THE IMPACT OF BREEDING ON FRUIT PRODUCTION IN WARM CLIMATES OF BRAZIL[1]

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ABSTRACT-Brazil is a very large country with a diverse climate. This fact allows a diversity of plants to grow ranging from tropical rainforest in the Amazon, passing through Atlantic Forest along the coast, the *cerrados* (Brazilian savannah) in the Central West region, and semi-arid area in the Northeast. Latitude ranges from 5° N to 33° S, with most of this territory in the tropical region. There are enough reasons to plant breeders devoting great amount of their effort to improve plants suitable for warm climates, though. Among fruit crops, results of breeder's work have been noticed in several species, especially on peaches, grapes, citrus, apples, persimmons, figs, pears and others not so common, such as acerola, guava, annonas (sour sop, sugar apple, atemoya, cherimoya) and passion fruit. Peach tree introduced at low latitude (22 ± 2ºS) requires climatic adaptation to subtropical conditions of low chilling. In Brazil, the first peach breeding program aiming adaptation of cultivars to different habitats was developed by *Instituto Agronômico de Campinas* (IAC) beginning in the end of the 40's. Apple low chill requirement cultivars obtained in a South state, Paraná, are now been planted at low latitudes. Banana and pineapple breeding programs from Embrapa units along the country are successfully facing new sanitary problems. Petrolina/Juazeiro, in the Northeastern region (9°S), is the main grape exporting region with more than 6,000 ha. Grape growing in the region is based in the so called "tropical" rootstocks released by IAC, namely: IAC 313 'Tropical', IAC 572 'Jales'. Recently, Embrapa Grape and Wine released tropical grape seedless cultivars that are changing table grape scenario in the country.

Index Terms: temperate fruits, tropical fruits, tropical and subtropical climates, productivity.

O IMPACTO DO MELHORAMENTO GENÉTICO NA PRODUÇÃO DE FRUTAS EM CLIMAS QUENTES DO BRASIL

RESUMO-O Brasil, com suas dimensões continentais, apresenta grande diversidade de climas. Este fato permite o crescimento de grande diversidade de plantas desde a floresta tropical úmida do Amazonas, passando pela Mata Atlântica ao longo da costa, os cerrados, na região centro-oeste e nas áreas de semi-árido no nordeste. A maior parte do território encontra-se na região tropical onde a latitude abrange de 5° N a 33° S. Há, portanto, razões suficientes para os melhoristas de plantas devotarem boa parte de seus esforços para melhorar plantas apropriadas aos climas mais quentes. Entre as frutíferas, os resultados dos trabalhos dos melhoristas têm sido notados em diversas espécies, especialmente pêssegos, uvas, citros, maçãs, caquis, figos, pêras e outras, não tão comuns, como acerola, goiaba, anonas (graviola, pinha, atemóia, cherimóia) e maracujá. Pessegueiros introduzidos em baixas latitudes (22 ± 2ºS) requerem adaptação climática às condições subtropicais de baixa ocorrência de frio. No Brasil, o primeiro programa de melhoramento de pêssego visando adaptação de cultivares a diferentes *habitats* foi desenvolvido pelo Instituto Agronômico de Campinas (IAC) começando no final dos anos 1940. O melhoramento da macieira com baixa necessidade frio levado a cabo no IAPAR, Paraná, produziu cultivares que podem ser plantados com sucesso em regiões de baixa latitude. Os programas de melhoramento da banana e do abacaxi conduzidos em unidades da Embrapa em todo o país estão conseguindo fazer frente aos fortes problemas fitossanitários com as cultivares melhoradas. Petrolina/Juazeiro, na região nordeste (9°S), é a principal região exportadora de uvas no país com mais de 6.000 ha. A viticultura na região está baseada nos chamados porta-enxertos "tropicais" lançados pelo IAC: IAC 313 'Tropical', IAC 572 'Jales'. Recentemente, a Embrapa Uva e Vinho lançou cultivares tropicais de uvas sem sementes que estão mudando o cenário da uva de mesa no país.

Termos para indexação: frutas de clima temperado, frutas de clima tropical, novas cultivares, produtividade, fruticultura em clima quente.

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INTRODUCTION

Brazil is the world's third largest fruit producer, after China and India, with a harvested area surpassing easily 2.5 million hectares as shown in Table 1. Citrus, for instance, totalizes more than 800 thousand hectares, and banana, more than 490 thousand hectares, representing 52% of the total area (Ibraf, 2008). In spite of this large fruit production, which includes temperate, subtropical and tropical fruits, only 2.3% or 828 thousand tones are exported since the priority is the internal market. Banana, papaya, pineapple and mango are four of the most important tropical fruits cultivated in Brazil with a total area of 655 thousand hectares and a total production of approximately 12 millions of tones in 2005. The data show an increase on cultivated areas of these tropical fruits ranging from 15% to 58% and similarly an increase on fruit production ranging from 9 to 63% between 1985 and 2004/2005. In recent years fruits ranked fifth in the export ranking, with a 91% increase in sales, after ethanol, sugar, meats, coffee and grains. Brazilian fruit production is 41 million tons and among the exported fruits are bananas, melons, mangoes, lemons, coconuts, grapes, oranges, pineapples, cashew nuts, and Brazil nuts. There are more than 200 native fruit species in the Amazon, which account for 44% of the 500 Brazilian plant varieties that yield edible fruits. Many of these species are now being rediscovered in Brazil, and attracting the world's attention. The potential of Brazilian fruit production is undeniable, most notably in its irrigated form. Several positive factors account for these increases in fruit production which greatly influences a higher and stronger competitiveness of the Brazilian agribusiness (Pinto and Genu, 2006). Brazil has a remarkable production of other fruits which data are not quoted in FAO data bases although presenting areas of more than 10,000 hectares planted. Examples are acerola, guava (from 2005, guava data are presented in FAOSTAT together with those of mangoes and mangosteen), Annonaceae (sour sop, sugar apple, atemoya or custard apple, cherimoya) and passion fruit. Fruit farms today in Brazil are equipped with the latest technology with an aim to exporting by using plantation and harvesting methods approved by recognized international agencies (Faveret Filho et al., 2008). The results of these efforts can be seen in the export numbers. In 2007, Brazil exported 918,000 tons of fresh fruit, worth US$642,000,000 in comparison with 2000, when the country exported US$170,000,000, i.e., an increase of over 270% in seven years. The investments in research and development with direct results on new technologies and knowledge as well as the improvement on fruit quality and safety are the main factors involved in the process. There is no doubt, however, that the strong breeding programs in several areas highly contributed to this present situation, giving the necessary support for such incredible numbers. In this review, part of the work done by Brazilian research institutions will be discussed. It must be emphasized, however, that there are other breeding programs very successful in Brazil, releasing considerable number of improved fruit cultivars, such as Embrapa Temperate Agriculture. Nevertheless, the objectives of this review was to highlight fruit breeding programs devoted to warm climate regions, tropical and subtropical. Fruit species were divided into a number of almost subjective didactic items, grouping those where breeding work showed a clear marked influence on production, those whose breeding programs have considerable influence on production, and finally those where there are a noticeable breeding work, still needing production of new cultivars and/or acceptance of those already released.

FRUIT PRODUCTION WITH MARKED INFLUENCE OF BREEDING WORK

There is a number of fruit species cultivated in Brazil which production presents a marked influence of previous breeding work.

Peach

Peach (*Prunus persica* L.) has been cultivated during centuries in the Orient, Europe and Americas at high latitudes (30º and 50º, North and South), with 500 to 2,000 hours of temperatures below 7.2ºC. Typically from temperate climate, peach tree introduced at low latitude (22°S ± 2°) requires climatic adaptation to subtropical conditions of low chilling (Barbosa et al., 1997). In Brazil, the first peach breeding program aiming at adaptation of cultivars to different habitats was developed by *Instituto Agronômico de Campinas* (IAC) beginning at the end of the 40's (Barbosa et al., 1993). As a result, cultivar such as 'Tutu' and other old varieties from sixties and seventies had small fruit, green skin and/or late. From 1950 to 1990, many cultivars were released in São Paulo, Brazil. With better pomological characteristics and adequate evolution of peach orchards, these cultivars have been widely accepted by fruit growers in areas with 50-100 hours of chilling or less (Ojima et al., 1983, 1984, 1989). In the seventies,

crosses among nectarines and peaches led to segregation of intermediary color skin (between green and red), originating peaches with pink skin and earlier production (Ojima et al., 1985). Later on, intercrossing F1's or backcrossing to nectarines resulted in types with very red skin, large fruits, yellow and firm flesh. The breeding work allowed a range of possibilities to growers as shown in Table 2 (Barbosa et al., 1990). This fact allowed an increase in the area with peaches and nectarines in mild and warm climate areas (São Paulo and Minas Gerais, for instance), estimated in 4,000 hectares. Recently released cultivar 'Douradão' has been determinant to peach producing in areas never thought before (Barbosa et al., 2000). In 2007, new cultivars were released by IAC (Barbosa et al., 2007), being one yellow-fleshed clingstone peach selection from IAC for mild climates similar to those prevailing to the State of São Paulo (Chagas et al., 2007a), named BigAurora, and the other a new yellow-fleshed nectarine, named Aurojima, also for mild climates (Chagas et al., 2007b).

