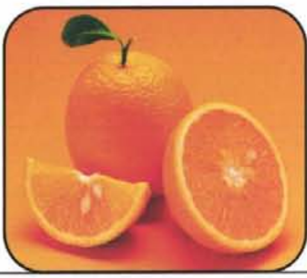

FRUIT CROPS

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Introduction to Fruit Crops

Some of the world's most widespread and debilitating nutritional disorders, including birth defects, mental and physical retardation, weakened immune systems, blindness, and even death, are caused by diets lacking in vitamins and minerals. Low fruit and vegetable intake is a major contributing factor to such micronutrient deficiencies.

While research shows nine or ten servings of fruits and vegetables a day is optimal, dietary guidelines tend to recommend a minimum of five servings a day. Yet studies show that most populations are consistently not reaching even half this goal. This is particularly troubling given the surge of new science suggesting that fruits and vegetables can not only help prevent nutrient deficiency disorders, but also reduce the risk of cardiovascular diseases—another leading cause of morbidity and mortality around the globe—and many cancers.

The rise of such non-communicable diseases in both wealthy nations and poorer countries is partly due to declining physical activity and excessive food energy intake. But World Health Organisation (WHO) attributes approximately 3 million deaths a year from such diseases to inadequate fruit and vegetable intake— a risk factor almost as deadly as tobacco use or unsafe sex.

There are various reasons why different populations tend to shy away from fruits and vegetables—cost, convenience, taste and stigma, to name a few. But as science increasingly supports the need for people to consume more produce, national health agencies, industry representatives and international organisations, including Food and Agriculture Organisation (FAO), are working together to address these obstacles and discuss ways to boost fruit and vegetable consumption around the globe.

USES OF FRUITS

Many hundreds of fruits, including fleshy fruits like apple, peach, pear, kiwifruit, watermelon and mango are commercially valuable as human food, eaten both fresh and as jams, marmalade and other preserves. Fruits are also in manufactured foods like cookies, muffins, yoghurt, ice cream, cakes, and many more. Many fruits are used to make beverages, such as fruit juices (orange juice, apple juice, grape juice, etc) or alcoholic beverages, such as wine or brandy. Apples are often used to make vinegar.Fruits are also used for gift giving, Fruit Basket and Fruit Bouquet are some common forms of fruit gifts. Many vegetables are botanical fruits, including tomato, bell pepper, eggplant, okra, squash, pumpkin, green bean, cucumber and zucchini. Olive fruit is pressed for olive oil. Spices like vanilla, paprika, allspice and black pepper are derived from berries.

Nutritional Value

Fruits are generally high in fiber, water and vitamin C. Fruits also contain various phytochemicals that do not yet have an RDA/RDI listing under most nutritional factsheets, and which research indicates are required for proper long-term cellular health and disease prevention. Regular consumption of fruit is associated with reduced risks of cancer, cardiovascular disease, stroke, Alzheimer disease, cataracts, and some of the functional declines associated with aging.

Fruits are good source of fiber, vitamins, minerals, and antioxidant. Dietary fiber is very important for our digestive system. Antioxidant will help us to prevent cancer.

Apple, grapes, kiwi, berries, pineapple, orange, apricot, plum are in general you can eat any time. Dont eat few fruits just before going to bed. Banana, mangoes, jack fruit, papaya, avocado, are good to have two hours before going to bed.

Eating fresh fruit is always better, but again it depends on how you are preparing the juice, and also how much convenient to consume. For example when we are making strawberry smothie or milk shake we wont remove anything from fruit and as juice we will consume more too. But in case of commercial apple juice we are not going to get any dietary fiber and also more sugar is added. Select your choice considering what else you had too.

For starters, they are full of vitamins and minerals, which serve an array of important functions in the body: Vitamin A, for instance, maintains eye health and boosts the body's immunity to infectious diseases; potassium promotes proper nerve and muscle functioning; and B-vitamins are necessary for converting food into energy. Other micronutrients in fruits and vegetables, such as vitamin C and vitamin E, serve as powerful antioxidants that can protect cells from cancer-causing agents; vitamin C, in particular, can increase the body's absorption of calcium—an essential mineral for strong bones and teeth—and iron from other foods.

Many fruits and vegetables are also very high in dietary fibre, which can help move potentially harmful substances through the intestinal tract and lower blood cholesterol levels. Much of fruits and vegetables' potency is believed to also come from substances known as "phytochemicals". These unique compounds are naturally produced by plants to protect themselves against viruses, bacteria and fungi.

Over the last decade, scientists have begun to isolate hundreds of these compounds and discover their wide-ranging health benefits. But the exact mechanisms by which phytochemicals promote health is still unclear. Scientists suspect it may be due to their individual effects and their interaction with one another, both within the same food and with phytochemicals found in other fruits and vegetables, as well as whole grains, nuts and legumes. Nutrients from other types of foods may also be an important piece of the puzzle, since some vitamins and minerals—and certain phytochemicals—are known to depend upon other nutrients for their absorption and use.

As difficult as it may be to get people to heed a simple message like "Eat more fruits and vegetables", the real challenge may lay before the world's food supply and distribution systems. FAO is playing its part to make sure agriculture, particularly in the developing world, can help meet the demand for healthy foods.

"One of the main objectives is to make sure the safety and health of foods is not compromised by increasing production levels," says Alison Hodder, an agricultural officer in FAO's Plant Production and Protection Division. FAO encourages farmers to follow good agricultural practices, and is working with different partners to develop a general framework for food production systems that are both economically and environmentally sustainable.

Since the harvest period for many fruits and vegetables can be limited, FAO also provides information on the best methods for preserving produce while retaining the maximum amount of nutrients. Another goal of the Organisation is to improve people's access to fruits and vegetables. In rural areas, FAO strives to integrate gardening messages with nutrition information, encouraging local communities to grow and consume a variety of crops. In urban areas, FAO has launched the "Food for the cities" initiative, a programme designed to link production with transportation, storage and marketing strategies, and address such critical issues as urban poverty and food costs. As public awareness campaigns about the benefits of fruits and vegetables continue to develop, producers may have a unique occasion to increase their production and enter new markets.

Nonfood Uses

Because fruits have been such a major part of the human diet, different cultures have developed many different uses for various fruits that they do not depend on as being edible. Many dry fruits are used as decorations or in dried flower arrangements, such as unicorn plant, lotus, wheat, annual honesty and milkweed. Ornamental trees and shrubs are often cultivated for their colorful fruits, including holly, pyracantha, viburnum, skimmia, beautyberry and cotoneaster.

Fruits of opium poppy are the source of opium which contains the drugs morphine and codeine, as well as the biologically inactive chemical theabaine from which the drug oxycodone is synthysized. Osage orange fruits are used to repel cockroaches. Bayberry fruits provide a wax often used to make candles. Many fruits provide natural dyes, e.g. walnut, sumac, cherry and mulberry. Dried gourds are used as decorations, water jugs, bird houses, musical instruments, cups and dishes. Pumpkins are carved into Jack-o'-lanterns for Halloween. The spiny fruit of burdock or cocklebur were the inspiration for the invention of Velcro.

Coir is a fibre from the fruit of coconut that is used for doormats, brushes, mattresses, floortiles, sacking, insulation and as a growing medium for container plants. The shell of the coconut fruit is used to make souvenir heads, cups, bowls, musical instruments and bird houses.

IMPORTANCE OF FRUIT CULTIVATION

India is an agriculture based country. Hundreds of fruits and vegetables types are grown in all parts of India. Fresh fruit and vegetable reach small scale fruits vegetables suppliers, they are then sent to local markets as well as fruits and vegetables exporters. Last decades have seen the number of Indian fruit vegetables suppliers and fruits vegetables exporters rising to an all time high. Especially there has been a steep rise in the number of vegetable exporters.

The total production of fruits and vegetables in the world is around 370 MT. India ranks first in the world with an annual output of 32 MT. While there are almost 180 families of fruits that are grown all over the world, citrus fruits constitute around 20% of world's total fruit production. Major Indian fruits consist of mango, banana, citrus fruits, apple, guava, papaya, pineapple and grapes. The fruits are processed into various products such as fruit juices and concentrates, canned fruit, dehydrated fruit, jams and jellies etc.

