fruits can be harvested/ha and it is resistant to drought.

Balanagar

Tree grows up to 3 m height. Fruits are spherical, pyramidal or cordate in shape; medium to big in size. Average fruit weight is 200 g but recoded up to 640 g; rarely 8.3 cm long and 3.5 cm in diameter. Areoles are tuberculate, very rough, pitted, forming deep furrows; rind greenish, mesocarp white with coarse and medium granules, pulp white, buttery sweet, with moderate to plenty of juice, flavor excellent; seeds 40–80. Highly productive, fruits remain green when ripe; rich in reducing sugars and proteins.

Barbados

Tree grows up to 2.4 m height. Fruits are spherical to cordate in shape; medium in size. Average fruit weight is 230 g. Fruits are 7.0 cm long and 7.7 cm in diameter; areoles tuberculate, very rough; rind fine; mesocarp with medium granules; pulp creamy white, moderately juicy, with agreeable flavor, sweet; seeds 40-60. Flowering late in June to early September and prolific yielder.

British Guinea

Tree grows up to 1.8 to 2.4 m. Fruits are spheroid to cordate in shape; medium in size. Fruit weight ranges from 170 to 335 g. Fruits are generally 6.8 cm long and 6.8 to 7.5 cm in diameter; areoles tuberculate, acute, rough, rind grayish or grayish green; mesocarp white, soft; pulp white, soft buttery, crisp, moderately juicy, sweet, seeds 30-50. Flowering is late in June to mid September. High yielder and fruits remain green at ripening.

Crimson custard apple

Tree grows up to 1.8 to 2.0 m. Fruits are spherical to oval in shape; small to medium in size. Areoles medium-tuberculate, truncate, slightly rough, rind crimson, with grayish blue bloom, mesocarp reddish with medium to big granules, pulp with light red tinge, soft, moderately juicy, sweet, seeds 40-60. Flowering occurs early June to end of August; trunk and branches dark green, new growth pinkish green.

Local custard apple

Tree grows up to 1.8 to 2.4 m. Fruits are spherical or cordate or conical in shape; Fruit weight ranges from 140 to 330

g and recorded up to 615 g. Areoles small to big, smooth to very smooth, round or mamillate; rind green, becoming light yellow on ripening. Mesocarp white, with fine, small to medium granules; pulp dull white, juiciness little to plenty, insipid to very sweet, seeds 30-80. It is an average yielder.

Mammoth

Tree grows up to 1.5 m. Fruits are irregular, triauetrous to spherical in shape; average in size. Fruit weight ranges from 170- 250 g, recoded up to 450 g. Areoles medium to big, very smooth, round, rind light russet; mesocarp white with small to medium granule; pulp white and translucent, soft bright, juicy, sweet, seeds 20-40. It has tendency to branch profusely; prolific bearer; rind becomes wrinkled on ripening; possesses low acidity; fruits have a good keeping quality and stand transport better.

Red Sitaphal

Tree grows up to 1.8 m. Fruits are spherical and cordate in shape. Fruit weight ranges from 170-250 g. recorded up to 450 g; areoles medium to big. tuberculate, truncate, rough and pitted; rind pink; grayish blue; mesocarp pinkisk with coarse and big granules; pulp with pink tinge, moderately crisp, juicy, slightly acidic, sweet, seeds 40-60. Trunk and stem dark green; section of the stem shows the presence of pink coloured parenchyma in a circular band; mesocarp becomes deep pink on ripening; seeds small as in Annona reticulata. It contains maximum reducing sugars.

Red specked custard apple

Tree grows up to 1.50 to 2.0 m. Fruits are spherical to cordate in shape; small to medium size. Fruit weight ranges from 170-335 g. Areoles medium, tuberculate, truncate, very rough, ridged, pitted; rind light russet-green; splashed with red colour; mesocarp white with red colour; with medium to big granules; pulp dull white, moderately juicy, slightly stringy and just sweet, seeds 40–70. Flowering till the end of August; poor yielder; appears to be a cross between 'Red Custard apple' and Local Custard apple.

