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# Prologue

Archaeological remains of fruit and their pictorial and literary evidences suggest ancient origin of fruit culture. Prehistoric humans were nomadic hunter-gathers who followed the migration of animals and the ripening of foods, such as berries, in order to feed themselves. The fruit tree culture originated/occurred in various locations including the Fertile Crescent, Asia, and the New World in the late Neolithic and Bronze Age. About 8000 years ago, a period known as the Second Neolithic Revolution occurred in the Fertile Crescent that involved a change from villages to urban communities. Zohary and Spiegel-Roy (1975) proposed that fruit culture, in contrast with mere collection, originated 4000 to 3000 BCE. The development of fruit culture in the Fertile Crescent evolved at two loci: the Tigris Euphrates civilization of Mesopotamia and the Nile Valley culture of Egypt. The activities related to fruit breeding also started along with the beginning of fruit culture. The domestication process is traced in pre-history and antiquity, where useful fruit species were chosen and cultivated.

Centres of origin of crops and diversity regions provide clues to the geographic distribution of centres of plant domestication. These centres would obviously be located in areas with maximum diversity and from where agriculture could spread to more regions of crop plant diversification. De Candolle (1886) was perhaps the first to indicate the regions where the initial plant domestication might have taken place. Nikolai Ivanovich Vavilov (1951) gave more elaborate account of the cradles of agriculture. He believed that time is the only factor that influenced the dispersal and variation of a species. Based on this hypothesis, Vavilov (1951), named eight Centres of Origin of crop plants. Zhukovsky (1965) proposed 12 mega gene centres of crop plant diversity. The new areas added to Vavilov's eight centres were Australia, Africa and Siberia followed by revision of the boundaries. Zeven and Zhukovsky (1975) elaborately dealt on this in 'Dictionary of Cultivated plants and their centres of diversity' listing species for different mega gene centres and the range and extent of distribution of genetic/varietal/specific diversity. Zeven and de Wet (1982) preferred the term 'Region' to 'Centre'. These twelve regions have by and large wider coverage and more acceptability and list the prominent crop plants for which rich diversity occurs.

1. **Chinese-Japanese Centre:** Vavilov called it 'East Asian Centre of Origin'. Sometimes this region is associated with the primary region of diversity of fruit crops in Amur-Ussuri area. China is one of the richest regions contributing many crops particularly fruit trees. Orange/citrus, peach, apricot, litchi, kiwifruit, Chinese jujube, Japanese plum, loquat, Asiatic or sand pear, water chestnut, wampee and Chinese chestnut are important fruit crops that originated in this region. Japan is a secondary centre of diversity for several crops.