India with its current production of around 32 million MT of fruit, accounts for about 8% of the world's fruit production. The diverse agro-climatic zones the country make it possible to grow almost all varieties of fresh fruits and vegetables in India. The fruit production in India has recorded a growth rate of 3.9%, whereas the fruit processing sector has grown at about 20% per annum. However, the growth rates have been extensively higher for frozen fruits & vegetables (121%) and dehydrated fruits & vegetables (24%). There exist over 4000 fruit processing units in India with an aggregate capacity of more than 12 lakh MT. It is estimated that around 20% of the production of processed fruits is meant for exports, the rest caters to the defense, institutional sectors and household consumption, Mango and mango-based products constitute 50% of exports.

India is the second largest producer of vegetables in the world and accounts for about 15% of the world's production of vegetables. The current production level is over 71 million MT and the total area under vegetable cultivation is around 6.2 million hectares which is about 3% of the total area under cultivation in the country. In case of vegetables, potato, tomato, onion, cabbage and cauliflower account for around 60% of the total vegetable production in the country. Vegetables are typically grown in India in field conditions, the concept is opposed to the cultivation of vegetables in green houses as practiced in developed countries for high yields. The fruit and vegetable processing industry in India is highly decentralised. A large number of units are in the cottage/home scale and small scale sector, having small capacities upto 250 tonnes/annum. But big Indian and multinational companies in the sector have large capacities in the range of 30 tonnes per hour or so. Since liberalisation and withdrawal of excise duty on fruit and vegetable products there has been significant rise in the growth rate of the industry.

CURRENT STATUS OF FRUIT MARKET

The focused attention to horticulture has paid dividend and resulted increased production and export. Large area was brought under improved cultivars, production of quality planting material as seed increased, large number of farmers were trained, and innovative technology like drip irrigation, green house cultivation were encouraged. Consequently availability of fruits, vegetables and flowers increased. Evidently, more than 50 per cent increase in production of fruits and vegetables is seen between 1991-92 and 1999-2000.

Table 1. Top Ten fresh fruit Producers - 2005

Country	Production (Int $1000)	Production (MT)
India	1,052,766	6,600,000
Vietnam	438,652	2,750,000
China	271,167	1,790,000
Indonesia	255,216	1,600,000
Nigeria	223,314	1,400,000
Iran	223,314	1,400,000
Myanmar	183,436	1,150,000
Papua New Guinea	129,203	810,000
Nepal	82,945	520,000
Korea	78,160	490,000

Table 2. Top Ten tropical fresh fruit Producers - 2005

Country	Production (In $1000)	Production (MT)
Philippines	389,164	3,400,000
Indonesia	377,718	3,300,000
India	335,368	2,930,000
China	177,413	2,164,000
Colombia	131,629	1,150,000
Thailand	83,556	730,000
Pakistan	60,893	532,000
Brazil	55,513	485,000
Bangladesh	31,934	279,000
Mexico	28,615	250,000

India is the second largest producer of Fruits after China, with a production of 44.04 million tonnes of fruits from an area of 3.72 million hectares. A large variety of fruits are grown in India, of which mango, banana, citrus, guava, grape, pineapple and apple are the major ones. Apart from these, fruits like papaya, sapota, annona, phalsa, jackfruit, ber, pomegranate in tropical and sub tropical group and peach, pear, almond, walnut, apricot and strawberry in the temperate group are also grown in a sizeable area. Although fruit is grown throughout of the country, the major fruit growing states are Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Bihar, Uttar Pradesh and Gujarat.

Mango is the most important fruit covering about 35 per cent of area and accounting of 22 per cent total production of total fruits in the country, which is highest in the world with India's share of about 54%. India has the richest collection of mango cultivars. Major mango growing States are Uttar Pradesh, Bihar, Andhra Pradesh, Orissa, West Bengal, Maharashtra, Gujarat, Karnataka, Kerala and Tamil Nadu. The main varieties of mango grown in the country are Alphanso, Dashehari, Langra, Fajli, Chausa, Totapuri, Neelum etc.

Banana comes next in rank occupying about 13 per cent of the total area and accounting for about 34.2 per cent of the total production of fruits. India has first position in the world in banana production. While Tamil Nadu leads other States with a share of 19.00 per cent, Maharashtra has highest productivity of 58.60 metric tonnes against India's average of 32.50 metric tonnes per ha. The other major banana growing states are Karnataka, Gujarat, Andhra Pradesh and Assam The main varieties of banana are Dwarf Cavendish, Bhusaval Keli, Basrai, Poovan, Harichhal, Nendran, Safed velchi etc.

Table 3. Area and Production of Fruits in India during 1999-2000

Crop	*Area (000 ha.)*	*Production (000 MT)*
Apple	238.3	1047.4
Banana	490.7	16813.5
Citrus	526.9	4650.6
Grapes	44.3	1137.8
Guava	150.9	1710.5
Litchi	56.4	433.2
Mango	1486.9	10503.5
Papaya	60.5	1666.2
Pineapple	75.5	1025.4
Sapota	64.4	800.3
Others	601.2	5707.6
Total	3796.8	45496.0

Citrus fruits rank 3rd in area and production accounting for About 12 and 10.4 per cent of the total area and production respectively. Lime, lemons, sweet oranges and mandarin cover bulk of the area under these fruits and are grown mainly in Maharashtra, Andhra Pradesh, Karnataka, North Eastern States, Punjab, Orissa and Madhya Pradesh.

Guava is the fourth most widely grown fruit crop in India. The area under guava is about 0.15 Million ha producing 1.80 MT. The popular varieties of guava are Allahabad Safeda, Lucknoe-49, Nagpur Seedless, Dharwar etc. Bihar is the leading state in guava production with 0.30 MT followed by Andhra Pradesh, and Uttar Pradesh. The other states where guava is grown widely Gujarat, Karnataka, Punjab and Tamil Nadu.

Grapes occupies fifth position amongst fruit crops with a production of 1.08 MT from an area of 0.04 Million ha. The major varieties of grapes grown in India are, Thomson Seedless, Sonaka, Anab-e-Shahi, Perlette, Banglore blue, Pusa seedless, Beauty seedless etc. Maharashtra occupies the first position with a production of 0.68 MT of grapes, followed by Karnataka. The other states growing grapes are Punjab, Andhra Pradesh and Tamil Nadu. The other major fruits grown in the country are Apple, Litchi, Papaya, Pineapple and Sapota

For increasing the fruit production of India, several efforts are being taken up by government. The efforts to build up the infrastructure facilities, like cold storage, will continue in the coming years. Emphasis will be on developing export-oriented fruit crops. We will also be implementing 'model marketing systems for fruits and vegetables. It will be first implemented in Delhi, Mumbai, Calcutta and Bangalore, subsequently, it will be extended to other cities.

WORLD FRUIT PRODUCTION

World fruit production has been relatively steady over the past four years. In 2003 world fruit production reached 379.15 million metric tons, a 0.85 percent increase from 2002. The percentage increase in world production is only slightly higher than the 0.65 percent increase from 2001 to 2002. Before production leveled off in 2000, world fruit production grew at an average of 3.15 percent per year between 1995 and 2000, compared to an average growth rate of 0.86 percent per year for the period 2000 – 2003.

China is the world's largest fruit producer, producing 19 percent of the world's fruit in 2003. The European Union (EU) is the world's second largest producer, with 14 percent of the world's production. The third largest fruit producer is India, where 12 percent of the world's fruit was grown in 2003. Production is increasing in China at a much faster rate than in the other top producing countries. Production growth averaged almost 6 percent per year during the period 1996 – 2003 in China, while production growth in India averaged 2.73 percent per year. The EU experienced a lower annual growth rate of 0.89 percent during the 1996 – 2003 period.

Other key producers include Brazil, the United States, Mexico, Chile, and South Africa. Production in the United States and Brazil has been relatively constant over the period 1996 – 2003, with average annual growth rates of 0.61 percent in the United States and 0.34 percent in Brazil. Mexico, South Africa, and Chile have experienced slightly higher average annual production growth rates over the same period at 2.12 percent, 2.56 percent, and 1.3 percent, respectively.

Fresh Fruit Trade

The total export value of fresh fruits from all exporters was greater than $11 billion in 2003 and continues to grow rapidly. Fresh fruit exports have more than doubled in value since 1996 to reach the current value, and have increased in dollar terms by nearly 30 percent since 2000. In terms of quantity, exports have nearly doubled since 1996 and have increased 16 percent since 2000. The export market is growing largely due to increased consumption demand and the development of technology to facilitate trade in fresh fruits.

Consumption of fresh fruits is increasing in the United States as well as abroad and is expected to continue to increase. Demand for fresh fruits on a year-round basis is increasing, and consumers are willing to pay higher prices for out-of-season fresh fruit. The invention and adoption of new transportation and controlled atmosphere technologies allow fresh fruit to travel greater distances and still maintain its freshness. The increased demand and technology facilitate increased international trade in fresh fruit, providing consumers with greater choices of quality fresh fruit on a year-round basis. The export market for fresh fruits is highly competitive among the top exporters. Gaining access to foreign markets is critical to countries that are large exporters.

Free trade agreements are one means to provide increased market access and encourage increased exports. In addition to negotiating trade agreements, top exporters also use various export promotion and marketing techniques to increase their market share in foreign markets. Specific marketing and promotion techniques will be discussed on an individual country basis. This analysis will first describe the fresh export market in the United States and identify the key export markets for U.S. fresh fruit. Competition within those key markets will be identified and discussed.

United States

The United States is the fifth largest fruit producer and is the world's largest exporter of fresh fruit, in terms of value and quantity. The value of U.S. fresh fruit exports in 2003 was over $2.2 billion amounting to nearly 3 million metric tons. These exports amount to more than 20 percent of the global export market value. The primary export products from the United States are grapes, oranges, and apples. The United States is the second largest exporter of grapes, and the largest exporter of oranges and apples. Over 9 percent of total fruit production in the United States is for fresh export. For the past 10 years, U.S. fresh fruit exports have increased in terms of value, but have been relatively steady in terms of quantity. The increase in fruit exports from competitors is beginning to erode U.S. market share around the world.

The U.S. share in the fresh fruit export market has been declining over the past several years, losing 3.2 percent in value and 2 percent in quantity of the export market since 2000. The United States does not subsidise fruit production, but it does provide promotion and marketing assistance to trade groups and exporters. The United States promotes fresh fruit exports through the Market Access Programme (MAP) and other programmes. Through MAP, the Commodity Credit Corporation (CCC) provides funding to agricultural trade organisations, state regional groups, and cooperatives. The MAP allocations for 2004 provide over $125 million in cost-share funding for overseas marketing and promotional activities. These activities include consumer promotions for retail products; seminars and workshops for educational purposes about biotechnology and food safety; and training and assistance to foreign processors and manufacturers. Canada, the largest market for U.S. fresh fruits, buys 47 percent of all U.S. fresh fruit exports. Japan is the second largest market, with 12 percent. Mexico, Hong Kong, the European Union, and South Korea are also large importers of U.S. fresh fruit.

Canada

Canada is the largest market for U.S. fresh fruit exports, particularly strawberries, grapes, and oranges. In 2003 the United States exported $827 million in fresh fruit to Canada, which was a 10-percent increase from the previous year. The United States held a 51-percent share of the Canadian market in 2003, down from 53 percent the previous year. Chile, Costa Rica, and Mexico are also substantial exporters of fresh fruit to Canada.

Canada imported $129 million of fresh fruits from Chile in 2003. The key products imported from Chile include grapes, apples, and peaches, which are also key imports from the United States. Imports from Chile increased by over 20 percent from 2002 to 2003. Chile is a southern hemisphere producer, and for the most part, the production cycles do not coincide with those in the United States. Canada increased its imports from Costa Rica by more than 44 percent to $129 million in 2003. The imports consist primarily of tropical fruits including bananas and pineapples as well as some other fruit products including melons, most of which are not competitive products with the United States.

Canada imported nearly $100 million in fresh fruits from Mexico in 2003, which is a 35-percent increase from the previous year. The primary products originating in Mexico are grapes, avocados, and guavas. Mexico is competitive in Canada with the United States in grapes, lemons and limes, watermelons, strawberries, and other melons. Unlike Chile, Mexico is on a production cycle similar to that in the United States for many products. The increase in imports from Mexico could be a factor in explaining the U.S. loss of market share in Canada.

Japan

Japan is the second largest market for U.S. fresh fruit products, importing $347 million worth in 2003. The primary exports to Japan, in value, are citrus including grapefruit, oranges, and lemons as well as some non-citrus, including cherries and melons. U.S. fresh fruit comprised over 33 percent of the fresh fruit import market in Japan in 2003. However, the U.S. share of the Japanese market has been continually decreasing in recent years, dropping 14.3 percent since 2000.

In terms of value, U.S. fruit exports to Japan have decreased by over $58 million since 2000, equivalent to an average annual decrease of $19 million. Decreasing exports of grapefruit and cherries, the two primary export products, contribute to the overall decrease in fresh fruit exports to Japan. At the same time, total fresh fruit imports into Japan are increasing annually, with a $51 million increase from 2002 to 2003.

Japan imports the largest amount of fresh fruit, for both quantity and value, from the Philippines. Fresh fruit imports from the Philippines are increasing annually and continue to gain market share in Japan. The products imported from the Philippines are primarily tropical products that the United States does not produce such as bananas, pineapples, guavas, and papayas. New Zealand is another large exporter of fresh fruit to Japan. However, New Zealand is in the southern hemisphere so it is not on the same production cycle as the United States and also specialises in different products.

Japanese fresh fruit imports from Mexico are increasing rapidly. An increase of more than 43 percent from 2002 to 2003 brought imports from Mexico to $92 million in 2003. The largest imports from Mexico are avocados, followed by citrus, including lemons, limes, and oranges. Mexico is gaining market share in the Japanese market, while at the same time the United States is losing market share. Mexican fresh fruit imports appear to be the largest and most direct competition for U.S. fresh fruits in Japan. Substantial increases in fresh fruit imports from South Africa, Australia, and especially Thailand have also occurred in recent years. However, these countries do not pose the direct competition that Mexico does in terms of products and production cycle.

Mexico

Mexico can be identified as a significant competitor in fresh fruits to the United States, but Mexico also imports over $200 million annually in fresh fruit from the United States. The Mexican market is very important for apples, grapes, pears, and strawberries. Mexican imports of U.S. fresh fruits peaked in 2000 and have declined since. Although some of the Mexican market share has been slipping away from the United States in recent years, the United States still maintains over 68 percent of the Mexican fresh fruit import market.

Chile is the other primary supplier to Mexico, with 26 percent of the import market. Chilean fresh fruit exports continue to grow while U.S. exports decline. Again, Chile is an exporter to Mexico during the U.S. "off-season." The United States does not face much direct competition from foreign suppliers other than Chile in the Mexican fresh fruit market, but does compete with local domestic products, since Mexico is a large producer and exporter of many fruits.

Hong Kong

The United States is the largest supplier of fresh fruit to Hong Kong, and held 32 percent of the Hong Kong fresh fruit import market in 2003. Total fresh fruit imports from the United States were valued at $235 million in 2003. Fresh fruit imports into Hong Kong from the United States have risen steadily over the past several years. Hong Kong also imports fresh fruit from Thailand, Australia, and China. Thailand exports tropical fruits that the United States does not produce at all, or only on a very small scale. Australia exports some similar products as does the United States, but is in the southern hemisphere and on a different production cycle. Imports from Thailand, Australia, and China were all down in 2003. However, China primarily exports oranges, apples, and pears, which are competitive products with the United States. Fresh fruit imports from China have continued to increase annually and China has been increasing its share in the Hong Kong market.

The European Union (EU)

The EU is the largest importer of fresh fruits, importing $7.3 billion (8.4 million metric tons) in 2003. Fresh fruit imports into the EU are increasing on an annual basis, with a 5-percent increase in quantity from 2002 to 2003. The largest suppliers to the EU market are South Africa, Costa Rica, and several South American countries. The EU is also a large producer of fruits, and primarily imports from countries with marketing years that don't coincide with their production season.

The largest fruit import into the EU is bananas, which makes up 65 percent of imports. The United States is not a large supplier relative to the size of the EU market, and only holds about 2-percent of the market share. In 2003, the United States exported $153 million of fresh fruit to the EU. The EU is the United States' fifth largest fresh fruit export market. Although value of exports to the EU increased from 2002 to 2003, the actual quantity shipped decreased by 9.7 percent. Fresh fruit exports from the United States to the EU have been trending downward since 1997.

South Korea

The United States is the largest exporter of fresh fruit to South Korea in value, but the Philippines is the largest supplier in quantity. In 2003, the United States exported $92 million of fresh fruit to South Korea. The primary imports from the United States are citrus, including oranges, lemons and limes, and grapefruits. Grapes, kiwis, and cherries are also key products imported into South Korea from the United States. South Korea imports tropical products, including bananas, pineapples, and papayas from the Philippines, which are generally not competitive with U.S. products. In quantity, imports from the United States are increasing at a faster rate than are imports from the Philippines.

New Zealand is another large supplier of fresh fruits to the Korean market. South Korea imports many of the same products from the United States as it does from New Zealand, including kiwis, cherries, and citrus. However, New Zealand is in the southern hemisphere and on a different production cycle than the United States. Similarly, Chile has gained a large percentage share of the South Korean market in grapes and kiwis.

Global Export Competition

The focus of this section is to identify large producers and exporters and to determine which countries have been gaining market share. It discusses market trends in the exporting countries and discuss the marketing and promotional activities employed in those countries to gain market share.

EU

Although the EU is not a major direct competitor in the largest U.S. markets, the EU is a significant producer and exporter of fresh fruit. The EU is the second largest exporter of fresh fruits, in value and quantity. EU fresh fruit exports in quantity terms have remained relatively constant. However, the value of EU exports has increased dramatically. In 2003, the EU exported $1.9 billion in fresh fruits, up 20 percent from the previous year. This increase in value could be due to both increased fresh fruit prices as well as the euro appreciating relative to the dollar. The EU held about a 16-percent share of the world fresh fruit export market by value, which is a slight increase over the previous year's 15 percent market share.

The primary export markets for the EU are surrounding European countries. The EU's largest markets in 2003 were Switzerland, Poland, and Norway. The EU has recently expanded its membership to include Poland as well nine other European countries. Russia is also a large market for EU exports of fresh fruit. EU fresh fruit exports are comprised of citrus, including mandarins, oranges, lemons and limes, as well as grapes and apples. Aside from mandarins, the products that the EU exports are similar to those the United States exports. Also, the EU and the United States have similar production cycles. Although the EU focuses on different export markets than the United States, the EU is a direct competitor for U.S. exports.

The EU provides subsidies to fruit producers, as well as marketing and promotion assistance. All assistance is provided through producer organisations. The producer organisation can qualify for subsidies to carry out activities aimed at supply and price management, marketing programmes, quality improvement, and for promoting environmentally friendly methods. Subsidies are primarily in the form of either market intervention and export refunds. In 2001, withdrawal compensation subsidies authorised by the EU totaled 117 million euros. EU export refunds in 2001 for fresh fruits and vegetables equaled 36.1 million euros. Combined, the EU subsidised 153 million euros in 2001, in addition to assistance for marketing and promotional activities. In 2004, the EU approved five programmes to receive EU assistance for marketing outside the EU. The EU will provide another 3 million euros to selected groups for marketing of fruits and wine in Switzerland, Japan, Russia, the United States, Canada, and Brazil.

Chile

Chile is the third largest exporter of fresh fruits, in value, exporting $1.3 billion of fresh fruit in 2003. Approximately 45 percent of total fruit production is for fresh export, indicating that Chilean fruit producers are very dependent on the export market. Chile's share in the global fresh fruit export market has been relatively steady at 11 percent over the past five years. In value and quantity, Chilean fruit exports have steadily increased over the same time period. The United States is by far the largest importer of Chilean fresh fruit. Chile exported $613 million to the United States in 2003.

The second largest importer of Chilean fresh fruit is the European Union. Mexico is the third largest importer of fresh fruit from Chile. Chile's location in the southern hemisphere allows it to produce during the northern hemisphere's off-season, making it a key supplier of fresh fruit during the northern hemisphere's winter months. Grapes are the primary export from Chile, valued at $1.143 billion in 2003. Chile is actually the largest exporter of fresh grapes, followed by the United States.

Apples are the second largest export, valued at $262 million in 2003 followed by avocado exports, valued at $176 million in 2003. Due to its marketing season, Chile is an indirect competitor with the United States in the fresh fruit market. Chile actively promotes fresh fruit exports by providing funding for promotional and marketing strategies as well as technical assistance. The primary institution for marketing and export promotion is prochile, which is the Chilean government's export promotion agency. Prochile provides export assistance through matching grants, technical assistance, overseas representation, and market information services. prochile administers a $10 million Export Promotion Fund, providing matching grants to assist development of new markets and promotion of all nontraditional agricultural products.

The Chilean Ministry of Agriculture (MOA) also provides monetary support to promote agricultural exports. Additionally, the MOA provides policy and technical support to assist exporters. Chile has actively sought free trade agreements with trading partners such as the United States, European Union, Mercosur, Peru, Colombia, Venezuela, Bolivia, Panama, Mexico, and Canada.

Mexico

Mexico is the fourth largest fresh fruit exporter by value, with over $900 million in 2003. In quantity, Mexico is the world's seventh largest fresh fruit exporter, exporting 1.5 million metric tons in 2003. Since 1998, export value has increased annually, while export quantity has remained relatively stable, indicating increased prices received for fresh fruit exports.

The United States is by far Mexico's largest market, with over $800 million in annual sales to the United States alone. Approximately 88 percent of total fresh fruit exports from Mexico are shipped to the United States. The EU is the second largest market, followed by Canada. Mexico also exports fresh fruit to Japan and many Latin American countries. NAFTA alone makes up 95 percent of Mexico's fresh fruit exports. Although exports are increasing, Mexico does not hold significant market share in the EU or Japan.

Mexico is the world's largest exporter of avocados; in 2003, Mexico exported $195 million of avocados, of which $98 million were shipped to the United States. The remainder was shipped primarily to the EU, El Salvador, Canada, and Japan. Mexico's second largest export product is fresh grapes, again most of which are shipped to the United States. Mexico is also a large exporter of guavas, lemons and limes, as well as strawberries. Mexico's fresh fruit export sector is becoming more competitive in the world market, particularly in the United States and Canada. The increase in fresh fruit exports has been aided by the numerous free trade agreements and economic cooperation accords Mexico participates in as well as through the export promotion programmes supported by the Economic Ministry (ECONOMIA) and Mexico's foreign trade bank (BANCOMEXT).

ECONOMIA aids promotion of Mexican products through the Foreign Trade Directorate, with methods similar to those used by FAS to promote exports, including participation in foreign trade shows, coordination of exporter missions abroad, coordination for groups abroad, and organisation of educational seminars. The Economic Ministry also houses the Foreign Trade Development Directorate, which supports programmes for large exporters (ALTEX), temporary exporters (PITEX), and the Maquiladora Programme.

BANCOMEXT assists exporters primarily through participating in and encouraging participation in trade shows and business conventions. Incentives are provided to exporters that participate in trade shows, including 50-percent refunds on participation costs to both trade groups and private enterprises.

China

China is the largest producer of fruit, and production has been increasing for more than a decade. Fresh fruit exports from China have also been increasing since 1999, with more dramatic increases in recent years. Although exports increased by more than 30 percent in quantity (metric tons) from 2002 to 2003, only 2 percent of 2003 production was for export. Regardless, the rapidly increasing exports from China are also beginning to gain share in the global export market, while many other countries are losing market share. China is a large exporter of apples, mandarins, and pears. Export value of these top three products has grown tremendously in recent years; from 2002 to 2003 apple exports jumped 40 percent, and exports of mandarins and pears increased by 27 and 34 percent, respectively.

Russia is the largest importer of Chinese fresh fruit. This indicates that China so far may be more of a direct competitor with the EU than with the United States. China's other primary markets are located in Southeast Asia. Hong Kong is one market that could place the United States and China in direct competition for market share, although Hong Kong is often a middle market rather than the final destination for many products. Japan imports surprisingly little fresh fruit from China. Canada actually imports more fresh fruit from China than does Japan.

South Africa

Fruit production in South Africa is very dependent on the export sector. The amount of fruit grown for export has been steadily increasing since 1997. In 2003, over 38 percent of production was exported. In terms of quantity, fresh fruit exports from South Africa have also been increasing since 1997.

South Africa is a large exporter of fresh citrus fruit, including oranges, grapefruit, lemons and limes, and mandarins. Oranges are the top fresh fruit export from South Africa, followed by grapes and apples. South Africa is the third largest exporter of fresh oranges, and is the top exporter of fresh oranges from the southern hemisphere. The EU is by far the largest importer of fresh fruit from South Africa. Russia, the United Arab Emirates, and Japan are also importers of fruit from South Africa. South Africa, due to its location, is more of a direct competitor with Australia and Chile than the United States. The Department of Trade and Industry manages export promotion programmes.

The primary export enhancement programme is the Export Marketing and Investment Assistance Scheme (EMIA), which has an annual budget of $19 million. EMIA provides export market research and information, foreign direct investment promotion, and foreign exhibitions. It also provides assistance to industry-specific sectors and manages a special fund for small and medium-sized exporters. An export guarantee programme is also managed by the Department of Trade and Industry through the Export Credit Guarantee Scheme. This programme provides export assistance to small and medium businesses that do not have access to working capital. The Export Credit and Insurance Corporation of South Africa also facilitates trade by backing bank loans and investments outside of South Africa in order to enable foreign buyers to purchase South African products.

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2

Anatomy of Fruits

Some of the world's most widespread and debilitating nutritional disorders, including birth defects, mental and physical retardation, weakened immune systems, blindness, and even death, are caused by diets lacking in vitamins and minerals. Low fruit and vegetable intake is a major contributing factor to such micronutrient deficiencies.

The term fruit has different meanings dependent on context, and the term is not synonymous in food preparation and biology. Fruits are the means by which flowering plants disseminate seeds, and the presence of seeds indicates that a structure is most likely a fruit, though not all seeds come from fruits. No single terminology really fits the enormous variety that is found among plant fruits. The term 'false fruit' (pseudocarp, accessory fruit) is sometimes applied to a fruit like the fig (a multiple-accessory fruit) or to a plant structure that resembles a fruit but is not derived from a flower or flowers. Some gymnosperms, such as yew, have fleshy arils that resemble fruits and some junipers have berry-like, fleshy cones. The term "fruit" has also been inaccurately applied to the seed-containing female cones of many conifers.

Many true fruits, in a botanical sense, are treated as vegetables in cooking and food preparation because they are not sweet. These culinary vegetables include cucurbits (e.g., squash, pumpkin, and cucumber), tomatoes, peas, beans, corn, eggplant, and sweet pepper; some spices, such as allspice and chilies, are botanical fruits. Occasionally, though rarely, a culinary "fruit" is not a true fruit in the botanical sense. For example, rhubarb is often referred to as a fruit, because it is used to make sweet desserts such as pies, though only the petiole of the rhubarb plant is edible. In the culinary sense, a fruit is usually any sweet tasting plant product associated with seed(s), a vegetable is any savoury or less sweet plant product, and a nut any hard, oily, and shelled plant product. Although a nut is a type of fruit, it is also a popular term for edible seeds, such as walnuts and pistachios. Technically, a cereal grain is a fruit termed a caryopsis. However, the fruit wall is very thin and fused to the seed coat so almost all of the edible grain is actually a seed. Therefore, cereal grains, such as corn, wheat and rice are better considered edible seeds, although some references list them as fruits. Edible gymnosperm seeds are often misleadingly given fruit names, e.g. pine nuts, ginkgo nuts, and juniper berries.

FRUIT DEVELOPMENT

A fruit is a ripened ovary. Inside the ovary is one or more ovules where the megagametophyte contains the mega gamete or egg cell. The ovules are fertilized in a process that starts with pollination, which involves the movement of pollen from the stamens to the stigma of flowers. After pollination, a tube grows from the pollen through the stigma into the ovary to the ovule and sperm are transferred from the pollen to the ovule, within the ovule the sperm unites with the egg, forming a diploid zygote. Fertilization in flowering plants involves both plasmogamy, the fusing of the sperm and egg protoplasm and karyogamy, the union of the sperm and egg nucleus. When the sperm enters the nucleus of the ovule and joins with the megagamete and the endosperm mother cell, the fertilization process is completed.

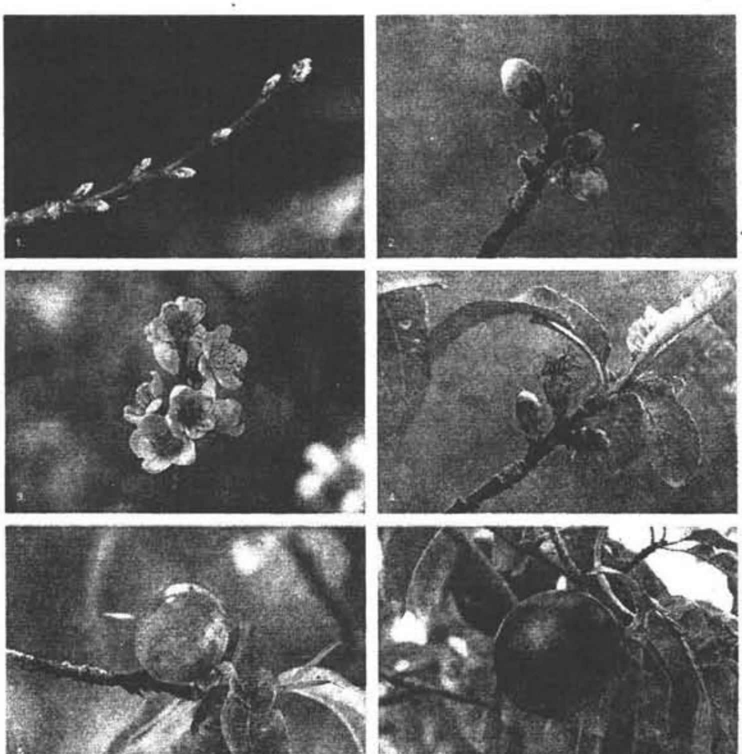

Figure 1. The development sequence of a typical drupe, the nectarine (Prunus persica) over a 7½ month period, from bud formation in early winter to fruit ripening in midsummer.

As the developing seeds mature, the ovary begins to ripen. The ovules develop into seeds and the ovary wall, the pericarp, may become fleshy (as in berries or drupes), or form a hard outer covering (as in nuts). In some cases, the sepals, petals and/or stamens and style of the flower fall off. Fruit development continues until the seeds have matured. In some multiseeded fruits, the extent to which the flesh develops is proportional to the number of fertilized ovules. The wall of the fruit, developed from the ovary wall of the flower, is called the pericarp. The pericarp is often differentiated into two or three distinct layers called the exocarp (outer layer, also called epicarp), mesocarp (middle layer), and endocarp (inner layer). In some fruits, especially simple fruits derived from an inferior ovary, other parts of the flower (such as the floral tube, including the petals, sepals, and stamens), fuse with the ovary and ripen with it. The plant hormone ethylene causes ripening. When such other floral parts are a significant part of the fruit, it is called an accessory fruit. Since other parts of the flower may contribute to the structure of the fruit, it is important to study flower structure to understand how a particular fruit forms.

Fruits are so diverse that it is difficult to devise a classification scheme that includes all known fruits. Many common terms for seeds and fruit are incorrectly applied, a fact that complicates understanding of the terminology.

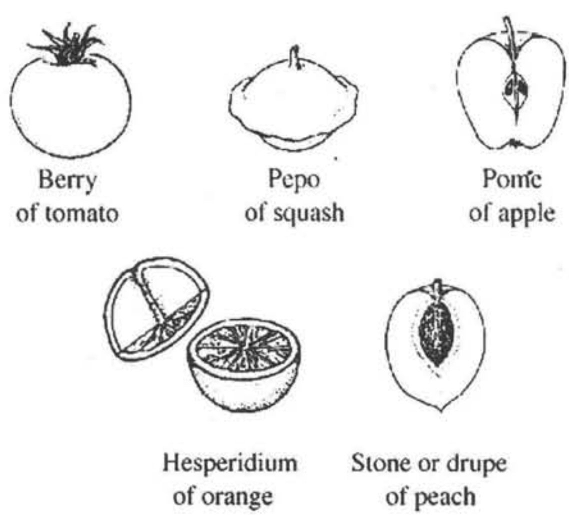

Figure 2. Fruit Diversity

Seeds are ripened ovules; fruits are the ripened ovaries or carpels that contain the seeds. To these two basic definitions can be added the clarification that in botanical terminology, a nut is not a type of fruit and not another term for seed, on the contrary to common terminology.

The seed develops from the ovule and contains the embryo and endosperm, surrounded by the maternally derived seed coat. The function of the seed is to protect the embryo, to sense environmental conditions favorable to germination and to nourish the germinating seedling.

Fruits develop from organs of the flower and thus involve differentiation or redifferentiation of preexisting organs. Evolutionarily, floral organs represent modified leaves and so the fruit is also a modified leaf. Fruits serve 2 functions: to protect the seeds during development, and then to disperse the seeds following maturation.

All mature seeds contain an embryo and a protective covering called a seed coat (testa). In early development all angiosperm seeds also contain an endosperm, but in many seeds the endosperm is completely absorbed by the developing embryo. The embryo and endosperm are products of fertilization while the seed coat develops from the integuments of the ovule.

The seed coat contains a variety of adaptations related to protection and dispersal mechanisms. The seed coat usually forms a dry tissue. It may contain waxes for water impermeability, mucilage to make seeds sticky, compounds resistant to digestion by animals, etc. In pomegranate, the seed coat forms the fleshy tissue that is consumed by humans. The seed coat often contains multiple layers with different characteristics.

Maternal tissues appear to have an important influence on seed development. An arabidopsis mutant called aberrant testa shape (ats) that lacks one of the 2 integuments also lacks several cell layers in the testa (3 layers vs. 5 normally). The seed are abnormally shaped in this mutant and seed shape shows maternal effect (ie. the genotype of the maternal parent determines the shape of the seed). Therefore, the seed coat and not the embryo determines the shape of the seed, and the embryo just grows to fill in the shape determined by the testa.

Another maternal gene called FBP7 is specifically expressed in the ovule and seed coat and is required for normal ovule development. Downregulation of this gene in transgenic plants resulted in degeneration of the endosperm that was dependent on maternal genotype. This demonstrates the interaction between maternal tissues and those produced by fertilization.

Several genes have been identified that negatively regulate seed development until fertilization has occurred. A mutant screen on a sterile line identified 3 genes that regulate seed development. Seeds develop on these mutants in the absence of fertilization. They are called fis for fertilization independent seeds. The genes appear important for control of seed development by fertilization. Several similar genes have been identified and cloned. They include:

- FIE = fertilization independent endosperm, encodes a WD type POLYCOMB protein
- MEDEA encodes a SET domain type POLYCOMB protein
- FIS2 = fertilization independent seed2, encodes a zinc finger protein
- POLYCOMB proteins are involved in chromatin structure and regulate (repress) the expression of genes in big portions of the genome. Therefore, the repression of large groups of genes is necessary to inhibit seed development until fertilization has occurred.

All three genes show parent-of-origin effects (imprinting). The maternally inherited gene is expressed and required but the paternally inherited gene is not expressed or required for seed development. (I.e. heterozygous mutants show 50% seed abortion, even when fertilized by wild type pollen.

Most cell division is complete by the beginning of the maturation phase of embryo development, but the embryo can increase in size up to 100 fold. This is by cell expansion and accompanies a massive accumulation of storage compounds. The major storage compounds are proteins, starch and lipids. These storage compounds are what give nutritional value to important crops such as cereals and beans. They are also valuable for other uses such as production of vegetable oil and starch which are used in a wide variety of ways ranging from cooking to industrial lubricants and plastics. Therefore there is a huge economic interest in seed storage compounds.

Storage proteins represent an important source of amino acids, nitrogen and carbon for the germinating seedling. Storage protein mRNAs represent up to 20% of the total mRNA found in a maturation phase embryo. They are synthesized on the RER and accumulate in the vacuole or as membrane bound vesicles called protein bodies. The storage proteins are encoded by several multigene families with up to 55 different genes coding for a given storage protein. Synthesis is controlled at the transcriptional level, with a few regulatory genes each controlling particular classes of storage proteins. An example is the opaque2 gene of maize which codes for a transcription factor.

The regulation of starch and lipid accumulation, although no less important, is less well understood. These compounds are produced by complex enzymatic pathways. Each class of compound is a mixture of molecules with different chain lengths, chain branching characteristics, levels of saturation and other chemical modifications. Thus the synthesis of these compounds is much less straight forward than storage proteins.

At the end of embryonic development, most seeds dehydrate to about 5% moisture content. Such severe dehydration is lethal to most plant tissues and embryos express a developmental program that allows them to survive. Acquisition of dessication tolerance is part of the seed maturation program. Two problems faced by desiccated cells are high ionic concentrations and membrane stresses. At such low moisture levels, solutes would tend to crystallize and precipitate. Hydrophobic interactions with the aqueous solution are important for maintaining the integrity of the lipid bilayer. With no aqueous phase, the membrane becomes unstable and leaky.

A group of proteins called dehydrins are expressed in late maturation. The role for these proteins in desiccation tolerance is supported by their induction by drought stress in vegetative tissues and during desiccation of the resurrection plant, one of the few plants that can tolerate desiccation of postembryonic tissues. They are hypothesized to function in ion sequestration and in forming a protective layer for stabilizing membranes.

Morphogenesis and maturation appear to be controlled by independent developmental programs. Viviparous mutants fail to undergo the maturation program leading to seed dormancy but instead germinate directly. Morphogenesis in viviparous mutants is normal whereas other mutants arrested at various stages of morphogenesis undergo normal maturation as evidenced by the absence of necrosis following desiccation and the accumulation of storage proteins.

Integration of these programs involves both hormonal mechanisms and genetic programs. ABA is necessary to induce the expression of genes involved in maturation and desiccation tolerance. Viviparous mutants are either ABA deficient or insensitive. An ABA independent genetic program is also necessary to confer ABA sensitivity to the embryo and mutants in this progfam show ABA insensitive vivipary. The LEC gene, in which mutants both display seedling instead of embyro morphological characteristics and bypass embryo maturation are likely candidates for coordinating the two different programs.

Contributions of different flower parts to the fruit

Most fruit develops from the ovary. In fact some schemes classify fruit derived from a single ovary as "true fruits" while "false fruits" are composed of tissues derived from flower parts other than the ovary or from more than one ovary.

In "true fruits" the outside of the fruit is called the pericarp and develops from the ovary wall. The pericarp can be dry and papery, like in maple or dandelions, woody like in nuts or fleshy as in berries (grapes and tomatoes) and stone fruits (cherries and peaches). These pericarp differences reflect adaptations to different dispersal mechanisms (eg. wind for papery pericarps, animal consumption for fleshy fruits). The fruit can contain a single seed as in corn, or many seeds like a pea pod or pumpkin. The pericarp of some fruits is further differentiated into specialized layers called exocarp, meso- and endocarp. For example in citrus the rind is the exocarp, the white covering is the mesocarp and the juice sacs are the endocarp.

Many fruits we consider berries, such as raspberries and strawberries, are botanically not classified as berries. Raspberries are examples of aggregate fruits. Each juicy little sphere is actually an individual fruit of the same class as cherries, and what we consider as the fruit is really an aggregation of fruits.

Strawberries and apples are examples of accessory fruits, where some of the fleshy tissue is derived from flower parts other than the ovary. Strawberry fruits are actually what we consider the seeds. They are called achenes, which are dry fruits in the same category as dandelions. The fleshy part that we eat develops from the receptacle. Most of the fleshy tissue in apples develops from the hypanthium which is a region of the flower where sepals, petals and stamens are all fused to the ovary. Thus all floral organs contribute to the fleshy portion of apples.

Phases of Fruit Development

Fruit development can generally be considered to occur in four phases: fruit set, a period of rapid cell division, a cell expansion phase, and ripening/maturation.

Fruit set involves the decision whether to abort the ovary or proceed with fruit development. Fruit set is normally dependent on pollination. Pollen triggers fruit development indicating that positive signals are generated during pollination. In the absence of these signals, the flowers abscise. Growing pollen produces GA and application of GA can induce parthenocarpic fruit, therefore it is believed that GA is a triggering signal. Lagging slightly behind the growing pollen tube is a wave of increased auxin production by the style and then the ovary. Auxin application can also induce parthenocarpy and so it is thought that GA acts by inducing auxin production. However, most GA deficient mutants are able to produce fruit indicating that this is not the sole mechanism to induce fruit development and in an auxin insensitive tomato mutant, fruit growth is normal.

Continued fruit development usually relies on the continued presence of developing seeds. Seed abortion or removal causes fruit abortion, which can be reversed with auxin application. For example. removal of strawberry "seeds" prevents the development of the receptacle as a "fruit" but if auxin is applied following seed removal, fruit development continues. Commercial crops that produce parthenocarpic (seedless) fruits, such as bananna, often show quantitaive or qualitative differences in GA or auxin content in the ovary when compared to nonparthenocarpic varieties.

The phase of rapid cell division involves all growing parts of the fruit. This is thought to be controlled by the developing seeds. The number of fertilized ovules in a fruit is correlated with both the initial cell division rate and the final size of the fruit. Also, fruits with an uneven distribution of seeds are often lopsided. There is a correlation between cytokinin levels in developing embryos and cell division in surrounding tissues but there is no direct evidence that embryo cytokinin in fact regulates fruit cell division. It is difficult to reconcile the complete development of parthenocarpic fruit with the requirement of embryos for cell division except to say that parthenocarpy represents an abnormal situation.

The cell division phase gradually shifts into the cell expansion phase. The rate and duration of cell division varies among fruits and also among tissues within a fruit. Tissues made up of many small cells at maturity continue dividing while tissues composed of large cells have begun expanding. In tomato the cell division phase lasts approximately 7-10 days while cell expansion lasts 6-7 weeks. Cell expansion accounts for the largest increase in fruit volume, often contributing in excess of a 100 fold size increase. Gibberellins are also associated with fruit expansion and removal of the seeds from pea pods inhibited GA biosynthesis in the pericarp. Many believe that auxins from seeds regulate cell expansion of the pericarp, but auxin application does not always compensate for seed removal, and in an auxin insensitive tomato mutant, fruit growth is normal.

Fruit Ripening

Ripening represents the shift from the protective function to dispersal function of the fruit. Ripening occurs synchronously with seed and embryo maturation, as described in the lecture on embryo development. In dry fruits (cereals, nuts, dandelions) ripening consists of desiccation and is considered maturation. Ripening in fleshy fruits is designed to make the fruit appealing to animals that eat the fruit as a means for seed dispersal. Ripening involves the softening, increased juiciness and sweetness, and color changes of the fruit. Fleshy fruits are either climacteric or non-climacteric. Climacteric fruits produce a respirative burst with a concomitant burst in ethylene synthesis, as the fruits ripen. These include fruits with high degrees of flesh softening, like tomato, banana, avacado, peach etc.

Ripening has been most intensively studied in tomato. Ethylene is a major regulator of the ripening process. Inhibitioin of ethylene with inhibitors, transgenic approaches or mutants blocks ripening. Exogenous ethylene accelerates ripening. There are also developmental factors involved because fruit does not attain competence to respond to ethylene until near the end of the cell expansion phase (the mature green stage). Several genes associated with ripening are ethylene inducible. This occurs transcriptionally in most genes but at least one is known where mRNA accumulation is regulated post-transcriptionally. None of these genes are induced until competence for ethylene response is attained.

The tomato never-ripe mutation blocks fruit ripening and is insensitive to ethylene. The mutated gene is similar to the ethylene receptor isolated from arabidopsis, suggesting that never-ripe is an ethylene receptor mutant. NR mRNA is not expressed until the mature green stage, suggesting that lack of this ethylene receptor might be related to the lack of competence to respond to ethylene at earlier stages.

Ethylene production is autocatalytic. That is, exposure to ethylene stimulates the synthesis of more ethylene. This occurs because the genes for the biosynthetic enzymes (e.g. ACC SYNTHASE) are ethylene inducible. The result is a positive feedback loop. Furthermore, the Never-ripe gene is ethylene inducible, resulting in a positive feedback loop for ethylene sensitivity as well. Both these factors contribute to the dramatic burst of ethylene production during ripening. Fruit softening involves a partial breakdown of cell walls. Several enzymes are known to be involved in this process. Polygalacturonase hydrolyzes bonds in pectins. The gene for this enzyme is ethylene inducible. Changes in fruit color involve changes in the expression of pigment biosynthetic genes. The major pigment in tomato is a carotenoid. The first committed step in carotenoid biosynthesis is catalyzed by phytoene synthase, and the gene for this enzyme is induced by ethylene.

Germination

Seeds have mechanisms to ensure germination occurs only under favorable environmental conditions for seedling growth. The primary factors are water availability and season. All seeds must imbibe water to germinate and for some this is the only requirement. Some also contain growth inhibitors that must be leached out of the seed. Some have impervious seed coats that must be fractured by freezing or passage through the digestive tract of an animal. Yet others have light or photoperiod requirements. All these mechanisms ensure the seeds germinate in the correct season and when moisture is available.

Arabidopsis seeds have certain requirements for germination, including a period of dormancy (which can be substituted for by cold treatment) and light (a phytochrome response). Mutations in a gene called DAG1 (Dof Affecting Germination1) cause seeds that germinate in the dark without a dormancy period. Dof proteins are zinc finger transcription factors. The gene is expressed in the maternal tissues and all seeds of a mutant show this phenotype even if they result in pollination by a wild type (i.e. the embryo is wild type). Therefore, the maternal tissues during seed development control the dormancy behavior of the seed after being shed from the plant.

Upon imbibition, active metabolism resumes. Imbibed seeds contain high levels of GA. It is produced by the germinating embryo and stimulates the synthesis of hydrolytic enzymes by inducing the transcription of their genes. These enzymes appear after radicle elongation and are therefore postgerminative. The hydrolytic enzymes include proteases, amylases and lipases that break down storage compounds making building blocks available to the growing seedling. One enzyme of particular importance is a-amylase which cleaves starch into glucose and maltose molecules. This reaction is of economic importance to the malting industry and so the regulation of a-amylase gene expression has been carefully studied. It is transcriptionally induced by GA. Plants also contain a unique metabolic pathway called the glyoxylate cycle. This enables plants to convert fatty acids of the stored lipids into carbohydrates, specifically glücose and sucrose. In contrast, animals are unable to convert fatty acids to glucose.

GA and ABA act antagonistically to regulate the germination vs. maturation programs. ABA promotes maturation while GA promotes germination. As mentioned, ABA is necessary for seed maturation because ABA deficient mutants are viviparous and desiccation intolerant. Therefore, without ABA, seeds directly enter the germination program. Exogenous ABA can inhibit germination following dormancy. Conversely, promotes germination. GA is required for germination because GA deficient mutants are unable to germinate. Exogenous GA application to developing seeds can block maturation and induce vivipary. The VP1/ABI3 protein is a central regulator in these functions. This protein is a transcription factor that promotes the expression of maturation genes and inhibits the expression of germination genes. Mutants in this gene are ABA insensitive.

True Fruits and False Fruits

Fruits can be divided into 'true fruits' and 'false fruits'. The true fruits can be classified further according to their botanical structure. During fertilisation an embryo is formed in the ovule. This results from the fusion of male and female reproductive cells (a nucleus in the pollen grain and a nucleus in the female egg cell in the ovule). There are other nuclei in the pollen grain and the egg cell and these also fuse and form a structure known as the endosperm. This becomes a food store for the developing seed.

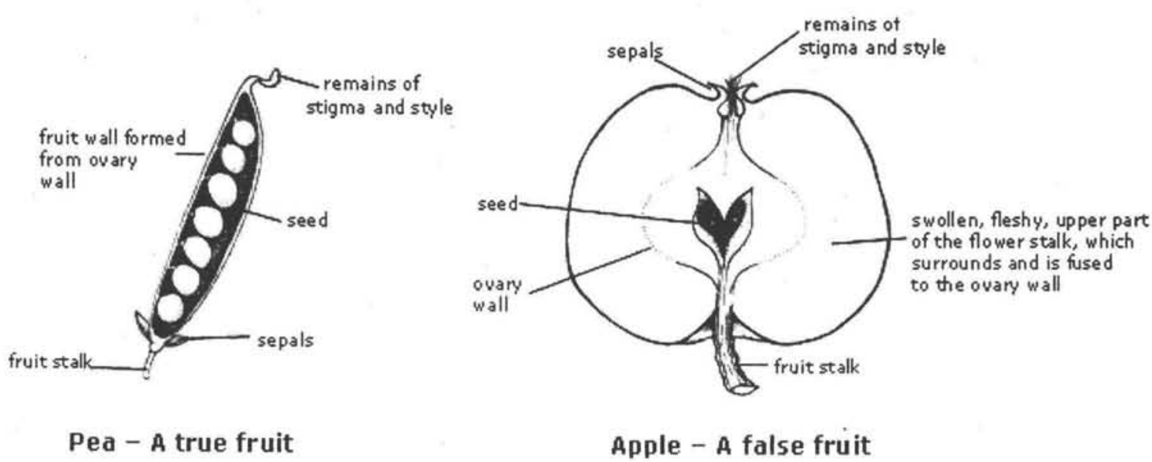

Figure 3. True Fruits and False Fruits

In some plants, the fruit may be formed from just from the ovary and the other floral parts (e.g. sepals, petals, stamens, stigma and style) persist only as withered remains. When this happens, the fruits are described as 'true fruits'. Often, however, other floral parts form an integral part of the fruit. An example is the apple, in which the top of the flower stalk becomes fleshy, surrounds the ovary wall and fuses with it. Such fruits are often referred to as false fruits to distinguish them from the true fruits that are formed only from the ovary. Fruits can, however, also be grouped according to their dispersal mechanism. This approach is more likely to be used in a school teaching programme and the images given here have therefore been arranged into the four main dispersal groups as follows: fruits and seeds that are dispersed by animals, dispersed by wind, self dispersed and dispersed by water.

TYPES OF FRUITS

There are three basic types of fruits:

- Simple fruit
- Aggregate fruit
- Multiple fruit

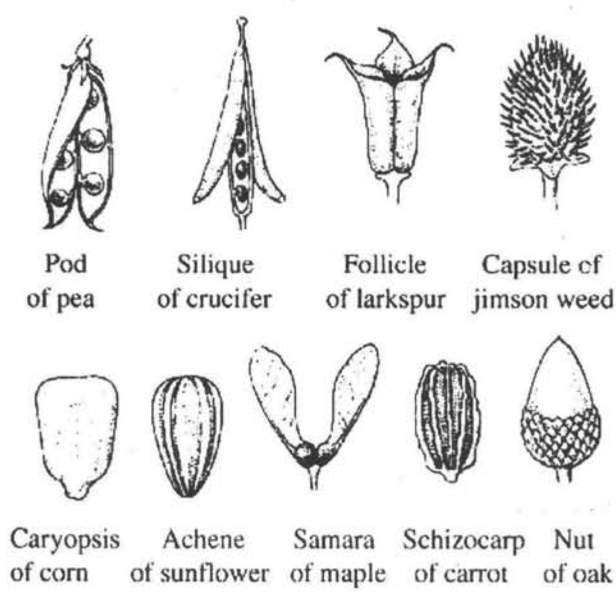

Figure 4. Differnet types of fruits

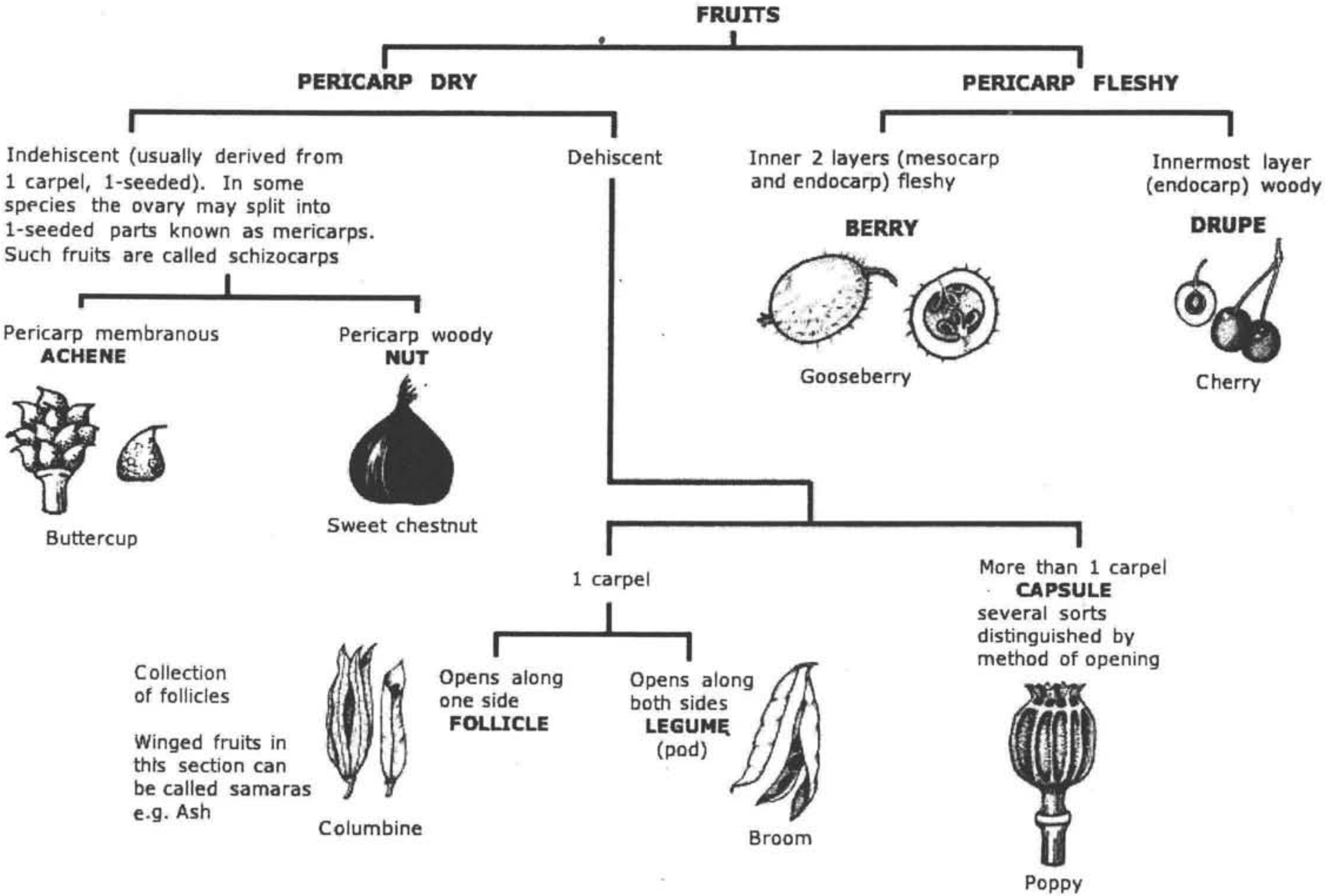

Figure 5. A key for true fruits

Simple Fruit

Simple fruits can be either dry or fleshy, and result from the ripening of a simple or compound ovary with only one pistil. Dry fruits may be either dehiscent (opening to discharge seeds), or indehiscent (not opening to discharge seeds).

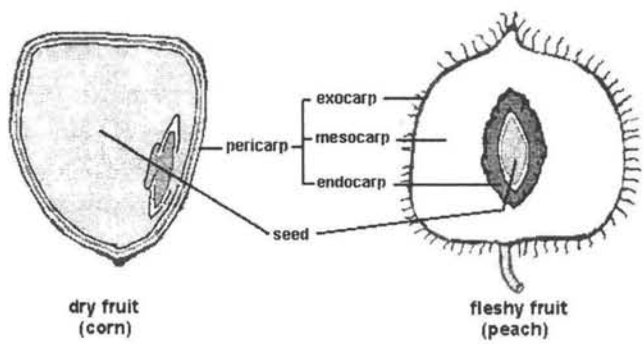

Figure 6. Structure of Simple Fruit

Types of dry, simple fruits, with examples of each, are:

- achene - (dandelion seeds, strawberry seeds)
- capsule - (Brazil nut)
- caryopsis - (wheat)
- fibrous drupe - (coconut, walnut)
- follicle - (milkweed, magnolia)
- legume - (pea, bean, peanut)
- loment
- nut - (hazelnut, beech, oak acorn)
- samara - (elm, ash, maple key)
- schizocarp - (carrot seed)
- silique - (radish seed)
- silicle - (shepherd's purse)
- utricle - (beet)

Fruits in which part or all of the pericarp (fruit wall) is fleshy at maturity are simple fleshy fruits. Types of fleshy, simple fruits (with examples) are:

- berry - (redcurrant, gooseberry, tomato, avocado)
- stone fruit or drupe (plum, cherry, peach, apricot, olive)
- false berry - Epigynous accessory fruits (banana, cranberry, strawberry (edible part).)
- pome - accessory fruits (apple, pear, rosehip)

Aggregate Fruit

An aggregate fruit, or etaerio, develops from a flower with numerous simple pistils. An example is the raspberry, whose simple fruits are termed drupelets because each is like a small drupe attached to the receptacle. In some bramble fruits (such as blackberry) the receptacle is elongated and part of the ripe fruit, making the blackberry an aggregate-accessory fruit.

Figure 7. An aggregate fruit

The strawberry is also an aggregate-accessory fruit, only one in which the seeds are contained in achenes. In all these examples, the fruit develops from a single flower with numerous pistils. Some kinds of aggregate fruits are called berries, yet in the botanical sense they are not.

Multiple Fruit

A multiple fruit is one formed from a cluster of flowers (called an inflorescence). Each flower produces a fruit, but these mature into a single mass. Examples are the pineapple, edible fig, mulberry, osage-orange, and breadfruit.

In some plants, such as this noni, flowers are produced regularly along the stem and it is possible to see together examples of flowering, fruit development, and fruit ripening.

In multiple fruits, there are several flowers, each with an ovary, develop into small fruits which are clustered or fused together into a larger fruit. An example of this is a pineapple. