FOODS OF PLANT ORIGIN

Production, Technology, and Human Nutrition

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Fruits and Vegetables

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INTRODUCTION

Fruits and vegetables are soft, fleshy, edible plant products and, because of their high moisture content, are relatively perishable in the freshly harvested state. Botanically, the word "fruit" refers to the mature seed-bearing structures of flowering plants; this covers a very wide and heterogeneous group of plant products, including cereals, pulses, oilseeds, spices, and fleshy fruits. The edible fleshy fruits, however, represent a well-defined class on their own and exhibit a wide variety of plant products. They have much in common from a culinary point of view with the soft, edible structures developed from other parts of the plant body, commonly referred to as vegetables. Although botanically the line between fruits and vegetables cannot be clearly drawn, the products have been differentiated based on common verbal usage and the way in which they are consumed. Popularly, the term "fruit" has been restricted in its use to those botanical plant parts that have fragrant, aromatic flavors and are either naturally sweet or normally sweetened with sugar before eating; that is, fruits are essentially consumed as dessert items. The term "vegetable," in contrast, is applied to all the other soft, edible plant products that are usually eaten with meat, fish, or other savory dish, either fresh or cooked. Both fruits and vegetables are utilized in different ways in different parts of the world—in some instances, even within a given community. For example, banana and plantain are the fruits of two very closely related plant species but are utilized distinctively: Whereas banana is an important dessert fruit, the starchy plantain is usually consumed cooked as a vegetable.

The percentages of nutrients contributed by fruits and vegetables as a group, according to the amount consumed per year in the United States, are as follows (Salunkhe and Desai 1984a,b): vitamin C, 91%; vitamin A (β-carotene), 48%; vitamin B_6, 27%; magnesium, 26%; iron, 19%; thiamin, 17%; niacin, 15%; and calories, 9%.

Table 3-1. The Probable Original Centers of Distribution of the Ancestors of Some Presently Cultivated Fruit and Vegetable Species.

Center	Species
Central Asia	Apple, broad bean, cherry, lentil, mulberry, olive, onion, pea, pear, plum, pomegranate, quince, radish, spinach
Mediterranean	Carrot, celery, cucumber, date, eggplant, lettuce, melon, mustard, turnip
Medit. & S.E. Asia	Artichoke, asparagus, cabbage, cauliflower, fig, horseradish, parsley, parsnip
Southeast Asia	Banana, breadfruit, peach, persimmon, orange, yam
Central America	Avocado, cassava, corn, cranberry, kidney bean, lima bean, pineapple, potato, pumpkin, squash, sweet potato, tomato

Source: Duckworth (1966).

PRODUCTION HISTORY

Duckworth (1966) pointed out the probable original centers of distribution of the ancestors of some of the modern cultivated fruit and vegetable species (Table 3-1). The wild ancestors of all the important fruits and vegetables grown today were originally confined to one or another of four main centers of distribution. The ancient Greek and Roman civilizations were familiar with many edible plant species, including fruits and vegetables, that were indigenous to Central and Southwest Asia and the Mediterranean region. According to Duckworth (1966), the Greeks and Romans cultivated quite a wide range of fruits and vegetables and lived largely on a vegetarian diet. The sun drying of fruits such as grapes and prunes was already widely practiced during these times, and trade in dried fruit products flourished around the Mediterranean.