2. **Indo-Chinese-Indonesian Centre:** Vavilov called it Tropical Asian Centre of origin. This region is important for crops such as mango, banana, rambutan, durian, breadfruit, *Citrus*/lime, pummelo, grapefruit, jamun and mangosteen.
3. **Australian Centre:** Australian Centre was not described by Vavilov, but Zhukovsky (1970) marked it for the domestication of several plant species/ crops. The region is important for origin of crops such as *Musa* spp*.,* macadamia nut and Fei banana.
4. **Hindustani Centre:** The important fruit crops that originated in this region are mango, banana, jackfruit, ber, bael, aonla, phalsa and *Citrus* species.
5. **Central Asian Centre:** Vavilov called it Southwestern Asian Centre. Important crops of this centre are apple, walnut, almond, pistachio, grapes, plum and species of pear and apricot.
6. **Near Eastern Centre:** Vavilov called it Near Eastern Centre. Important fruit crops found in this region are European hazelnut, almond, sweet chestnut, *Malus* sp*., Prunus* sp., sweet cherry, *Pyrus* sp., fig, pistachio nut, grapes, plum, pear, apricot and pomegranate.
7. **Mediterranean Centre:** Vavilov called it Mediterranean Centre. Darlington (1956) suggested the name Mediterranean Region. The crops that have been domesticated in this region are olives*,* grapes and carob.
8. **African Centre:** Darlington (1956) described two areas in Africa, Ethiopia and Central Africa as regions of origin. The most important West African region could be subdivided into A (the Senegambian subcradle), B (the Central Niger subcradle), C (the Benin subcradle) and D (the Adamawa subcradle). The crops of African origin are tamarind, *Ensete ventricosum,* and *Phoenix* sp.
9. **European-Siberian Centre:** Darlington (1956) was the first to refer Europe as a region of origin of crop plants. Zhukovsky (1968, 1970) recognized it as a mega centre of diversity but of a relatively small importance. Important fruit crops that have developed in this region are peach, pear, plum, apricot, apple, almond, walnut, pistachio, cherry, *Fragaria* sp*., Ribes* sp*., Rubus* sp. and gooseberry.
10. **South American Centre:** It was first restricted to the Andes and was described by Vavilov (1949/50) as the Andean Centre of Origin. Vavilov divided it in two areas, a. Peru, Ecuador and Bolivia, and b. on the island of Chiloe and Chile. Zhukovsky (1968) created the mega centre of South America. The fruit trees originated from this region are papaya, cashew, passion fruit, cherimoya, Brazil nut, pineapple*, Feijoa* and *Solanum* sp.
11. **Central American and Mexican Centre:** Important fruit crops that have been domesticated in this region are papaya, white sapote, soursop, mamey sapote, avocado, pineapple and guava.
12. **North American Centre:** This centre is home of important crops like pecan nut, American chestnut, *Fragaria virginiana, Prunus* sp., *Rubus* sp., blueberry, *Vaccinium macrcarpon* (cranberry) and *Vitis* spp.

Fruit tree domestication and cultivation came after establishment of grain agriculture, probably during the fourth millenium BC. Although the pattern has been similar in many fruit trees, domestication of some fruits preceded others. Vegetative propagation (grape, olive, date, fig and banana) or polyembryony (citrus, mango) facilitated the process. Major changes that occurred during domestication are self fertility (peach, sour cherry), hermaphroditism (grape), elimination of bitterness (almond), lower resin (mango) and thornlessness (many fruits). Polyembryony, persistance of syconia (fig), parthenocarpy and seedlessness (banana, citrus) were other notable changes.

A number of popular fruits and nuts including various brambles, *Vacciniums*, pecan, and kiwifruit were domesticated during 18$^{th}$ to 20$^{th}$ century. Many others (lingonberry, various cacti and durian) although were extensively collected and marketed but are still in the process of domestication. Selection of elite natural variants was done with further improvement through identification of promising types arising from recombinants after natural intercrosses. Simultaneously, adoption of practices such as grafting, rootstocks, pruning and training, pollination, irrigation, storage and processing, often unique to each crop, were developed to increase productivity, improve quality and extend availability of the produce.

Domestication of fruits involves a combination of events including species selection, recurrent selection of elite clones and vegetative propagation coupled with techniques such as irrigation, pruning and training, controlled pollination, etc. Fruit crops have a number of characteristic features considered important during selection. Noteworthy is the obvious appeal of natural taste which may be desirable or delicious depending on the combination of sweetness, acidity and aromatic constituents. The taste and colour of fruits are traits associated with seeds dispersed in nature very often mediated through mammals. Subsequent improvement of fruit crops resulted from continual selection in seedling populations, especially of natural inter-crosses, elite wild or introduced clones. Most fruits are highly cross-pollinated and generally have long juvenile phase and longevity. Some have ability to propagate through vegetative organs such as off-shoots, cuttings and nucellar seed. Many grower-selected clones are still grown and are very popular.