Guava

The figures on guava (*Psidium guajava* L.) in Brazil (Table 3), one of the major producers in the world, give a good idea on how growers are responding to market demand. Although the total area in production increased 45% from 1999 to 2004, in Northeast Brazil where guava is produced under irrigation and intensive technology, it increased 90%. Guava production in Brazil has increased 45% in the last 4-5 years although the Northeast region, with irrigation and applied high technology, shows an increase of almost 100% in the same period. In this particular case, improved varieties play a very important role, as newly released varieties, such as 'Paluma', were used to establish new orchards (Pereira, 1984). Pereira and Nachtigal (2002) in Brazil, at UNESP, Jaboticabal, started in 1976 a selection program of new cultivars, through the introduction and selection of seedlings originated from open pollinated American, Indian and Brazilian varieties of different provenance and local selections, leading to the obtaining of the cultivars Rica and Paluma. Since 1985, the second phase of guava genetic improvement is under development, with the goal of obtaining plants with favorable agronomic attributes and fruits that can be destined to industrialization as well as for consumption as fresh fruit.

Yellow Passion Fruit

The yellow passion fruit, *Passiflora edulis* Sims., is of high economic importance in Brazil and other countries. Two types of passion fruit are cultivated today – yellow passion fruit and purple passion fruit. While both passion fruits possess an oval shape and contain yellowish flesh with edible black seeds within, the yellow passion fruit is larger in size than the purple passion fruit and contains more fruit juice. However, the purple passion fruit is typically sweeter in taste than the yellow passion fruit. The first cultivars of the plant species were released by IAC in 1999, selected for fruit quality and larger yields. The IAC cultivars originated from nineteen open pollinated progenies, pre-selected from commercial orchards in São Paulo, Maranhão and Bahia, plus some introductions from Australia and Colombia (supplied by CENARGEN, EMBRAPA) (Meletti, 1999, 2001). Two mass selection cycles were applied. The best material in productivity, weight and fruit size, pulp color and total soluble solids (TSS) were intercrossed, recombined as intra-varietal hybrids F1 and F2; backcrossed to the best parent with large and elongated fruits. The best eight resulting combinations were tested in experimental fields of IAC for eight years (Meletti et al., 2000). As a result of this program, cultivars IAC-273 and IAC-277 were released for fresh fruit market, showing oval shape fruits larger and heavier than those obtained so far. Average yield is 45 t/ha and they have been cultivated in all Brazilian States since 2000. Cv IAC-275 was obtained as well, been the first with special characteristics for juice industry. It differs from others by having thin rind and internal cavity totally filled with an intense orange pulp, larger vitamin C content and an increase of 2° Brix in TSS, what gives a high pulp weight/fruit weight ratio. Yield reaches 50t/ha with a hand made complementary pollination. It is cultivated in a large scale in states of TO, MT, MS, PA and SP, been already presented in commercial fields of Colombia and Venezuela. Concentrated juice is superior in flavor and color and for this reason have been exported to Italy in 2006/2007 seasons. The meaning of this breeding work can be seen in the comparisons stated in Table 4. This IAC program released in 2005 the cv IAC-Paulista, a purple-redish passion fruit, much more prized in Europe due to its less acid (or more sweet) pulp. For this reason, it is destined for export purposes and is under cultivation as another commercial alternative to growers (Meletti et al., 2005). Although without visible results to the moment, there are many other successful yellow passion fruit breeding programs carried out at different regions of the country, such as the Amazon basin (Nascimento et al., 2003), central Brazil "cerrados" (Melo et al., 2001 and Junqueira et al.,

2006), Northern Southeast region (Viana et al., 2003, Gonçalves et al., 2007), São Paulo State (Oliveira et al., 2000 a and b). It must also be mentioned that some programs are using advanced techniques (Carneiro et al., 2002). Four new varieties of passion fruit obtained via a technique of genetic manipulation unheard of in Brazil are being grown on the campus of ESALQ/USP, at Piracicaba, SP, and at Universidade Federal de Viçosa (UFV), at Viçosa, MG. They are plants originating from a process called somatic hybridization, which makes possible the fusion of the cells of cultivated species with wild species that are resistant to various diseases mainly Passion fruit woodiness and cowpea aphid-borne virus. Very different from the interspecific hybrids used in agriculture, which are obtained by crossings, these have the sum of the number of chromosomes of the species used in the cellular fusion. Embrapa Cerrados released in 2008 three new yellow passion fruit cultivars (Castelões, 2008): BRS Gigante Amarelo (Yellow Giant), with high yield (42 t/ha in the first year), even under virus disease incidence. In the second year, yield drops to 20-25 t/ha. Fruits are bright yellow, with strong yellow pulp. It is tolerant to anthracnosis (*Colletotrichum gloesporioides*) and bacteriosis (*Xanthomonas axonopodis* pv. *passiflorae*), although susceptible to viruses, verrugosis and soil borne pathogens. BRS Ouro Vermelho (Red Gold) is the hybrid with the largest vitamin C content. Pulp is of a strong yellow color. Yield in the first year is around 40 t/ha without hand pollination. It is tolerant to leaf diseases including those caused by virus. BRS Sol do Cerrado (Savannah Sun) also has fruits with bright yellow color and strong yellow pulp. Productivity is similar to that of BRS Ouro Vermelho, 40 t/ha in the first year, without hand pollination, and 20-25 t/ha in the second year. It is tolerant to leaf diseases including those caused by virus (Passion fruit woodiness and cowpea aphid-borne virus), but susceptible to soil borne fungus diseases.

Citrus

Although not so well identified, citrus (*Citrus* spp.) breeding program has developed a very important role in orange and other citrus production in Brazil. Cultivars were developed initially based on natural mutations such as 'Natal', 'Baianinha', 'Westin', 'Piralima' (Moreira and Pio, 1991; Donadio et al., 1995). Other works take advantage from the occurrence of nucelar clones. Since 1938 IAC breeding program has released more than 100 million plants of premunized clones of cultivar 'Pêra' and other cultivars (Teófilo Sobrinho et al., 1988; Pio et al., 2005). Diseases are still the great challenge, for instance 'Tristeza' virus, CVC – *Xylella fastidiosa*, which indirectly contributed with the first description of the genome of an important disease agent. Lately, works are dealing with Greening disease. It must be said that despite a general decrease in the total citrus area in Brazil (Table 5) the area with other citrus such as tangerines, clementines, mandarines, lemons, and others (Pio et al., 1998, 2000). Cultivars Fremont IAC 543 and Thomas IAC 519, did not show any symptoms of alternaria disease so far, showing tolerance to it; they also present characteristics that please fresh fruit market. These varieties represent new option to growers, remembering that alternaria do attack Murcott and Ponkan, representing 80% of commercial plantings; this only fact allow grower to remain in the tangerine market, which represents 4% of citrus business in São Paulo State (Feichtenberger et al., 2005; Azevedo et al., 2007; Pio et al., 2006). Recently IAC and Embrapa are testing seedless varieties for fresh market, such as 'Nova' and 'Clemenules', adapting them to warm climates of São Paulo State (Pio and Borges, 2006). Efforts are also dispensed in other research centers such as Embrapa Cassava and Fruit Crops that recently released cultivars Salustiana CNPMF and Pineapple. 'Salustiana CNPMF' is a seedless table orange, released by Embrapa in 2004, originated from a nucelar clone of a seed from Florida. It has rounded crown 4,2m high. Pulp with intense orange color. Mid-season and high yield (40t/ha) (Passos et al., 2003). Orange 'Pineapple' was obtained through nucelar clone from seeds introduced from California. Pineapple is a variety with tall trees (3.6m), rounded top with a shape resembling a pineapple fruit, which gives the name to the cultivar. Fruits are medium sized, weighing 240g, bark lightly rough, non-uniform yellow color, yellowish pulp, juicy, 10.9% total soluble solids content and 0.9% titratable acidity. It is an early variety, harvested from March to June, and with a high yield up to 40 t/ha. Cv Pineapple is recommended in order to enlarge range of harvest in a year to attend juice industry. Ponkan is one of the most popular and prized tangerine for fresh market in Brazil. In São Paulo State its fruits ripen from April to August, creating an excessive production, reducing prices and, consequently unstimulating growers. Fruits of cultivar Span Americana IAC 595 are quite similar to the traditional 'Ponkan'; it shows very early ripening, and fruits can be harvested two months earlier than Ponkan allowing sells anticipation in fresh fruit market (PIO et al., 2001).