The common people realized the value of fruit and vegetable growing as a means of providing a more varied and inexpensive diet and a good source of income. The cultivation of fruits and vegetables on a commercial scale reached a high level of development in Europe during the Middle Ages. The major fruits of tropical and subtropical regions gradually spread from their original centers of distribution to other areas where the climate was suitable for their cultivation. Banana, which was grown in Malaysia since the second millennium B.C., was introduced to tropical America at the beginning of the sixteenth century; the orange, another native of Southeast Asia, also probably reached America about the same time. Greenhouse culture, introduced in the seventeenth century, enabled the small-scale cultivation of exotic species such as vines, peaches, and citrus fruits. In the following hundred years, fruit growers started to realize the problems of transporting and marketing fresh produce on a commercial scale. Eighteenth-century medical science was positively affirming that consuming

Table 3-2. World Production of Some Important Fruits and Vegetables.[a]

Produce	1983	1984	1985	1986	1987	1988
Fruits	313.9	312.9	313.0	326.7	324.7	329.3
Total nuts[b]	3.94	3.87	3.79	3.77	4.06	4.12
Root crops	560.3	594.0	578.4	582.4	584.3	583.7
Potatoes	265.4	292.3	283.1	290.2	284.1	287.2
Vegetables & melons	373.0	396.5	406.0	416.4	421.1	427.3

Adapted from: FAO Q. Bull. Stat. 1(4), 1988.
[a]In millions of metric tons.
[b]Includes both true nuts and those that are drupes or seeds.

fruits and vegetables was necessary for normal well-being. Consumption steadily increased worldwide during the nineteenth century, witnessing a marked acceleration due to an increase in the rate of population growth. During this period, foundations were laid for the subsequent exploitation of such modern methods of food preservation as cold storage, canning, and artificial drying of fruits, and commercial production of jams, jellies, and fruit juices.

Blessed with a range of climates suitable for growing a wide variety of fruit species, the newly formed United States of America quickly emerged as a leading producer of fruits and vegetables, transporting them to its southern neighbors, where the consumption of these commodities was traditionally high. The fruit processing industry rapidly expanded during the early part of this century. "Quick-freezing" was introduced in 1929, followed by the development of other branches of the processing industry. In the 1950s there was a rapid increase in the production of fruit and vegetable juices and dehydrated products, followed by the development of use of ionizing radiations to conserve perishable foods (Duckworth 1966).

A comparison of recent world production of fruit and vegetable crops is shown in Table 3-2.

FRUITS

Fruits are highly remarkable sources of wholesome food, and are valued for flavor, aroma, and texture. Fresh fruits appeal to all the senses: smell, taste, touch, sight, and even sound—as when one bites into a crunchy apple. Nutritionally, they have a vital role to play, vitamins and minerals being their major contribution to the human diet. Some fruits are considered a fairly rich source of energy and contribute notable amounts of fat (e.g., avocados and nuts), sugars (e.g., dates, figs, bananas), protein (e.g., *tucuma*) (Hall et al. 1980; Nagy and Shaw 1980), and dietary fiber (White 1979). Fruits play an especially important role in health by providing low-sodium diets to people with certain diseases, such as hypertension and kidney disorders (Goddard and Matthews 1979). One of the greatest health problems in the Western world is obesity, and fresh fruits can supply a large portion of a diet while contributing very few calories (Goddard and Matthews 1979; White 1979). Because of their higher nutrient density ratios, a normal serving of fruits will supply the recommended daily dietary allowances for most nutrients without concomitantly supplying excess calories (Hansen, Wyse, and Sorenson 1979).

Botanically, fruit is the structure that develops from the ovary wall (pericarp) as the enclosed seed or seeds mature; but although fruit is often an important feature in the diagnosis of family or genus, its classification is somewhat artificially based on gross morphology rather than on mode of origin. Thus fruits may be classified as *succulent* or *dry* depending on whether or not the middle layer (the mesocarp) of the pericarp develops into a fleshy covering. It may be further classified as *dehiscent* or *indehiscent* according to whether the fruit wall splits open to release the seed. Fruits that develop from the gynoecium of a single flower are termed *simple* or *true fruits*. If they are derived from a single ovary, they are called *monocarpellary;* those that incorporate a number of fused ovaries are termed *polycarpellary*. An aggregate fruit may develop from an apocarpous gynoecium (e.g., "pseudocarp" pomes and strawberries); others may develop from a complete inflorescence (e.g., pineapples, mulberries, and figs). Some fruits may develop even though the ovule has not been fertilized; termed *parthenocarpic* fruits, this class includes melons, figs, cucumbers, and bananas.