Genetic changes associated with domestication of fruits include breakdown of dioecy, loss of self-incompatibility, induction of parthenocarpy and seedlessness, polyploidy and allopolyploidy, loss of toxic substances, ease of vegetative propagation, and loss of spines, thorns or pubescence. The changes that occur due to selection process include increase in fruit size, sugar content, and in shelf life. The contributing factors to these changes are interspecific recombination, polyploidization and generations of sexual recombinants. Many fruits differ from their wild progenitors in a few characters that have appeared as a result of mutations. Normally mutations are not advantageous to the plant in its natural setting as they reduce fitness, but would have been spontaneously selected by humans owing to some desirable characters. For example, the change from bitter to sweet seed in almond, and seeded to seedless fruit along with parthenocarpy in banana and plantain, citrus, fig, grape, persimmon and pineapple may have negative fitness in nature but is of very positive selection value. Parthenocarpy is valuable as it eliminates the need for pollination. Seedlessness in grape, banana, and citrus is considered a valuable edible quality. In dioecious fruits such as strawberry (*Fragaria* spp.), wild grape and papaya, induced mutations resulted in hermaphroditism.

Other major changes that occurred under domestication process are self fertility (e.g. peach, sour cherry), loss of spines (e.g. brambles, pineapple, pome fruits and citrus), loss of pubescence on fruit (e.g. peach), and in growth habit (e.g. pome and stone fruits). Colour sports have become increasingly important, especially in apple, pear and grapefruit. Some of these mutations are not heritable because they do not occur in the appropriate meristematic layer.

Interaction of genetic changes with development of cultural practices often evolved a unique growing technology for each fruit species. The history of two recent domesticates, cranberry and kiwifruit, may illustrate this. Both cranberry and kiwifruit were widely appreciated and had entry in commerce from wild stands long before domestication. Cranberry had been collected from the wild in North America since colonial times, but became cultivated only in 19$^{th}$ century when a series of practices to grow under aquatic conditions were developed. The kiwifruit, a dioecious vine native to China has been appreciated since the 8$^{th}$ century in China and probably much earlier but was never cultivated there. From seed introduced into New Zealand from China, the preferred pistillate and staminate clones (Hayward and Bruno, respectively) were selected. A cultivation system involving training and pruning on trellis with provision for pollination was worked out by nurserymen and growers. When introduced to England and North America in the beginning of the 20$^{th}$ century, the technology was transferred and kiwifruit became a world fruit crop in less than 25 years. In both cranberry and kiwifruit, the early elite selections of wild plants were of high quality and could be propagated by cuttings (cranberry) and grafting (kiwifruit). Thus selection, combined with vegetative propagation became a key domestication technique in these crops. However, even after 100 years, the old selections still dominate.

The related species of kiwifruit -- the yellow-fleshed *Actinidia chinensis* and the small-fruited *A. arguta* (also known as Tara fig) are potential new crops. The latter is widely planted in home gardens. The related blueberry (especially lowbush types) in Maine and lingonberry in Sweden, although harvested from the wild, are popular. Blueberry had greater species diversity than cranberry or lingonberry and had more promise because the fruit could be consumed fresh as well as processed. While domesticates of cranberry and kiwifruit have changed little from their wild forms, the blueberry has undergone remarkable transformation due to interspecific hybridization and ploidy manipulation. The culture of blueberry was dependent on the understanding that the *Vacciniums* are acid loving species and required ammonium form of nitrogen. Intensive selection and breeding with various species of different ploidy levels transformed this crop for wide adaptation. On the other hand, lingonberry was never domesticated, probably because there was no shortage of fruit collectable from the wild. In other fruits, such domestication efforts probably occurred much earlier owing to unique set of problems and prospects.

Further upsurge of interest in fruit tree evolution involving discovery, knowledge and use of wild relatives stems from the growing concern and consciousness of their genetic vulnerability. This imposes a search of wild relatives for breeding, especially for disease tolerance and use as rootstocks.