FRUIT PRODUCTION WITH CONSIDERABLE INFLUENCE OF BREEDING WORK

Grape

Grapevine (*Vitis* spp.) is planted in less than 70,000 hectares in Brazil (Table 6), been almost all grape (more than 90%) produced in the South region destined to wine production, while more than 98% produced in the Southeast is for fresh consumption (Pommer, 2003). In the Northeast region grapes are produced mainly for exportation (more than 90%) as table grapes (Terra et al., 1994; De Leão and Soares, 2000). In the last 15 years total area in Brazil increased by a 16.5% rate and by a 292% rate in Northeast region, as a result of good profits. Grapevine is cultivated in Brazil from 30°S up to 5°S (Boliani and Corrêa, 2001). Petrolina/Juazeiro, in Northeast Brazil, is the main grape exporting region with more than 6,000 ha (Pommer, 2006). Grape growing in the region is based in the so called "Tropical" rootstocks released by IAC, namely: IAC 313 'Tropical' and IAC 572 'Jales' (Santos Neto, 1955; Sousa, 1996). Recently, almost all new plantings (with seedless varieties) are being grafted on IAC 766 'Campinas'. In Brazil, the first grapevine crosses were made in 1889 but a consistent program was the one initiated by Santos Neto, at the IAC, in 1942 and extended for almost half century (Pommer et al., 2000). Results with progenies obtained from about 300 crosses performed from 1978 to 1985, showed that the choice of parents was towards the two main cultivars of the Brazilian table grape industry, 'Niagara Rosada' and 'Italia'. 'Madalena' and 'Jd 930' were chosen for their marked muscat flavor. 'A Dona', 'Maria', 'Iracema' and 'Aurora' were included due to their seedlessness. Large numbers of American grapes or their hybrids were also used as parents. Recently, this same program has released IAC 'Juliana', white table grape with muscat flavor (Pommer et al., 2002). The genetic grape breeding program conducted by the Brazilian Agricultural Research Corporation - Embrapa - aims at the development of new cultivars, which combine the characteristics of adaptation, productivity, resistance to diseases and quality of the grapes (Camargo, 2000). Embrapa released in 2003 new seedless grape cultivars: BRS Clara, originated from the cross CNPUV 154-147 x Centennial S. It has conical clusters, sometimes with shoulders; elliptical yellowish berries, large seed trace, firm and crispy flesh, light muscat flavor, high soluble solids content (20° Brix). Using growth regulators: clusters with 500 to 900g, berries from 16.3 to 18.0mm Ø, yield 30 t/ha. BRS 'Morena', originated from the cross 'Marroo Seedless' x 'Centennial S'. It presents conical-cylindrical clusters; elliptical berries, bluish, firm and crispy flesh, very nice neutral flavor, with good sugar/acid ratio, high soluble solids content (18 to 20°+ Brix, in average). Using growth regulators: clusters with 470 to 650g, berries from 19.6 to 20.0mm Ø, yield 20-25 t/ha. BRS 'Linda', from the cross CNPUV 154-90 x 'Saturn', it has large conical-cylindrical clusters, elliptical greenish berries, neutral flavor (15° Brix), low acidity, firm and crispy flesh. Using growth regulators: clusters with 700 to 1000g, berries from 19.9 to 24.0mm Ø, yield 30 t/ha in average. All were tested on rootstocks IAC 572 & IAC 766 (Nachtigal et al., 2004). Among these three, BRS 'Clara' is being planted in many states with warm climate (ES, MG, PE, BA, CE, RN, RJ).

Papaya (*Carica papaya* L.)

Brazil is the largest grower and exporter of papayas (Brapex, 2007); the largest plantations are in the states of Bahia and Espírito Santo and in the northeastern area of the country. The climate of these regions makes it possible to produce, pick and offer the consumer papayas year-round (Dantas et al., 2002). The constant sun and modern planting techniques (conserving the environment by employing extremely low levels of agricultural chemicals) make it possible to offer high quality, healthful fruit. In the last years new improved varieties began to act as another important factor in the success of Brazilian papaya (Yamanishi et al., 2002). Brazil harvested about 1,500,000 tons of papaya in an area of almost 35,000 hectares in 2007 (Table 7). Until recently all this production was based on the cultivation of hybrids of Chinese origin of the Formosa group and Hawaiian cultivars of the Solo group (Pereira, 2003). Currently the North of Espírito Santo State accounts for 69.7% of the national exportation for fresh consumption (Brapex, 2007) in the United States, Singapore, Hong Kong, China, Japan and Canada (Rangel et al., 2002). A small number of Brazilian papaya cultivars was recently released such as 'Baixinho de Santa Amália' (Fonseca & Censi, 2000) and 'Golden' (Censi & Fonseca, 2000). 'Baixinho de Santa Amalia' (a natural mutant of the 'Sunrise Solo' cultivar), is a dwarf cultivar flowering early and not high up in the plant. 'Golden' is another mutation of 'Sunrise Solo', which was also selected by Caliman S/A, in Linhares, Espírito Santo. None of these cultivars, however, is comparable to the outstanding hybrid UENF-Caliman01 (Marin et al., 2006). It is a hybrid obtained from a cross between a progenitor of Formosa group

and a progenitor of Solo group (Pereira et al., 2004). The hybrid presents phenotypical characteristics of the Formosa group with elongated fruits in the hermaphrodite plants with average weight of 1.25 kg, presenting a red and firm pulp with high content of soluble solids, good flavor and quite pleasant aroma (Marin, 2001). The State University of North part of Rio de Janeiro – UENF - has initiated in 2000, a program of papaya genetic improvement, supported by FINEP and in partnership with Caliman S.A. Following genetic procedure of Partial Diallel crossings 64 F_1 hybrids were obtained, involving all of the possible combinations among eight progenitors of Solo Group and eight progenitors of the Formosa group, besides selfing the 16 parents. The eighty genotypes were evaluated in field conditions, and nine hybrid combinations came up with qualitative aspects and uniformity, superior to the hybrid commonly planted until then, 'Tainung-01' (Yamanishi et al., 2002). More important than the fruits exportation is the economy that the variety developed by UENF will allow to the country. Up to now all Formosa papaya orchards were planted with imported seed of Taiwan, in Asia. Loss in balance of trade can reach approximately US$ 2 million annual. Producing the seed in the country, Brazil will also stop importing diseases. According to Pereira (UENF/LMGV) (Pereira, 2004, 2005) project coordinator, exist approximately 10 thousand hectares of Formosa papaya planted in the country. This whole area represents a demand of 500 kg seeds/year—potential size of the market for the variety produced by UENF. The most interesting characteristic in the hybrid papaya is the quality. The fruit has a better flavor, around 20% more soluble solids, in other words, it is tastier. Brazilian production of Formosa papaya is about 600 thousand tons a year. Average yield in the country is of 60 tons/ha, but cultivations well handled can get even the double — with the Brazilian seed or the imported one (Cattaneo, 2001). Only very few years after being released, UENF Caliman 01 hybrid, called 'Calimosa', is already cultivated in approximately 200 hectares and this area is fast growing thanks to the efforts of Caliman in producing and distributing seeds. Marin et al. (2005) selected 14 papaya genotypes to be used as parents, separated in two groups of seven, representing cultivars from Solo and Formosa groups, installed in crossing blocks from 2002 to 2005 at Linhares, Espírito Santo. Traits studies were plant height, insertion height of the first fruit, stem diameter at 60 cm height, number of fruits per plant, total fruit production, fruit weight, and volume of ovarium cavity, total soluble solids, pulp color, and fruit taste. Hybrid combinations 1 to 6 showed the best performance in relation to those characteristics and can be important alternatives to the cultivation of papaya Formosa hybrids. Hybrid number 1 showed the best values for fruit production, number of fruits per plant, total soluble solids content, and pulp color and taste, and also presented the highest fruit weight. Hybrids 2 to 6 showed an average weight between 1.6 and 1.9 kg what turn them viable to international market. As presented at Papaya Brasil (Papaya Brasil, 2007), research with this fruit at Incaper, Espírito Santo, aimed to evaluate papaya genotypes of Solo group to obtain high yielding material with quality fruits; they also evaluated 11 papaya genotypes and concluded that cultivars Sunrise Solo 72/12, common Sunrise Solo and hybrid Tainung 02 showed best quality for export purposes. Also in Espírito Santo State, Cattaneo (Papaya Brasil, 2007) among 60 genotypes obtained through selfing selected 23, with at least 10 of them having same yield or superior to hybrid 'Tainung 01'. At Universidade Estadual do Norte Fluminense (UENF), Rio de Janeiro, Pereira et al. (Papaya Brasil, 2007) study with papaya improvement proceeds with development of new hybrid combinations with better yield and quality, development of inbred lines to be recommended to growers or used in obtaining new hybrids as well as sex conversion of genotypes assisted through DNA markers; increasing of genetic variability through hybridizations and studies on floral biology. At Embrapa Cassava and Tropical Fruits, Bahia, studies with papaya are being done by Cruz et al. (Papaya Brasil, 2007) including development of 14 inbred lines submitted to 5 or 6 selfing generations started with material from germplasm collection, used to obtain new hybrids. Identification of resistance sources to *Phytophthora palmivora*, which were found in three accessions, now in use in a recurrent selection program; implementation of germplasm collection; development of new molecular tools; evaluation of genetic transformed papaya genotypes; since 2007 experiments were installed in field conditions to agronomic evaluations and biosecurity analysis of two events of GM papaya resistant to virus. At the Espírito Santo State, Cattaneo et al. (2007) evaluated 23 genotypes originated from the Incaper papaya breeding program compared to two commercial hybrid cultivars as control 'Tainung 01' and 'Caliman 01'. Genotypes evaluated showed promising agronomic performance and several of them can be recommended to commercial crop due to their superior fruit production and fruit weight around 1.2 kg.

Pineapple

With a succulent pulp that can range from sweet to acid, pineapple (*Ananas comosus* L.) was worshipped by kings and queens of Europe at that time of the colonial expansion. Called pineapple by the native Guarani, it was the iuaka´ti" denomination, however, that ended for originating the word pineapple (*abacaxi*) in Portuguese. The different consumption forms, in natura, as jellies, pies, drinks and beverages, among other, turns pineapple one of the elect among the tropical fruits. From 2001 to 2005, Brazil ranked as number one in world pineapple production, with more than 2 million tons (2,145,027 to 2,292,470) (FAO, June 2006). At present time, Brazil is the third largest pineapple producer of the world, with a production of 1.6 billion fruits, obtained in a planted area of 60,988 hectares (IBGE, 2008). The most complete program of pineapple genetic improvement in Brazil is the one carried out by the Embrapa Cassava and Tropical Fruit since 1978 (Cabral et al., 2007). According to these authors, the objectives of that program are to develop pineapple cultivars resistant to fusariosis disease, major problem of the pineapple crop in Brazil, with good fruit quality and spineless leaves. Research done led to establishment and maintenance of the Pineapple Active Germplasm Bank, composed by 627 accessions under field conditions and 146 accessions under in vitro preservation (Matos and Cabral, 2006); development of a technique for early evaluation of pineapple resistance to fusariose based on artificial inoculation; recommendation of the cultivars Primavera and Perolera, both resistant to fusariose. Moreover, the model of genetic heritability was determined and currently studies related to selection of molecular markers to identify resistant genotypes at seedling stage are under conduction. From 2002, backcrosses and crosses between selected hybrids were done and the progenies obtained are under evaluation. Several self pollinated genotypes were obtained from the cultivars Perolera, Primavera, Roxo de Tefé and Smooth Cayenne being now under evaluation (Cabral et al., 2007). The program already obtained and released two varieties: 'Imperial', in 2003, and 'Vitória ', in 2006, in a joint venture with Incaper - Capixaba Institute of Research Technical Assistance and Rural Extension. Both cultivars are resistant to fusarium disease, one of the most limiting for pineapple culture in Brazil (Ventura et al., 2006). An arduous work was done to develop those two varieties, being necessary at least seven years of research to reach to the genotype that should be, then, appraised in the main pineapple producing areas of the country (Matos and Cabral, 2006). As a result of the program of pineapple genetic improvement developed there are six more hybrids that showed resistance to *Fusarium* and presented other favorable characteristics in Cruz das Almas conditions. Those new hybrids are now under regional evaluation, fundamental for the validation and release of new varieties. Genetic improvement is a fundamental activity when intended to maintain the sustainability of the cultivation of important species. With this effort it is possible to guarantee new varieties for the different markets demand. It is like always having a new alternative to solve emerging new problems. Among other studies, the collection also allows diversified use, for instance, exploring pineapple plants for ornamental use (Souza et al., 2007a and b). Pineapple cv Imperial, cultivar originated from a cross between 'Perolera' x 'Smooth Cayenne' was released in April/May 2003 by Embrapa, tested in several Brazilian States showing resistance to *Fusarium* disease caused by *Fusarium subglutinans*, responsible for losses greater than 80% of total production (Cabral and Matos, 2005). It is a protected cultivar. Pineapple cv Vitória, is a cultivar derived from recurrent selection applied to the hybrid PRIxSC-08 originating access EC-099, selected as the new variety and released in November 2006 by Incaper, in Sooretama, ES. It showed resistance to *Fusarium* disease caused by *Fusarium subglutinans* f. sp. *ananas*, responsible for losses greater than 80% of total production (Table 8) (Ventura et al., 2006). In São Paulo State, pineapple breeding program has started in the 70's (Giacomelli and Py, 1981; Giacomelli and Teófilo Sobr., 1984) and experienced a new phase started in 1991 (Spironello et al., 1994). Variety IAC Gomo-de-mel was selected and released for its excellent pulp qualities (very sweet, low acidity, soft, golden yellow color and detachable fruitlets). It was introduced from China in 1991 and released by IAC in 1999 (Usberti et al., 1999). There are at least two areas of about 10 ha each, one in Bahia State and another in Tocantins State, plus several small areas spread all over the country, but its potential is low due the high susceptibility to fusariosis. Several other hybrids were developed, increasing the number of entries in IAC germplasm bank. The outstanding one will be released soon and named IAC Fantástico, already registered. It resulted from a random cross between variety Tapiracanga (female parent) and cv Smooth Cayenne. Previously, all pineapple industry was based on old varieties such as 'Boituva', 'Cabeça-de-onça' and 'Primavera' (Ritzinger, 2000); not so many years ago, 'Perolera' was introduced, but even

so, practically only 'Pérola' and 'Smooth Cayenne' were cultivated in almost all regions (Reinhardt et al., 2002 and 2006). Recently, Del Monte Gold (MD-2) was introduced and is now under cultivations in Northeast Brazil and in the Espírito Santo State.

Cashew

Cashew (*Anacardium occidentale* L.) is explored in an area of 700,000 ha in Brazil, 94% concentrated in the States of Ceará, Rio Grande do Norte and Piauí (Northeast). More than 15,000 hectares were already submitted to crown renovation, grafted with dwarf cashew plant scions, especially CCP 76 clone (Barros, 2000; Paiva et al., 2003). This procedure allowed a sensible gain in nut production, besides the easiness in orchard treatments due to earliness and lower plant height. Cashew dwarf clones most cultivated in Brazil (CPC 06, CPC 09, CPC 76 and CPC 1001) were obtained through selection made by EPACE (Ceará Research Agricultural Enterprise) on natural populations of the Brazilian Northeast coastal region and introduced at Embrapa Experimental Station, in Pacajus, Ceará State, followed by phenotypic individual selection (Paiva et al., 2007; Paiva et al., 2005;). Subsequently, new methodological procedures, as the policross method, selection among and within progenies and inter- and intra-specific hybridization, resulted in the development of dwarf cashew clones Embrapa 50, Embrapa 51, BRS 189, BRS 226 and 265. Clone BRS 226 resulted from phenotypic selection in commercial orchards of Piauí State, in the matrix plant MAP-42 (Barros et al., 2005; Paiva, 2005). Recently, Embrapa Tropical Agroindustry released two new clones: BRS 274, the first clone of common cashew for commercial planting, and BRS 275, the first hybrid cashew clone, obtained from a cross between common cashew and dwarf cashew clone (CPC 1001). BRS 274 was obtained through phenotypic selection of a mother plant of common (giant) cashew in a segregating population, followed by cloning. On the other hand, BRS 275 was obtained through phenotypic individual selection within a controlled pollination progeny from a cross between a dwarf early cashew clone CCP1001 and a common (giant) clone CP 12. Tables 9 and 10 present the average values for cashew nuts and cashew apples for some advanced clones. The expected yield, for the dwarf cashew under natural conditions is around 1.000 kg/ha of raw cashew and 10.000 kg/ha of cashew apple. Under irrigation it may reach 3.800 kg/ha of raw cashew nut and 30.000 kg/ha of cashew apple (Oliveira, 2008). The well established cashew breeding program at Embrapa continues to produce good results with new clones being released (Paiva, 2003; Paiva and Barros, 2004; Fernandes et al., 2005). Studies on genetics and breeding give the necessary basis to this program. Cavalcanti et al. (2007) estimated genetic parameters in an interpopulation of cashew using the REML/BLUP methods for vegetative growth, yield and nut quality traits. Results showed that plant height, canopy diameter, kernel weight and nut weight are under strong additive genetic control and do not present heterosis. The heritability of nut number and yield were higher in the broad rather than in the narrow sense. This indicates dominance and heterosis of these traits that should be adequately exploited in cashew breeding programs. Therefore, the best-suited breeding strategy to exploit heterosis is reciprocal recurrent selection using individual crosses between parents with high mean genotypic performance and high specific combining ability.

Banana

Banana (*Musa* spp.) is one of the three most important fruits produced in Brazil, reaching an area of half million hectares and almost 7 million tones (Table 11), distributed all over the country. The industry is based on a large number of types and cultivars belonging to different genomic groups (wild species *Musa acuminate*, AA, and *Musa balbisiana*, BB, with triploids and hybrids belonging to groups AAA, AAB, ABB, and AAAB). Although growers are used to the many diseases attacking the plant, in 1998 it was confirmed the occurrence of Black Sigatoka (Cordeiro et al., 1998) the most devastating disease for bananas. This fact has driven all breeders' attention for obtaining improved varieties resistant to Black Sigatoka, besides the other diseases. The major problem is to obtain a resistant variety belonging to the Cavendish group AAA, the most valued in the international market. At least, and up to the moment, IAC 2001, belonging to AAA Cavendish group is cited as having good degree of resistance to Black Sigatoka. Other varieties, mainly from Prata subgroup are mentioned as well: FHIA-18 (AAAB), Pacovan Ken ('Prata Ken'), Prata Zulu, Thap Maeo. Recently, Cordeiro et al. (2005) released a new resistant cultivar named 'Preciosa'. Preciosa variety (PV42-85), is a tetraploid of AAAB group, resulting from crossing of cultivar Pacovan (AAB) with diploid M53 (AA), created by the program of banana tree genetic improvement, executed by Embrapa Cassava and Fruit Crops. The variety was released in partnership with Embrapa Acre, destined, initially, to the cultivation by growers from Acre, where it showed resistance to Black Sigatoka. Before that, however, it was evaluated in several other

Brazilian ecosystems, standing out for its productivity, rusticity and resistance to the main diseases. More discerning evaluations on Yellow Sigatoka and Panama disease were driven in Embrapa Cassava and Fruit Crops experimental area, showing resistance to those two other diseases. Agronomic characteristics of 'Preciosa' were appraised in different ecosystems, standing out plant vigor and superior productivity to Pacovan. It presents high tallness, equivalent to the mother plant, and could be cultivated in populations varying from 1,111 to 1,667 plants/ha. Fruits, when ripe, present yellow peel, cream-colored pulp and sweet flavor, with low acidity. Due to its proven resistance to yellow and black Sigatokas and Panama disease, Preciosa variety constitute an excellent alternative for grower, with productivity up to 50% superior to cultivar Pacovan. When cultivated under irrigation and appropriate nutritional conditions, productivity should range 35-40 t/ha. Significant part of the history of banana breeding program held in Embrapa was presented in a review by Silva et al. (2001). Authors described the main factors related to the program: botanic classification, cultivars, origin and evolution of the banana, reproductive systems, sterility and partenocarpy, polyploidy, inheritance of characteristics. Authors emphasized that new resistant varieties were created to overcome problems caused by fungus, bacteria, virus, nematodes and insects, high stature and low productivity. The banana breeding program comprises: establishment, characterization and evaluation of wide germplasm collection, introduction and selection of clones, improvement through hybridization, mutation, somatic hybridization and also genetic transformation. The main results obtained were: the morphologic characterization of the germplasm, allowing the identification of promising genotypes and its recommendation to the producers; the obtainment of resistant tetraploid hybrid (Pome type) to yellow and black sigatokas and to Panama disease, with reduced stature and cycle and high productive; genetic improvement of diploid AA, whose pollen has been used in the improvement of the commercial cultivars and for the own hybrid diploid; the evaluation of the cultivars and hybrids in different ecosystems, allowing to identify potential cultivars to be recommended for several ecosystems; production of hybrids between Silk cultivar (AAB) and the diploid (AA) 'Lidi', through somatic hybridization. Along the recent years, other studies on banana breeding were presented. Lima et al. (2005) evaluated and selected new banana varieties with high productivity, good fruit flavor and resistance to most banana diseases, evaluating banana cultivars and hybrids in order to identify superior genotypes for productivity and disease resistance. The following characteristics are evaluated: plant height (cm); pseudo stem diameter (cm); number of living leaves during flowering; and at harvest number of fingers per bunch; bunch weight (kg); mean finger weight (g); finger length (cm); finger diameter (cm); skin thickness (mm); number of days from planting to flowering and number of days from planting to harvesting in the hybrids of Gros Michel (Calipso, Bucaneiro and Ambrosia); Yangambi (YB42-21 and YB42-17); Prata (ST42-08 and ST12-31) and Prata Anã (SH3640) and in the cultivars Pacovan (Prata Type) and Nanicão (Cavendish Type). The hybrids evaluated presented agronomic characteristics equal or superior to the corresponding varieties. The best hybrids of Prata, Yangambi and Gros Michel were ST12-31, YB42-21 and Bucaneiro, respectively. Tests in other regions were also presented as those by Ledo et al. (2008) who evaluated the performance of twenty genotypes of Musa sp., in the environmental conditions of the Low São Francisco River Basin, Propriá, SE, Brazil. A randomized complete block design with four replications and three useful plants per parcel was used. Growth and yield characteristics were analyzed during the first and second production cycles. Hybrids PV42-53, PV42-68, PV42-85 and FHIA-02 because of the bigger production and greater weight of the fruit, should be recommended for culture in the region. Hybrid FHIA-18 presented excellent agronomic characteristics, being an alternative to 'Prata Anã'. The hybrids Ambrosia and Buccaneer can be an alternative for Cavendish bananas, by showing great bunches and similar flavor. Hybrid YB42-07 could be an option for areas of 'Silk' banana culture in the region of Low São Francisco River, having potential to be set up as cultivar. Sixty-nine clones of Cavendish type bananas (49 Nanicão and 20 Grande Naine) collected in the States of São Paulo, Minas Gerais, Bahia and Santa Catarina were evaluated as stated by Silva et al. (2004). The results obtained showed medium variability in all the characteristics evaluated and five clones of Grande Naine (G.N. Taperão, G.N.Rossete, G.N. Willians, G.N. Magário, G.N. SC-074) and four of Nanicão (N. IAC Green Vault, N. Rossete, N. SC-0008 and N. SC-063) were selected for presenting superior characteristics. New cultivars are been continuously released as the one called Caipira, which original name is Yangambi km 5; it is from West Africa and was introduced in Brazil by Embrapa Cassava and Fruit Crops, and is a very adaptive plant, with pale-green-yellowish

pseudostem, with dark spots near to foliar rosette. Bunch is cylindrical and the male rachis has no bracteas. Fruits are short and thick showing a slightly sweetened taste, and can be fresh consumed or processed to flour and sweets. Its main agronomic characteristics are adequate for State of Amazon. From genomic group AAA, the plant is average to tall, vegetative cycle of 383 days, abundant suckering, bunch weight up to 40 kg, with more than 10 hands, and 360 fruits/bunch. It is an internationally recognized cultivar due to its resistance to the main diseases as black sigatoka, yellow sigatoka, Panamá disease and worm stem, although susceptible to moko and nematode. Banana breeding program of Embrapa (Silva et al., 2008) is based on hybridization between triploid and diploid improved cultivars, developed through diploid pre-breeding program, aiming to obtaining tetraploid cultivars with superior agronomic characteristics. Nowadays, the program is using modern biotechnological tools, including radiation, chromosome doubling, somatic hybridization, in vitro fertilization, transgenic and DNA-markers, and plant tissue culture to maximize genetic gains through selection generations. Using selection and hybridization procedures a number of cultivars have already being released and others are under evaluation in different places of Brazil. In recent years Embrapa Cassava and Fruit Crops have recommended banana cultivars Caipira, Thap Maeo, FHIA 18, Prata Graúda, Prata Baby (Nam), Pacovan Ken, Japira, Vitória, Preciosa, Tropical, Maravilha, Caprichosa, Garantida and Princesa. The main characteristics of these cultivars are presented in Table 12. Banana is an important fruit in the Brazilian Amazon region, and was always an issue of study by Embrapa Occidental Amazon. Silva and Souza (1999) evaluated the performance of banana cultivars, relative to production and diseases tolerance, under the environmental conditions of Manaus-Amazon region. Among the results ´Prata´, ´Prata-anã` and Ouro da Mata cultivars did not complete the yield cycle because of the yellow sigatoka disease. The best cultivars were ´Thap Maeo´, ´Nam´ and ´Caipira´, which presented bunch weight of 23.3 kg, 18.4 kg and 18.6 kg respectively. Tetraploid hybrids PV 03-44, PA 03-22 and JV 03-15 presented average bunch weight, during the first and second cicle, of 13.8 kg, 9.7 kg and 10.8 kg. Ten days after harvest, Caipira cultivar and ´PV 03-44´ hybrid presented the best evaluation of fruit quality. Studies with banana breeding and selection have been accelerated after the presence of black sigatoka disease (Pereira et al., 2002a and b). A number of papers presented results of banana cultivars facing this and other diseases, besides the usual agronomic and quality traits. Soon the first results appeared. Gasparotto et al. (2001) described Prata Ken cultivar, released in Northeast Brazil as Pacovan Ken. It is an AAAB tetraploid obtained from the cross between diploid M53 (AA) and cv. Pacovan (AAB), prata subgroup. It was obtained at Embrapa Cassava and Fruit Crops and selected as resistant to yellow sigatoka and Panamá disease. At Embrapa Occidental Amazon it was evaluated and selected for resistance to black sigatoka. It is a cultivar producing fruits with shape and flavor very similar to those from cultivars of subgroup prata. Pereira et al. (2004) discussed the use of Pelipita, also known as Pelipia, Lilimita and Banana Cacau, which is a triploid of ABB genomic group, subgroup Fig, which fruits must be consumed preferably after been cooked or fried or some other cooking preparations. It is a rough and tall cultivar, with good suckering, bunches weighing up to 40 kg and 10 hands. It is resistant to black and yellow sigatoka and Panamá disease. All the efforts of the banana breeding program at that institution led to the release of BRS Conquista cultivar (Pereira and Gasparotto, 2008). BRS Conquista was selected based on the number of viable leaves and severity attack of black sigatoka on leaf nr. 10 at flowering time, as well as the resistance to Panama disease evaluated through four consecutive cycles in a *Fusarium oxysporum* fsp. *cubense* natural infested soil and also considering the agronomic and commercial characteristics. It belongs to the AAB genomic group and was obtained from a natural mutation in a population of cv Thap Maeo at the experimental field of Embrapa Occidental Amazon. Besides that, BRS Conquista shows high yield, reaching 48 ton/ha/year. Mature fruits show light yellow color, cream color pulp, good sugar/acid balance (Table 13).

FRUIT PRODUCTION WITH ROOM FOR BREEDING WORK

Acerola (*Malpighia emarginata* DC)

Introduced in Brazil more than 50 years ago, the fruit received new incentives about 15 years ago thanks to the efforts of the Federal University of Pernambuco, being transformed since then in a commercial crop (Paiva et al., 1999; Ritzinger et al., 2003). Brazil today has an area of 11,000 hectares planted with acerola, producing 3,000 kg/ha and a total of 32,990 tons/year (mainly for juice processing). New acerola clones for juice processing, released by Embrapa Tropical Agroindustry in 2003, were selected among more than 90 plants picked in

commercial plantings and observed for several years (Paiva et al., 2003). The new varieties have lower plants and crowns that allow 'umbrella' shape formation: Apodi (BRS 235) with the highest yield and highest fruit weight; Cereja (BRS 236), showing highest vitamin C content; Roxinha (BRS 237), with the best crown shape (<pruning) and strong red-purple pulp color; Frutacor (BRS 238), presenting the high vitamin C and soluble solid contents; **'**Cabocla', a table acerola cultivar, released by Embrapa (Cassava and Fruit crops) in 2003, 'Cabocla' was selected from a population of more than one hundred entries (Ritzinger and Ritzinger, 2005). According to Carpentieri-Pipolo et al. (2002) the acerola breeding program at Londrina State University began in 1992 with the establishment of a clone orchard from selected genotypes collected in the north of Paraná state. UEL 3 -Dominga, UEL 4-Lígia, UEL 5-Natália cultivars were selected after five assessment cycles taking in consideration earliness, yield, vitamin C fruit content, pest and disease tolerance, fruit size and appearance. UEL 3-Dominga and UEL 5-Natália were outstanding for plant yield, vitamin C content and fruit size. UEL 3-Dominga cultivar presented an average fruit weight of 6.3g, vitamin C content of 2,906 and 1,250 mg/100g in unripe and ripe fruits respectively, acidity of 694 mg/100g and total soluble solid content of 9.2ºBrix. UEL 4-Lígia cultivar presented an average fruit weight of 7.85g, vitamin C content of 3,579 and 1,458 mg/100g in unripe and ripe fruits respectively, acidity of 1,110 mg/100g and total soluble solid content of 7.85ºBrix. UEL 5-Natália cultivar presented an average fruit weight of 7.47g, vitamin C of 3,134 and 1,098 mg/100g in unripe and ripe fruits respectively, acidity of 725 mg/100g and total soluble solid content of 7.6ºBrix. The authors indicated these three cultivars for planting in Paraná state.

Mango

Mango (*Mangifera indica* L.) breeding in Brazil is aimed at both cultivars and rootstocks breeding. As a result, many interesting new cultivars characterized in high fruit quality and very appealing appearance have been selected, although none of them are planted in sound areas (Donadio et al., 1996; Carvalho et al., 2004). As in any other perennial crop, in mango the adoption rate of new cultivars is also slow for obvious reasons. The low fruit set and long juvenile period affect evaluation, selection and releasing of hybrid cultivars. Additionally, the needs of large areas to evaluate the hybrid seedlings are expensive to maintain (Pinto et al., 2004b). In spite of the difficulties encountered in mango hybridization with controlled pollination, significant progress has been made in the recent past with regard to release of new Brazilian hybrid varieties. One possible reason can be pointed out as new techniques were improved as the one mentioned by Pinto (1995) by which means was possible to significantly increase the percentage of hybrids obtained in crosses (Table 14). Brazil has favorable climate and soil for mango growth and production. It is the major mango producing country in South America with cultivated area around 67.6 thousand hectares and production of 970 thousand tones (Pinto and Ramos, 2000). Northeast region is the most important producing area, representing 60% of the total cultivated area and 50% of the mango production. Brazil exported 94.2 thousand tons of mangos in 2001, which represents 60.8 million US dollars. Europe and North America, especially USA, are the major importers of Brazilian mangos. Cultivated area is around 79% concentrated on Tommy Atkins cultivar and the remaining area is planted with 'Haden', 'Palmer' and 'Keitt' and some Brazilian varieties, such as 'Espada', 'Rosa', 'Bourbon' and 'Ubá' (Pinto et al., 2004c). Due to this figures, efforts are been made by breeders to overcome difficulties. There are at least three different mango breeding programs in Brazil: at Embrapa Cerrados, Embrapa Cassava and Fruit Crops, and at the Agronomic Institute of Campinas (IAC) (Rossetto et al., 1997). Embrapa Cerrados studied fruit set success or compatibility among three genotypes: 'Tommy Atkins' and the Indian cultivars Amrapali and Mallika. Fruit set was studied weekly for six weeks. 'Mallika' had the lowest compatibility rate and 'Amrapali' x 'Tommy Atkins' had the best fruit set with 16.1% success (Pinto et al., 2004a). Embrapa Cerrados obtained cultivars Alfa, Beta, Roxa and Lita (Pinto et al., 2004b): Alfa - from the cross 'Mallika' x 'Van Dyke', semi-dwarf and high yielding, regular bearing, fruit 435 g, pink/red peel (Brix 16%, acidity 0,23%, ratio 70); Beta - from the cross 'Amrapali' x 'Winter', moderately vigorous and high yielding, irregular bearing, fruit 310 g, yellow peel, (Brix 24.8%, acidity, 0.16%, ratio 155); Roxa - from the cross 'Amrapali' x 'Tommy Atkins', moderately vigorous and medium yielding, regular bearing, fruit 287 g, purple reddish, very firm and fiberless pulp (Brix 19-21%, acidity 0.12%, ratio 158-175); Lita - from the cross 'Amrapali' x 'Tommy Atkins', vigorous and high yielding, regular bearing, fruit 414 g (Brix 18-20%, acidity 0.20%, ratio 90-100); Embrapa Cassava and Fruit Crops obtained cultivar 'Surpresa'. Two new mango cultivars, IAC 103 Espada Vermelha and IAC 109 Votupa, resistant to the mango wilt caused by the fungus *Ceratocystis fimbriata* were released

by the "Instituto Agronômico de Campinas" (IAC). 'Espada Vermelha' showed some resistance to fruit-fly (Rossetto et al., 2000). The cultivar Votupa showed high percentage of pulp, which was similar to the commercial cultivars Van Dyke, Tommy Atkins and Palmer (Rossetto et al., 2002). Mango breeding program for resistance to diseases and pests of the Instituto Agronômico de Campinas (IAC) (Rossetto et al., 1997) has two main objectives: (1) to obtain polyembrionic rootstocks resistant to the fungi *Ceratocystis fimbriata* which causes the mango-wilt. The first cultivar derived from this program, named IAC 100 Bourbon, was distributed to farmers on December 8, 1989. It is a resistant mutant of the popular table variety Bourbon, which had been almost eliminated by the mango-wilt. Two rootstocks resistant to the mango-wilt, IAC 101 Coquinho and IAC 102 Touro were distributed on January 12, 1994. Four new varieties, been two crowns, IAC 103 Mococa and IAC 105 Campinas and two rootstocks, IAC 104 Dura and IAC 106 Jasmin were distributed in 1998 and three other crown varieties, IAC 107 Tietê, IAC 108 Pindorama and IAC 109 Votuporanga in 2000 (Rossetto et al., 1997; Carvalho et al., 2004).

Pear

Brazilian pear (*Pyrus* spp) breeding program started at the Instituto Agronômico (IAC) by the end of 50's aiming to develop new cultivars with better fruit quality and well adapted to different areas of São Paulo State (SP). In Brazil, the majority of pear commercial cultivation is of the European type (Barbosa et al., 2003). However, there is a tendency of rapid increase of Asian pear crop in subtropical areas in the southeastern States. Therefore, new crosses among Asian (*P. pyrifolia* (Burm. f.) Nakai) and European (*P. communis* L.) pear cultivars were made in 1992 aiming to find interspecific hybrids for fresh market and industry (Barbosa et al., 2007). Ten years later, the breeding program selected two new hybrids: Alegria (fresh) and Limeira (processing) (Barbosa et al., 2007). 'Alegria' (Happiness in Portuguese) pear selection stands out for the exceptional fruit quality for fresh consumption; fruits are globose in shape, large (480g), gold-clear skin with a creamy pigmentation. Pulp is very juicy, although crispy and firm, with a very sweet and pleasant flavor (14ºBrix, pH 4.5). It is very early and can be harvested in the last weeks of December. 'Limeira' pear selection presents vigorous plants, of easy handling and produces 135kg of fruits annually, globose to oval-pyriform in shape, with a medium weight of 320g. When it ripens, the green-yellowish skin presents an intense russeting in 30 to 90% of its surface. Due to the special pulp type the fruit presents, which is very firm and sweet-acid flavor (15ºBrix, pH 4.1), this hybrid is qualified exclusively for processing industries. In preliminary tests, this pear showed great potential for processing as jellies, compotes and raisins, with a pulp/total weight ratio superior to 70%. Its crop happens from the beginning of February to mid March. These two hybrids are under regional trials and, depending on their ecophysiological behavior, they will be released to the commercial cultivation in subtropical-tropical climate regions of Brazil. Recently, IAC pear breeding program released two cultivars: 'IAC Princesinha' and 'IAC Culinária'. It is an excellent option for the European pear production in areas of subtropical climate, destined to the fresh market consumption (Chagas *et al*., 2007c; 2007d).

Apple (*Malus domestica* Bork.)