The various groups of fruits discussed here could be broadly defined as follows (see also Table 3-3):

Berry: A many-seeded fleshy indehiscent fruit. The epicarp usually forms a tough outer skin, especially in the pepo and hesperidium (defined below), and the mesocarp becomes massive and fleshy. The epicarp and mesocarp may be highly colored to attract animals that act as agents of dispersal. Typical examples are the tomato, grape, raspberry, blueberry, and strawberry.

Hesperidium: A type of berry that has a leathery epicarp, such as a citrus fruit. Fluid-filled trichomes fill the locule of each carpel to form the characteristic segments of the various citrus fruits.

Pepo: A type of berry with a hard exterior derived either from the epicarp or noncarpellary tissue of the plant. Examples include pumpkins, squashes, melons, and cucumbers. In members of the Cucurbitaceae (melon family), the hard exterior is formed from the receptacle of the flower.

Drupe: A fleshy, generally one-seeded, indehiscent fruit in which the seed or seeds are surrounded by a hardened schlerenchymatous endocarp, as in wild cherry. The endocarp may replace the testa in its protective role and may also play a part in the dormancy mechanism. Apricots, peaches, cherries, and plums are examples.

Table 3-3. Botanical Classification of Some Important Fruits and Nuts.

Type	Scientific Name	Family
Fruits		
Berries		
Brambles		Rosaceae
Blackberry	*Rubus* spp.	
Boysenberry	*Rubus ursinus*	
Loganberry	*Rubus ursinus* var. *loganobacus*	
Raspberry		
Black	*Rubus occidentalis*	
Red and yellow	*Rubus idaeus*	
Grapes		Vitaceae
American grape	*Vitis labrusca*	
European grape	*Vitis vinifera*	
Muscadine grape	*Vitis rotundifolia*	
Other berries		
Blueberry	*Vaccinium* spp.	Ericaceae
Cranberry		Ericaceae
American	*Vaccinium macrocarpon*	
European	*Vaccinium oxycoccus*	
Currant		Saxifragaceae
American black	*Ribes americanum*	
European black	*Ribes nigrum*	
Garden currant	*Ribes sativum*	
Northern red	*Ribes rubrum*	
Date	*Phoenix dactylifera*	Palmaceae
Gooseberry		Saxifragaceae
American	*Ribes hirtellum*	
European	*Ribes grossularia*	
Huckleberry	*Gaylussacia baccata*	Ericaceae
Strawberry	*Fragaria chiloensis* var. *ananassa*	Rosaceae
Pomegranate	*Punica granatum*	Punicaceae
Hesperidia		
Citrus		Rutaceae
Citron	*Citrus medica*	
Grapefruit		
Pomelo	*Citrus paradisi*	
Shaddock, pummelo	*Citrus grandis*	
Kumquat		
Nagami	*Fortunella margarita*	
Marumi	*Fortunella japonica*	
Lemon	*Citrus limon*	
Lime	*Citrus aurantifolia*	
Orange	*Citrus sinensis*	
Pepos		
Melons[a]		Cucurbitaceae
Melon, muskmelon	*Cucumis melo*	
Cantaloupe	*C. melo* var. *cantalupensis*	
Cassaba	*C. melo* var. *inodorus*	
Nutmeg melon	*C. melo* var. *reticulatus*	
Watermelon	*Citrullus vulgaris*	

Table 3-3. (*Continued*)