The fruits that were domesticated first appear to be date palm, olive, grape, almond, fig and pomegranate. Huxley (1978) believes that the first plant to be manipulated was the grapevine and that wine was probably first made in 6000 to 4000 BCE. Asian temperate pome fruits (apple, pear, quince, and medlar) and stone fruits (apricot, cherry, peach and plum) were fully domesticated by antiquity. Citrus fruits were domesticated early in China but reached the West in waves starting with citron. Tropical Asian fruits (mango and banana) and those from the Americas (avocado, papapa and pineapple) were developed in prehistory. Last five centuries witnessed much give and take in the world among the economically useful flora of different regions. In the process of colonisation during the sixteenth century and later, the Portuguese, British, French and Dutch introduced many plants in different regions. Such exchanges were also made by pilgrims and explorers or through introduction by invaders. For example, Mohammedan rulers introduced a variety of plants in India, such as cherries and grapes from Afghanistan and Iraq. By the seventeenth century, the Portuguese introduced New World crops, such as guava, custard apple, pineapple and cashew. In the last quarter of the eighteenth century, British East India Company introduced tea, litchi and loquat from China and mangosteen from Malaysia. Thus, fruit breeding activities aimed at improvement of fruit crops involves the use of methods such as introduction, selection, hybridization, polyploidy, mutation and biotechnology techniques.

As an organized activity, fruit breeding is a 19$^{th}$ century innovation. Throughout the millennia, genetic improvement of these fruit species has been achieved through selection by growers, first from natural seedling populations and then by plantations of unique genotypes fixed by vegetative propagation. Spontaneous hybridization between wild races and cultivated clones was critical to the early domestication of fruits. Breeding and genetic studies in tropical fruits are underdeveloped compared with those in temperate crops. Most improvements have come from selection of chance seedlings; open pollinated seedlings, or mutations, although cross breeding by controlled pollination has been done in pineapple, papaya and avocado.

The processes that were followed during domestication have now been intensified with emphasis on increased adaptability through hardiness, lower chill requirement, photoperiod insensitivity and resistance to biotic stress, plant architectural modifications and selection of colour mutations. Molecular techniques hold promise in increasing the efficiency of genetic improvement by selection using molecular markers and insertion of genes through transgene technology.

Fruit breeding phases broadly occurred in four stages, viz. (i) Pre-Mendelian era before 1900, (ii) Mendelian era - 1900 to 1920, (iii) Post- Mendelian era – from 1921 to 1950 and (iv) modern era – from 1950 to the present. The fruit breeding milestones achieved during these stages are given in Table 1.

**Table 1. Fruit breeding milestones.**

| Year | Major findings/results | Institute/ Author |
|---|---|---|
| 9000 BCE | First evidence of plant domestication in hills above Tigris River. | |
| 4000 BCE | Date, fig, olive and grape are earliest fruit crop domesticated. | |
| 700 BCE | Hand pollination of date palm was used by Assyrians and Babylonians. | |
| 1338 | Bhokri, Fakhri and Sahebi cultivars of grape introduced in Aurangabad (Daulatabad). | Muhammed Bin Tughlaq |
| 1492 | Introduction of avocado, papaya, pineapple, tomatillo in Europe. | Christopher Columbus |
| 1493 | Pineapple discovered in Guadeloupe. | Columbus |
| 1600 | Introduced pineapple, custard apple and cashew from Brazil during the 16$^{th}$ century. | The Portuguese |
| 1700 | Guava was introduced in the early 17$^{th}$ century. | The Portuguese |
| 1714 | *Fragaria chiloensis* was brought from Chile in France. | Amédée-François Frézier |
| 1750 | The garden strawberry was bred in Brittany, France by crossing *Fragaria virginiana* with *Fragaria chiloensis.* | |
| 1769 | Discovered breadfruit in Tahiti. | Captain James Cook |
| 1759-1838 | First to improve fruit crop by selection from genetic recombinants derived by inter-pollinations of clones. | Thomas Andrew Knight |
| 1765-1842 | Systematic breeding of European pear was first carried out. | Jean Baptiste Van Mons, a Belgian physician |
| 1798 -1877 | Developed Early Rivers, Early Transparent Gage, Monarch, Czar and President plum varieties. | Thomas Rivers |
| 1806 | Spent nearly 50 years in planting apple seeds throughout the wilderness of Pennsylvania, Ohio, Indiana, and Illinois thereby creating variability in apple. | John Chapman |
| 1810-1895 | Explained the role of juvenility in fruit growing. | John J. Thomas (1810–1895) |
| 1823 | Beurré d Anjou cv. of pear was identified. | Van Mons |