Despite the tropical and subtropical climate in most part of the country, Brazilian growers always attempt to grow apples even with no fully adapted cultivars. Area with apple has strongly increased in the last 30-35 years, but all plantings are restricted to the South, with more than 95%, and Southeast regions (Table 15). More than 95% of the area is planted with Gala and Fuji cultivars. Recently, due to release of some new cultivars with low chilling requirement, a few apple orchards are being established in some special areas in Southeast and even in Northeast regions. Fifty hectares have been planted in Bahia State, in 2004, in a region (Ibicoara), with 25° C maximum average temperature and 15° C mean temperature (Pacheco, 2007) despite the low latitude (13° 242 S, 41° 172 W) using cultivar Eva. This fact represents an important commercial window for growers, because blooming of Eva occurs in about the same date, around September, for the states of Paraná, São Paulo, Minas Gerais and Bahia, with the harvest starting in December up to January, when harvest of Gala begins. According to Hauagge and Bruckner (2002) several apple cultivars were obtained in Brazil, with the first breeding work performed by a grower, Albin Brückner, using seeds brought from Europe, back in 1932-33. He obtained 1356 pre-selected plants lowered to only 50 in juvenile phase. Among these he selected one named Bruckner or Brasil which allowed apple production in São Paulo and other states in the 60's and 70's. Since then, various apple breeding program were developed by official research institutions such as Instituto Agronômico de Campinas (IAC) in São Paulo, Instituto Agronômico do Paraná (IAPAR), in Paraná State, Epagri, in Santa Catarina, and Agriculture State

Department and Embrapa, in Rio Grande do Sul. The work done at IAC was initiated in 1953 and, as a result of the first phase of the program, a number of cultivars were released (Rigitano et al., 1975): Rainha (Golden Delicious X Valinhense) Paulista (Valinhense X Deliciosa), Delícia (Valinhense X Deliciosa) Bonita (Valinhense X Rome Beauty) Dulcina (Primásia X Valinhense) and Culinária (Valinhense X Rome Beauty) showing good fruit set. All these cultivars have a common characteristic that is not to show any dormancy in hot climates, but are responsive to plant growth regulators to break dormancy. Among these, Rainha was the only one to show some economic expression in São Paulo state, besides the fact of being used as pollinator for Gala cultivar in Paraná state (Hauagge and Bruckner, 2002). In a second phase, IAC released cultivars Galícia, Soberana, Centenária and Marquesa all of them with low chilling requirement (Campo Dall'Orto et al., 1987). Due to the area increase in Southern Brazil, apple cultivation in São Paulo reduced drastically with the corresponding low interest in research for better cultivars (Hauagge and Bruckner, 2002). In Brazil, states as Rio Grande do Sul and Santa Catarina devoted efforts to develop new apple cultivars, but due to the climate of the region, low chill requirement cultivars were not their main objectives, as it was in Paraná State with an intermediate climate. In the program of this state, scientists tried to use parents as Anna and Dorsett Golden which are far superior to any other in relation to Low Chilling Requirement (LCR). Apple breeding program at IAPAR, government research institution of Paraná State was started in 1979 with emphasis in cultivar development, introduction and development of germplasm (Hauagge and Bruckner, 2002). Main objectives of the program are LCR (for regions with less than 400 CU), high yields, early maturation, high fruit quality, and resistance to diseases such as glomerella leaf spot and scab. Many cultivars were released among them IAPAR 75-Eva, IAPAR 76-Anabela and IAPAR 77- Carícia, well adapted to regions with 100 to 500 CU and showing commercial possibilities in Brazilian market from December (Hauagge and Tsuneta, 1999). Among these, 'Eva' is the only one with increasing area showing potential as an option for subtropical areas. Eva is a low chill early apple variety developed at IAPAR, Curitiba, Brazil, from the cross between cultivars Anna and Gala (Hauagge and Tsuneta, 1999; Iapar, 2004). It is capable to produce quality fruit in warmer areas where apples were not growing before. It will break dormancy and produce naturally in locations that accumulate at least 250-400 chill units during the rest period. However, will perform well even there is no chill accumulation, with the aid of dormancy breaking agents. Eva is a highly productive variety, up to 100 tons/ha in the Center-South areas of Paraná State, Brazil. It is a bicolor apple, and resembles Gala in appearance. Fruit set is impressive high, and it needs heavy thinning for sizing. It responds well to chemical thinning agents, but for such it is necessary to promote a concentrated blooming period. Use of pollinator will increase productivity, both fruit shape and quality. Average fruit size varies between 120-160 grams, and depends on the thinning intensity. It is sweet, with balanced acidity. Harvesting stage is when background color becomes from greenish cream to light cream color. Fruit harvested too early have high quantity of fibers and it decreases fruit quality. It may be stored for up to 60 days. It is an early variety, and for this it should be commercialized immediately. In Brazil Eva has a wide adaptation, and it is cultivated since the extreme south in Rio Grande do Sul to the tropics in Pernambuco. It is already grown in many Countries in South America, Africa and Middle East, in similar climates. In some experimental conditions it was possible to produce up to two crops a year (Hauagge, 2008). Recently and complementing the excellent work, the same program released the apple cultivar IPR 'Julieta' (Hauagge, 2007; Mattiaso, 2008). Obtained from the cross Anna x Mollie's Delicious, in 1979, it was tested since 1995 in several Brazilian climates in the states of PR, SP, MG, and RS. It is partially self-fertile and recommended as pollinator for IAPAR 75-Eva cultivar. Very early, producing large (averaging more than 150g) and attractive fruits with excellent taste. IPR 'Julieta' is resistant to apple leaf-spot disease, more or less tolerant to powdery mildew, scab, and mites.

TABLE 1- Area harvested (hectares) with fruits in Brazil from 1990 to 2007.

Fruits	1990	1995	2000	2001	2003	2005	2006	2007
Avocados	17,385	13,441	12,699	11,833	10,053	11,548	11,548	10,500
Bananas	487,883	509,365	524,750	510,290	509,588	491,180	504,074	508,845
Cashew apple	551,844	647,499	580,000	590,000	598,000	600,000	600,000	600,000
Coconuts	213,908	242,549	264,311	273,338	280,382	290,515	280,158	273,459
Figs	3,295	2,249	2,805	2,904	3,109	2,911	2,911	3,100
Oranges	912,996	856,419	856,422	824,665	836,041	805,665	802,820	799,356
Tangerines, mandarins, clementines	44,926	50,319	61,513	63,328	64,999	61,000	61,000	61,000
Lemons and limes	40,400	40,147	50,323	49,371	50,950	50,266	50,266	50,400
Grapefruit (inc. pomelos)	2,650	3,100	3,500	3,500	3,600	4,000	4,000	4,300
Grapes	58,663	60,810	59,788	63,273	68,432	73,203	73,988	76,426
Guavas, mangoes, mangosteens	45,303	56,502	67,590	67,226	85,710	84,449	84,449	89,800
Papayas	16,012	32,926	40,202	35,299	36,244	32,559	32,559	36,700
Peaches and nectarines	20,029	20,258	22,039	23,129	24,507	23,794	23,794	24,200
Pears	2,190	2,238	2,073	1,948	1,784	1,759	1,759	1,800
Persimmons	3,960	4,819	6,230	6,900	7,472	8,309	8,309	8,600
Pineapples	33,167	44,384	60,406	62,597	57,986	61,787	61,326	64,615
Fruits (exc melons)	2,298,607	2,420,169	2,429,685	2,382,357	2,428,603	2,386,499	2,397,387	n.a.

Source: FAOSTAT, 2008.

TABLE 2 - Earliness of a number of peach and nectarines available to Brazilian growers (Barbosa et al., 2000, adapted).

Earliness	Cycle days	Harvest months	Cultivars
I. Ultraprecocious	≤ 74	August	Fla.7-3
II. Very precocious	75-90	Sept-Oct.	Flordaprince, Tropical, Maravilha
III. Precocious	91-120	October	Douradão, Aurojima, and groups Jóia, Dourado and Aurora
IV. Mid season	121-150	Nov.-Dec.	Canário, Cristal, Talismã
V. Late	151-180	Dec.- Jan.	Biuti, Rei da Conserva
VI. Very late	≥181	Jan.-Feb.	Bolão

TABLE 3 - Guava in Brazil: evolution of planted area (hectares).

Brazil	1999	2000	2001	2002	2003	2004	2005	2006	2007
Country	12,975	14,354	14,387	16,066	17,776	18,826	16,399	15,045	15,069
North	213	338	202	257	244	443	487	535	531
Northeast	5,026	5,428	5,738	7,355	9,138	9,543	7,331	6,654	6,734
Southeast	6,004	6,901	6,729	6,514	6,496	6,891	6,706	6,067	6,168
South	900	892	873	1,012	1,037	1,005	946	988	953
Middle-West	832	795	845	928	861	944	929	801	683

Source: IBGE, 2008.

TABLE 4 - Comparison of some characteristics of yellow passion fruit in Brazil (average data) and those from improved material of IAC program (Meletti et al., 2000).

Traits	Brazil	IAC 275	IAC 277
Fruit weight avge.	90-100g	180g	>160g
Fruit shape	Variable	Oval	Oval
Skin	Thick	Thin (< 5mm)	Thin (5-6mm)
Yield	10-15t/ha	> 45t/ha	35-45t/ha
Pulp color	Light yellow	Intense orange	Yellow-orange
Pulp weight/total weight	33%	52%	49%
Total soluble solids	13°Brix	15-18°Brix	13-16,6°Brix

TABLE 5 - Area planted (hectares) with citrus (oranges, tangerines and lemons)in Brazil, from 1990 to 2007.

Brazil and Regions	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007
Brazil	999,332	953,191	970,883	940,202	947,211	953,066	936,373	918,436	921,432	927,253
North	10,633	22,138	21,129	20,401	20,423	19,569	20,341	21,225	21,514	20,635
Northeast	78,961	104,409	119,316	117,690	120,103	118,064	124,589	124,087	134,799	129,062
Southeast	852,701	748,654	736,171	708,650	713,090	725,023	704,963	686,945	677,716	686,939
South	49,300	66,363	83,074	82,230	81,602	80,042	76,940	77,119	77,535	80,670
Middle-West	7,737	11,627	11,193	11,231	11,993	10,368	9,540	9,060	9,868	9,947

Source: IBGE, 2008.

TABLE 6 - Area (hectares) with grape cultivated in different Brazilian regions.

Brazil and regions	1990	1995	2000	2005	2006	2007	W/T
Brazil	58,764	61,339	59,838	73,222	75,385	78,325	W/T
North	-	-	-	27	29	33	-
Northeast	1,759	4,871	5,339	8,712	9,228	9,970	T
Southeast	9,510	10,371	11,237	11,878	11,341	12,006	T
South	47,494	46,076	42,930	52,277	54,467	55,994	W
Middle-West	1	21	332	328	320	322	T

Source: IBGE, 2008; Authors: W/T shows predominance of wine (W) or table (T) grape growing.

TABLE 7- Area planted with papaya in Brazil (1990 to 2007).

Brazil and regions	1990	1995	2000	2005	2006	2007
Brazil	16,130	34,128	40,448	33,210	37,060	34,973
North	2,368	2,974	3,370	3,061	3,681	3,361
Northeast	8,849	23,579	29,303	18,968	22,242	21,668
Southeast	4,118	6,883	6,968	10,534	10,350	9,123
South	589	466	490	397	418	411
Middle-West	206	226	317	250	369	410

Source: IBGE, 2008.

TABLE 8- Main characteristics of Vitória pineapple cultivar.

Characteristics	Cultivars		
	Vitória	Pérola	Smooth Cayenne
Reaction to Fusarium disease	R	S	S
Leaf type	Spineless	Spines	Partial
Slips/plant	4.2	7.4	3.7
Fruit weight (g)	1427	1309	1543
Fruit shape	Cylindrical	Conical	Cylindrical
Fruit color	Yellow	Green	Orange
Pulp color	White	White	Yellowish
Total Soluble Solids (°Brix)	15.8	13.2	14.0
Titratable Acidity (%)	0.8	0.5	0.7

Source: Ventura et al., 2006.

TABLE 9- Main nut characteristics of cashew clones (Barros et al., 2005; Paiva, 2007).

Characteristics	BRS 265 Pacajus	BRS 274 Jacaju	BRS 275 Dão
Nut weight(g)	12.5	16.0	11.4
Kernel weight (g)	2.6	3.5	3.1
Kernel/nut ratio (%)	21.3	20.7	22.4
Whole kernel (%)	98.0	98.5	89.2
% split kernel (%)	2.0	1.6	9.4
Halves (%)	1.3	4.7	5.6

TABLE 10 - Main cashew apple characteristics of cashew clones (Barros et al., 2005; Paiva, 2007).

Characteristics	BRS 265	BRS 274	BRS 275
Apple (peduncle) weight (g)	118.2	128.6	108.0
Color	Red	Orange	Orange
Total soluble solids - TSS (°Brix)	12.9	12.4	12.0
Total titratable acidity - TTA (%)	0.22	0.47	0.34
Ratio TSS/TTA	58.8	26.4	35.4
Vitamin C (mg/100 g pulp)	210.2	305.5	249.6
Anthocyanin (mg/100 g pulp)	14.5	12.0	5.6

TABLE 11- Area (hectares) planted with bananas in Brazil (1990 to 2007).

Brazil and Regions	1990	1995	2000	2005	2006	2007
Brazil	494,425	518,863	533,593	496,287	511,181	519,187
North	74,064	98,804	125,109	92,061	91,836	94,380
Northeast	189,698	191,606	172,543	194,214	210,374	217,000
Southeast	137,286	139,469	147,582	134,925	135,051	132,940
South	42,881	48,313	44,995	51,514	51,878	52,535
Middle-West	50,496	40,671	43,364	23,573	22,042	22,332

Source: IBGE, 2008.

TABLE 12 - Main characteristics of banana genotypes released by Embrapa (adapted from SILVA et al., 2008).

Genotype	Code	Genomic group	Resistance to diseases			Plant size	General observations
			BS	F	YS		
Maravilha	FHIA 01	AAAB	R	R	HR	Medium	More acid fruits, yield higher than Prata-Anã
FHIA 18	FHIA 18	AAAB	R	R	R	Medium	
Caprichosa	PC 42-01	AAAB	R	R	R	Tall	Sweet fruits with acidity similar to common 'Prata', resistance to finger drop
Japira	PV 42-142	AAAB	HR	R	R	Tall	Fruit number and size and yield superior to 'Pacovan'. Sweeter fruits and resistance to finger drop same as 'Pacovan'
Pacovan Ken	PV 42-68	AAAB	HR	R	R	Tall	Fruit number and size and yield superior to 'Pacovan'. Sweeter fruits and resistance to finger drop same as 'Pacovan'
Vitória	PV 42-81	AAAB	R	R	R	Tall	Fruit number and size and yield superior to 'Pacovan'. Sweeter fruits and resistance to finger drop same as 'Pacovan'
Preciosa	PV 42-85	AAAB	R	R	R	Tall	Fruit number and size and yield superior to 'Pacovan'. Sweeter fruits and resistance to finger drop same as 'Pacovan'
Prata Graúda	SH 3640	AAAB	S	R	S	Medium to Tall	Larger fruits with similar pulp, taste, and aroma to Prata-Anã. Yield 30% more
Garantida	ST 42-08	AAAB	R	R	R	Tall	Fruits and yield superior to those from cultivars Prata São Tomé and common Prata
Princesa	YB 42-07	AAAB	R	HR	R	Lower than silk	Yields from 15 to 20 tons/ha
Tropical	YB 42-21	AAAB	S	HR	R	Medium to Tall	Fruits similar to those from cv. Maçã (silk). Bunches can reach 12 kg, 8 hands and 140 fruits
Caipira	Yangambi km 5	AAA	HR	R	R	Medium to Tall	Smaller fruits but in higher number than 'Prata-Anã'. Vegetative vigor.
Nan	---	AAA	S	R	R	Medium to Tall	Can reach higher prices than 'Prata-Anã' in the market.
Thap Maeo	---	AAB	R	R	R	Tall	High rusticity and average yield up to 35 tons/ha

BS= black sigatoka; F= fusarium disease (Panama dis.); YS= yellow sigatoka; R= resistant; HR= highly resistant; S= susceptible.

TABLE 13 - Main characteristics of banana cultivar BRS Conquista(Pereira and Gasparotto, 2008).

Characteristics	Value
Nr. viable leaves at flowering	13-15
Nr. viable leaves at harvest	8-9
Bunch – average weight	29 kg
Nr hands/bunch	13
Hand – average weight	2.25
Fruits/bunch	326
Yield per hectare	48 t
Resistance to finger drop	High
Pseudo stem color	Light green
Pseudo stem spots	Absent
Leaf color	Light green
Genomic group	AAB
Cultural subgroup	Conquista
Black sigatoka	Resistant
Panama disease	Resistant
Yellow sigatoka	Resistant
Moko	Susceptible
Nematodes	Tolerant

TABLE 14 - Percentage of mango hybrids obtained through the useof different techniques (Pinto, 1995 and Pinto et al., 2004b).

Technique and authors	Area and period	Pollinated flowers #	Hybrids obtained number	%
Old technique				
Sen et al. (1946)	Sabour (1941-1944)	9,737	77	0.79
Jawanda & Singh (1963)	Qadian (1944-1958)	7,775	31	0.39
New technique				
Mukherjee (1961)	Krishnagar (1959-1961)	29,911	361	1.34
IARI	New Delhi (1961-1974)	67,000	1018	1.52
EMBRAPA/CPAC	Brasília (1981-1983)	2,000	29	1.45
Improved technique				
EMBRAPA/CPAC	Brasília (1986-2001)	34,800	2,088	6.00

TABLE 15 - Area planted with apple in Brazil (1990 to 2007).

Brazil and regions	1990	1995	2000	2005	2006	2007
Brazil	22,342	27,007	30,048	35,493	36,107	37,832
North	---	---	---	---	---	---
Northeast	---	---	---	---	3	5
Southeast	1,052	668	396	222	259	273
South	21,290	26,339	29,652	35,271	35,845	37,554
Middle-West	---	---	---	---	---	---

Source: IBGE, 2008

CONCLUSIONS AND PERSPECTIVES

As it happens in the breeding program of any plant, success of a fruit breeding program is based on the level of team knowledge and updating ability, work capacity of persons and institutions, and, last but not least, a planned work sequence along years, without significant interruptions. The examples in this review give a very good idea on how Brazilian Research Institutions are dealing with the matter. Practically every one involved in fruit breeding in any manner is presenting viable and important technologies to growers nationwide. Even those dealing with the species we named here as having room for breeding are releasing cultivars, some not planted yet, but with real improvement. Molecular tools are widely available in the programs and under intense use. Scientists are getting prepared to the challenge and impacts of global climate changes, as fruit crops are being tested in new areas, never thought before. It must be mentioned that fruit functional properties are under intense studies in institutions such as Embrapa Tropical Agroindustry, Unicamp and Unesp, just to mention a few. Moreover, some of these works are being done linking to recent knowledge on native Brazilian fruits. Surely, all these subjects should be reviewed in special issues in the near future.

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