Washington 98797

Tree grows up to 1.8 to 3.0 m. Fruits are spheroid to cordate in shape, medium to big size. Average fruit weight is 690 g, areoles medium, truncate, tuberculate, ridged, rough, rind light russet-green; mesocarp with medium to big granules; pulp creamy-white, soft, moderately juicy, pleasant, moderately sweet. Seeds 50–60. Flowering occurs till early September and it is heavy yielder.

Washington 107005

Tree grows up to 1.8 to 2.4 m. Fruits are spherical to short conical in shape. Average in size; fruit weight ranges from 170 to 335 g, recorded up to 560 g. Areoles tuberculate, with small pits; rind grayish green, mesocarp white with small to medium granules ; pulp soft, bright white, buttery; moderately to very juicy, sweet, flavor, delightful, seeds 30-50. Rich in reducing sugars and also in total acidity and protein.

APK-1

It is a clonal selection from a high yielding type in the State Horticultural farm, Courtallam. It bears higher yield in rainfed vertisol (black soil). It is a drought tolerant variety which bears sweet fruits (TSS of 24.5 Brix with an acidity of 0.2 per cent). The Fruit weigh ranges about 207.5 g with a mean of 72 fruits per tree per year. The first bearing commences in a graft/budded plant at 3-3 ½ years. The Optimum productive life is 25 yrs. The best season for planting is May-June/August-September. It yields about 7300 kg fruits/ha (14.90 kg/tree which is 30.7 per cent higher than Balanagar). It is suitable for cultivation in plains of Tamil Nadu especially in semi arid regions and marginal soils of both vertisol and alfisol in dry tracts. It is suitable for both rainfed and irrigated conditions.

Phule Janaki

It is hybrid between atemoya x custard apple. Trees are spreading in nature with dark green foliage. Average fruit weight: 392.7g; Fruit surface is rough with yellowish green colour.Fruit shape is oval and areoles are mammal in shape. Pulp colour is milky white with soft texture.Less seed content.Fruits are having better sugar acid blend

Phule Purandar

It is a clonal selection from Purandar Tahsil in Pune district of Maharashtra. Average fruit weight (366.17 g) and yield plant per plant is 50.90 kg. TSS - 23.60B), pulp - 47.82 % , better Shelf life (6 days).

GJCA-1

Gujarat Junagadh Custard apple-1 (GJCA-1) was developed from Madhadibag farm, Department of Horticulture, JAU, Junagadh. It requires 62.92 days days to maturity, fruit weight 139.89 g, fruit length 6.80 cm, fruit girth 7.06 cm. Less number of seed per fruit as compared to check. It is recommended for Saurashtra region.

Sindhan

Sindhan is a local variety found on large area in Girnar hills of Junagadh district in Gujarat state.

Dharur – 6

It has average fruit weight 386.0 g; TSS 25.0 ^{0}B; pulp recovery 47.5% and yield is 11.4 kg per plant.

TP-7

It has average fruit weight is 400-500 g, TSS 28.0 ^{0}B and yield 8.89 t/ha.

NMK-1 Golden

This variety has developed by the farmer Shri Kaspete of Garmele Village in Barshi Taluks of Solapur district in Maharashtra. Average fruit weight is 430.0 g; TSS 22.0 to 24.0 ^{0}B, less seeded 10-12 seeds /100g pulp. This variety has protected under PPV & FRA act.

Saraswati – 7 / Saraswati Saat

This variety also developed by the farmer Mr. Suresh Patil Jam on Wardha road in Nagpur. The fruit of Saraswati Saat is very big, more pulp, fewer seeds, thin skin and less prominent eyes.

Other custard apple varieties

Some cultivars were identified based on colour of the fruit, its origin and plant part: yellow custard apple named after the colour of the fruit. Cultivars like Kakarlapahad, Mahaboobnagar, Local Hyderabad and Saharanpur Local named after the place of origin; white stemmed custard apple named after the part of plant.

Cultivars from Alexandria and Egypt

Beni Mazar

Round, large, fruit weight ranges from 150 to 180 g; 56-60% flesh; 15-30 seeds per fruit (Morton, 1987).

Abd El Razik

Light-green or reddish rind; nearly round, large, average fruit weight is 236.3 g; 69.5% flesh; 14 seeds per fruit (Morton, 1987).

Cuban Seedless and Brazilian Seedless

One is a seedless form ('Seedless') with seemingly identical selections from Brazil and Cuba ('Cuban Seedless' and 'Brazilian Seedless'). This form is not likely to be widely grown because the fruit splits very badly as it matures on the tree and fruit quality appears to be slightly inferior to most-seedling fruit. It is not as productive as the seeded types, is nearly identical in quality and flavor. Another "seedless" sugar apple was introduced from Brazil, which appeared to be identical to the Cuban variety (http://university.uog.edu/cals/ people/PUBS/Sweetsop/ MG33000.pdf). Some selected cultivars of sweetsop are presented in Table 1 and germplasm conserved at different centres are given in Table 2.

Flower biology

The flowers of sweetsop are hermaphrodite and are produced singly or in small clusters on the current season's growth. The flower buds start appearing on new shoots in the spring, immediately after the commencement of the vegetative growth. The flowering period in sweetsop was from the middle of April to end of June. The average time from visible flower initiation to full flowering was 30.8 days (Nalawadi *et al*., 1975). Anthesis took place continuously throughout the day and night. Anthesis commenced at 6.00 AM and continued up to 6.00 PM, with its peak at 6.00 AM under Dharwar condition, between 5.30 and 6.30 AM under Bhubaneshwar (Sahoo *et al*., 2000) whereas anthesis occurs at 5.00 AM in Brazil (Ribeiro *et al*., 2007). Kiill and Costa (2003) reported from Brazil that the anthesis takes place around 5.00 PM, the flowers last for approximately two days, and show female phase in the first twenty hours and male phase in the following twenty hours, characterizing dichogamy. Anther dehiscence commenced at 12.00 PM and was completed by 4.00 AM, with a peak at 2.00 AM (Nalawadi *et al*., 1975). The flower exhibits a protogynous dichogamy nature that limits self-pollination and cross-pollination can increase fruit set. Pollen grains appearing early in a flowering season have lower germination rates than the pollen from late flowers (Chen and Paull, 2008). The highest pollen germination was recorded between 18.9 and 20.4% in 20% sucrose for green and red type, respectively. The stigmas were receptive from one day prior to anthesis till 2-3 days after anthesis indicating a protogynous condition (Thakur and Singh, 1965; Sahoo *et al*., 2000). Nitidulid beetles, Carpophilos domidiahus and Carpophilos hemipterous were identified as pollinators in terms of visitation frequency, pollination potential score and pollination efficiency. However, Carpophilos hemipterous was relatively effective pollinator than Carpophilos domidiahus. Sweetsop clearly

Table 1. Some selected cultivars of sweetsop (Chen and Paull, 2008)

Country/region	Cultivars
Taiwan	Ruan-zhi, Cu-lin , Da-mu , Xi-lin and Tai-nong no.1
India	Balanagar, Mammoth, Arka sahan, Barbadose, Washington and Red Sitaphal
Thailand	Fai Kaew, Fai Krung, Nang kaew, Nang Sir Krung and Nang Thong
Florida	Lessard, kampong Mauve, Red Sugar, Cuban seedless
Egypt	Abd El-Razik

Table 2. Custard apple germplasm conservation under AICRP on Arid Zone Fruits

Sl.No	Centre	No. of collections
1	Ambajogai	28
2	Anantapur	72
3	Aruppukottai	14
4	Jadhawadi	30
5	Jhalawar	23
6	Rahuri	20
7	SK Nagar	40
8	IIHR, Bengaluru	20

exhibit obligate specialization by filtering only Carpophilos hemipterous and Carpophilos domidiahus as pollinators and thereby explicitly indicating canthrophilous pollination syndrome (Kundan *et al*., 2012).

Artificial pollination is frequently practiced to ensure pollination and good fruit shape. Hand pollination is normally carried out before 8.00 AM using a small brush. Pollen can be collected in the morning between 5.00 and 8.00 AM from fully open flowers, when the sacs have turned from white to cream. The collected pollen is used to pollinate half-open flowers whose pistils are already receptive (Jalikop and Ravindra, 2007).

Varietal evaluation

Several varietal evaluation studies have been carried out in various regions of India using different cultivars. Evaluation of sweetsop genotypes (APK-1, Mammoth, Balanagar) under sodic soil at Trichy, Tamil Nadu by Krishnamurthy (2009) showed superiority of APK-1 with regard to yield in nine years old trees which produced 47.78 kg per plant, followed by Balanagar (27.05 kg/plant).Thirty five germplasm of custard apple have been evaluated for scarce rainfall zone under rainfed at Anantapur, Andhra Pradesh by Dhanumjaya Rao and Subramanyam (2011) in 10 years old trees and the maximum yield have been recorded from MMR-10 (15.0 kg/plant). Girwani *et al*., 2011 evaluated sweetsop hybrids under Sangareddy condition and revealed that All the hybrids varied in fruit shape (round, conical and cordate), fruit colour (yellowish green, grayish green, light green and red), pulp colour (creamy white, light pink and white), areole shape (tuberculate, hexagonal) and texture (course, soft and meaty). Time of fruit maturity varied from September 2nd fortnight and lasted till the end of December. Hybrid-1 (17/4 Atemoya x Balanagar) was earliest to mature. Maximum fruit weight (250 g) was recorded in Hybrid-1 (17/4 Atemoya x Balanagar) followed by Hybrid-6 (15/3 Red Sitaphal x Atemoya) (225 g) and Hybrid-4 (1/6 British Guinea x Atemoya) (220 g). Among all the hybrids, maximum number of fruits per tree (94) was recorded in Hybrid-1 (17/4 Atemoya x Balanagar) followed by Hybrid-6 (15/3 Red Sitaphal x Atemoya) (67). The TSS ranged from 22 to 28°B and was found to be maximum in Hybrid-2 (15/2 Red Sitaphal x Pondapple), while the seed content per fruit was also minimum (20) in this hybrid. Based on overall performance the Hybrid-1 (17/4 Atemoya x Balanagar) and Hybrid-3 (15/3 Red Sitaphal x Atemoya) and Hybrid-2 (15/2 Red Sitaphal x Pondapple) were found to be excellent in quality with pleasant aroma, smooth pulp texture with less seed, good sugar acid blend and shelf life.

Breeding objectives

The first objective is the determination of the specific characteristics that are important for the new cultivar the ideo-type (Table 3). These characteristics may help a breeder to select parental groups to be used in an annona breeding programme, in order to obtain desirable progenies. These progenies may not have all desirable characteristics, but at least will have those most important to growers, retailers and consumers. For instance, a sweet sugar apple cultivar with long shelf life fruits (>5 days), which is important from a consumer's viewpoint, may not be selected, if it presents low yield (<20 kg/tree/year) and fruit weight lower than 400 g. Genetic improvement for yield is the most difficult and expensive of all breeding objectives, due to the complex nature of its inheritance and the numerous environmental factors influencing the trait. Quality is another important characteristic for the improvement of annonas, as important or sometimes more so than yield, since market value is based on the fruit's appearance and its organoleptic characteristics (Pinto *et al*., 2005).

Breeding strategies

Most *Annona* species and cultivars differ in environmental adaptation, productivity and fruit quality. Therefore, different conventional methods can be used in their breeding. According to Fehr (1987), there are three requirements for the development of an asexually propagated cultivar: a) a suitable source of genetic variability; b) evaluation of individuals from the population; c) asexual multiplication of a new cultivar for commercial use. Introduction of superior genotypes and/or cultivars to establish a germplasm collection is, basically, the first requirement of any breeding programme. This can be complemented by the introduction into the collection of some wild *Annona* species with useful genes, mainly for resistance to diseases. All accessions require comprehensive characterization and documentation, followed by evaluation and selection. Several types of populations can be developed by hybridization, from which superior clones are selected.

Selection and cultivar development

India and Taiwan have selected a few named cultivars of sugar apple from seedling population that are propagated vegetatively (Table 4). In Cuba, researchers developed 'Cuban Seedless', which is a seedless cultivar with medium-sized fruits, and another cultivar with low fibre content that is very important for the commercial market (Nakasone and Paull, 1998). In the Philippines, there are 3 forms of sugar apple fruits: (a) a green-fruited seedy form, which is grown in most parts of the country; (b) a purple-fruited seedy form, reportedly introduced from India; (c) and the green-fruited seedless form, which is a recent introduction and whose origin is unknown. The selection of superior strains is aimed in the direction of a green-fruited seedy form (Coronel, 1994).

Hybridization

Tri-species hybrids between *A. atemoya* x *A. squamosa* have been attempted by Jalikop and released one hybrid for commercial cultivation during 1997 in India which is a cross *A. atemoya* cv. Island gem x *A. squamosa* cv. Mammoth and named as Arka Sahan (Jalikop and Ravindra Kumar, 2007). Likewise, Girwani *et al*. (2010) also developed certain sugar apple hybrids at Sangareddy.

Modern biotechnology

The first haploid plants induced by anther culture in

fruit trees were reported by Nair *et al*. (1983) with sugar apple. The availability of haploids is very important for fruit-breeding, because of the long generation intervals, the highly heterozygous nature of most fruit species and the presence of parthenocarpy and self-incompatibility. These researchers obtained callus differentiation, and formation of triploid roots and shoots from sugar apple endosperm (Nair *et al*., 1986). Their aim was development of seedless fruits, but a complete plantlet was not obtained.

Furure thrust

- Development of seedless sugar apple varieties.
- Development of coloured sugar apple varieties.
- Development of sugar apple varieties resistant to Anthracnose and fruit fly.
- Production of double haploid in sugar apple.

Table 3. Main characteristics of sugar apple ideo-types (adult plants)

Characteristics	Sugar apple
Plant	
Vegetative vigour	Medium to low
Reproductive vigour(Yield)	High (>20 kg per plant)
Bearing	Regular
Rootstock / scion compatibility	High
Flower number	Abundant (> 180 flowers per tree)
Pollen fertility (20°C)	High (>76%)
Fruit	
Size / Weight	
For industry	Large / >400g
For fresh consumption	Medium / 300- 400 g
Shape	Rounded to Heart
Fruit set (naturally)	High (>25%)
Skin	Tuberculate
Pulp	Sweet , low fibre
Flavour	Pleasant acidulous
Seed number per 100g of pulp	Low or absent (<10 seeds)
Shelf life (15 to 30°C)	Long (>5 days)

Table 4. Some selections and cultivars of sugar apple which are currently grown in various countries (Pinto *et al*., 2005)

Cultivar/Selection	Country of origin	Cultivar/Selection	Country of origin
IPA selections	Brazil	Leone	Italy
Libby	USA	Madeira	Portugal
Lisa	USA	Mateus 1	Portugal
Mossman	Australia	Negrito	Spain
Ott	USA	Reretai	New Zealand
Whaley	Australia	White	USA
Molate	Philippines	Cuban Seedless	Cuba
Lobo	Philippines	Noi	Thailand
Red Sugar Apple	USA/Florida	Mammoth	India
Balanagar	India	Red Sitaphal	India

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