Type	Scientific Name	Family
Drupes[b]		
Apricot	*Prunus armeniaca*	Rosaceae
Avocado	*Persea americana*	Lauraceae
Cherry	*Prunus avium*	Rosaceae
Mango	*Mangifera indica*	Anacardiaceae
Olive	*Olea europaea*	Oleaceae
Peach	*Prunus persica*	Rosaceae
Plum	*Prunus domestica*	Rosaceae
Pomes		Rosaceae
Apple	*Malus sylvestric* Mill.	
Pear	*Pyrus communis*	
Quince	*Cydonia oblonga*	
Other fruits		
Banana[c]	*Musa paradisiaca* var. *sapientum*	Musaceae
Fig[d]	*Ficus carica*	Moraceae
Pineapple[d]	*Ananas comosus*	Bromeliaceae
Nuts[e]		
True nuts		
Beechnut	*Fagus grandifolia*	Fagaceae
Cashew nut*	*Anacardium occidentale*	Anacardiaceae
Chestnut	*Castanea* spp.	Fagaceae
Filberts		Corylaceae
European/common	*Corylus avellana*	
American hazelnut	*Corylus americana*	
Hickory group		
Hickory nut	*Carya* spp.	Juglandaceae
Pecan	*Carya illinoensis*	Juglandaceae
Macadamia nut*	*Macadamia ternifolia* var. *integrifolia*	Proteaceae
Pistachio nut*	*Pistacia vera*	Anacardiaceae
Drupes[b]		
Almond	*Prunus amygdalus*	Rosaceae
Coconut*	*Cocos nucifera*	Palmaceae
Walnut group		Juglandaceae
Black walnut	*Juglans nigra*	
Butternut	*Juglans cinerea*	
English/Persian walnut	*Juglans regia*	
Seeds		
Brazil nut[f]*	*Bertholletia excelsa*	Lecythidaceae
Pinenut	*Pinus* spp.	Pinaceae

[a]Although true fruits, in world trade melons are grouped with vegetables.
[b]Some so-called nuts are also drupaceous fruits.
[c]Indehiscent fleshy fruit.
[d]Multiple fruits.
[e]Asterisk = (sub)tropical; all others are from temperate or cooler climates.
[f]Borne severally in a capsule fruit.

Pome: A type of fleshy pseudocarp in which the succulent tissues are developed from a greatly enlarged urn-shaped receptacle, which encloses the real fruit at its core. The pome is typical of family Rosaceae, the apple and pear being examples.

Nut: A nut is a dry, indehiscent fruit usually shed as a one-seeded unit. Although it forms from more than one carpel, only one seed develops, the rest aborting. The pericarp is usually lignified and is often partially or completely surrounded by a cup-shaped structure or *cupule*. True nuts include the acorn, hazelnut, and beechnut. The word "nut" is often loosely applied to any woody fruit or seed, such as the walnut and almond (which are drupes) or Brazil nut (which is a seed).

Present State of Fruit Growing

Based on the size of production, Samson (1986) distinguished four groups of fruit crops in the world:

1. those having a production of more than 10 million metric tons (MT) per year—grape, citrus, banana, apple, plantain, and mango;
2. those of which 1–10 million MT were produced—pear, avocado, papaya, peach, plum, pineapple, date, fig, and strawberry;
3. those with production figures of 100,000–1 million MT, such as cashew nut; and
4. the rest, for which there are no reliable statistics, such as guava, Brazil nut, litchi, macadamia, and soursop.

The production figures for major fruit crops and their leading producers are given in Tables 3-4 and 3-5, respectively. The production of grapes, pomes, and stone fruits (drupes) has doubled since 1950, whereas that of banana and citrus has tripled, and that of pineapple has increased sixfold. Avocado, kiwi, and litchi production is developing rapidly, but that of mango and cashew nut has remained more or less stationary in recent years.

According to Samson (1986), an increase in fruit production is not always accompanied by a rise in consumption; if consumption continues to lag for many years, the resultant overproduction leads to diminishing production. However, fruit growing is a long-term process, and changes only gradually.

Pieniazek (1977) stated that the average consumption of citrus and banana in Western Europe and the United States was about 10 kg/head/year, and <1 kg for the other tropical fruits; figures are much lower in Eastern Europe, but are increasing steadily. There has been a considerable rise in consumption and export of processed fruit products, particularly fruit juices. During 1960–70, this nearly tripled for citrus fruits, occupying one-third of the Florida and Brazil markets (Samson 1986).

Table 3-4. Production of the Major Fruit Crops.[a]

Fruits	1960	1970	1980	1981	1982	1983	1984
Subtropical							
Citrus	21	38	56	55	54	57	56
Banana	15	31	39	40	41	41	41
Plantain	—[b]	—	22[c]	22	23	20	20
Mango	10	12	13	13	13.5	14	14
Pineapple	2	4.2	7.8	8.6	8.9	8.7	8.8
Date	1.4	1.3	2.7	2.7	2.6	2.8	2.4
Papaya	—	—	1.8	1.9	1.9	2.0	2.1
Avocado	—	0.9	1.6	1.5	1.5	1.6	1.6
Cashew nut	0.4	0.5	0.5	0.5	0.5	0.5	0.4
Temperate							
Grape	45	60	67	61	71	65	64
Apple	15	24	34	33	39	37	40
Pear	4.2	7.2	8.5	8.7	8.9	9.5	9.1
Peach	3.8	5.5	7.3	7.3	7.1	7.4	7.7
Plum	4.5	3.9	4.6	5.0	6.2	6.2	6.1

Source: FAO (1985).
[a]In millions of metric tons, in order of descending yield.
[b]Dashes mean data are unavailable.
[c]Formerly included in banana.

Table 3-5. Major Producers of Fruits.[a]

Country	1979–81	1983	1984	1985
Brazil	18.30	19.82	25.21	26.23
India	20.68	23.06	24.23	23.96
Italy	20.66	22.36	19.12	18.75
Spain	12.60	12.36	11.41	12.11
USA	26.55	25.41	22.89	22.46
USSR	16.04	17.99	18.54	18.20
Developed countries	130.09	137.61	129.51	126.74
Developing countries	163.09	175.28	181.37	185.61
Worldwide	293.18	312.89	310.88	312.35

Source: FAO (1985).
[a]In millions of metric tons; excludes melons, which FAO groups under vegetables.

Fruit prices vary widely between and within years, the highest generally being obtained from October to November (Fajac 1974; Naville 1975). Countries such as Brazil, South Africa, and Australia have decided price advantage, since they can deliver their fruit in the autumn of the northern hemisphere. Owing to better opportunities for travel, faster shipments with refrigeration, and better processing methods and distribution systems, there has been enormous expansion in the transport of tropical fruits to Europe and the United States (Storey 1969). Intensive research on cultivation methods, crop protection, and postharvest biotechnology, along with developments in information media, have also helped fruit industry growth worldwide (Salunkhe and Desai 1984a).

Fruits as Sources of Nutrients

Although humankind cannot live by fruit alone, fruit has been an important source of nutrients. Barring high-protein nuts and fat-rich avocado, fruits are neither good nor economic sources of protein, fat, and calories, but are indispensable as sources of vitamins and minerals.

The proximate composition of some important fruits (Table 3-6) indicates that most contain more than 80% water. This value varies considerably depending on the availability of water to the crop, especially at the time of harvest. To maintain their crisp texture and freshness after harvest, fruits are generally harvested when their moisture content is at maximum. Carbohydrates, the next most abundant group of nutrient constituents, are present as low-molecular-weight sugars (glucose, fructose, and sucrose) or their high-molecular-weight polymers (e.g., starch, hemicellulose, cellulose, and pectins). Most ripe fruits are characterized by the presence of water-soluble sugars, whereas starch is the main constituent of unripe fleshy fruits, such as bananas. Cellulose, hemicellulose, pectins, and lignin (a polymer of aromatic alcohols linked by propyl units), which together constitute the dietary fiber, are essential components of the human diet. The incidence of such diseases as constipation, diverticulosis, and colon cancer is attributed to lack of fiber in the human diet.

The protein content of most fruits varies from 0.5% to 1%. These are mostly functional proteins (e.g., globular ones, such as enzymes) rather than storage proteins. With the exception of olives and avocados, fruits generally have <1% of lipids, mostly associated with the protective cuticle layers of the fruit surface and the cell wall. Citrus fruits contain >3% of organic acids, with citric and maleic acids predominating. Tartaric and isocitric acids are predominant in grapes and blackberry, respectively (Salunkhe and Desai 1984a).

Vitamin C (ascorbic acid) is one of the most important constituents of the human diet, a deficiency of which causes scurvy. The dietary vitamin C (about 90%) is essentially obtained from fruits and vegetables. Many fruits such as citrus, cherries, berries, and guava provide the recommended dietary allowance of about 50 mg of vitamin C in <100 g of fruit tissue. Papaya and mango are rich in vitamin A (β-carotene), and nuts are excellent sources of thiamin. The human body converts β-carotene into retinol, an active vitamin A compound important to maintain visual process. Fruits are also important sources of calcium, iron, and other minerals, but generally their contribution to total dietary requirements is of less importance. Recent research on human nutrition suggests that

Table 3-6. Nutritional Values of Some Fruits (per 100 g Edible Portion).

Fruit	Water (g)	Energy (cal)	Protein (g)	Fat (g)	Carbohydrate (g)	Ca (mg)	P (mg)	Fe (mg)	Na (mg)	K (mg)	Mg (mg)	Vit. A (IU)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Vit. C (mg)
Apricot	85.3	51	1.0	0.2	12.8	17	23	0.5	1	281	12	2,700	0.03	0.04	0.6	10
Peach	89.1	38	0.6	0.1	9.7	9	18	0.5	1	202	10	1,330	0.02	0.05	1.0	7
Orange	86.0	49	1.0	0.2	12.2	41	20	0.4	1	200	11	200	0.10	0.04	0.4	50
Grapefruit	88.4	41	0.5	0.1	10.6	16	16	0.4	1	135	12	80	0.04	0.02	0.2	38
Plum	81.1	66	0.5	0.2[a]	17.8	18	17	0.5	2	299	9	300	0.08	0.03	0.5	5[a]
Grape	81.6	69	1.3	1.0	15.7	16	12	0.4	3	158	13	100	0.05	0.03	0.3	4
Sour cherry	83.7	58	1.2	0.3	14.3	22	19	0.4	2	191	14	1,000	0.05	0.06	0.4	10
Apple	84.4	58	0.2	0.6	14.5	7	10	0.3	1	110	8	90	0.03	0.02	0.1	4
Strawberry	89.9	37	0.7	0.5	8.4	21	21	1.0	1	164	12	60	0.03	0.07	0.6	59
Watermelon	92.6	26	0.5	0.2	6.4	7	10	0.5	1	100	8	590	0.03	0.03	0.2	7
Pear	83.2	61	0.7	0.4	15.3	8	11	0.3	2	130	7	20	0.02	0.04	0.1	4
Banana	75.7	85	1.1	0.2	22.2	8	26	0.7	1	370	33	190	0.05	0.06	0.7	10

Source: Reprinted with permission from Salunkhe, Pao, and Dull (1974), Assessment of nutritive value, quality and stability of cruciferous vegetables during storage and subsequent processing. In *Storage, Processing and Nutritional Quality of Fruits and Vegetables,* ed. D. K. Salunkhe, pp. 1–38. © CRC Press, Inc., Boca Raton, Fla.

[a]From Heinz (1959).

sodium is responsible for blood-pressure-related disorders, and that potassium acts antagonistically. Since fruits have high potassium : sodium ratios (Table 3-6), nutritionists advise a daily intake of at least 100 g of fruits and as much variety as the season permits. The total fruit production in the world is around 250 million MT per year (i.e., 50 kg/person/year or 137 g/day); however, this is spread very unevenly. In many tropical countries, such as India, there is a serious shortage of fresh fruit, at least during part of the year.

Some fruits are nutritionally harmful and even poisonous. According to Purseglove (1968), in the *akee,* the unripe aril and the pink vein that attaches it to the seed are highly poisonous. *Carambola* and *bilimbi* contain 1–6% oxalic acid, which can cause calcium deficiency and kidney stones. Plantains contain serotonin, which, when consumed in large quantities, may cause high blood pressure.

Environmental Factors

Climate

Since weather changes from day to day whereas climate has a more stable character, Samson (1986) defined climate as "average weather" or "the whole of average atmospheric phenomena for a given region, calculated for a period of thirty years." These phenomena generally include light, temperature, water, and air.

Light

Fruit trees generally require more light and must be grown in a sunny atmosphere. Some fruit crops (e.g., banana) tolerate shade, whereas others (e.g., mangosteen) need shade during their early development. A third group of fruit crops (e.g., Salak palm, *duku,* and *carambola*) requires permanent shade (Terra 1949).

Daylength, the time elapsing between dawn and dusk, may exert a profound influence on flowering. Based on the required duration of the light periods, plants can be classified as short-day, long-day, and day-neutral plants. With the exception of pineapple, most tropical fruit crops are insensitive to photoperiod (Samson 1986).

Temperature

The average temperature at sea level near the equator is about 26–27 °C, the range usually being very small (2–3 °C between months and 6–10 °C between day and night). The temperature range, however, increases farther away from the equator. The altitude lowers the temperature by 5–6 °C for every 1,000 m.

According to Samson (1986), the growth rate of plants depends on temperature; thus plants that grow optimally at sea level will grow more slowly in the mountains. For example, in Jamaica, the growth cycle of the banana cultivar "Lacatan" was shown to be thirteen months at sea level but to increase by one month for every 100 m rise in altitude.

The sum of average daily temperatures during the growth cycle of the crop is called the *heat index*. Since perennial crops stop growing under extreme climatic conditions (too cold or below the minimum temperature and too hot or above the maximum), the average temperature is not a good criterion for judging crop growth and development. It is, therefore, better to use only effective temperatures, those between the minimum and the maximum, for growth. Apples and other pome fruits require low temperatures to break their bud dormancy; thus most deciduous fruits, such as apple, pear, peach and cherry, cannot be grown in tropical climates. Some deciduous fruit crops, such as macadamia, need cooler nights and chilling temperatures to induce flowering, whereas others (apple, peach, pear), depending upon the cultivar, require 250–1,000 h of temperatures below 7 °C (Samson 1986).

Excepting citrus and dates, most tropical fruits are highly susceptible to frosts. Even a temperature several degrees above zero may be harmful. Chilling injury, in the form of coagulation of latex in the skin that turns the fruit brown, is commonly observed in such fruits as banana, soursop, and sapodilla when grown below 12 °C. In contrast, the extreme high temperatures of the arid zones cause wilting, sun-scald, necrotic spots, and even death of fruit crops. Only the date crop resists temperatures up to about 50 °C.

Samson (1986) cited Koppen, who classified the world's climates into the following five groups:

1. rainy, with coolest month above 18 °C;
2. dry, either warm or cold;
3. rainy, with a mild winter;
4. rainy, with a cold winter; and
5. polar.

The last two have winters too cold to grow any tropical or subtropical fruit crops.

Water

The importance of sufficient moisture in the production of horticultural crops like fruits cannot be overemphasized. Within a particular temperature zone, the availability of water is perhaps the most important factor determining which fruit crops can or cannot be grown. Up to 10° latitude, about 200 cm/yr of rain falls on either side of the equator. Farther away there is less rain, especially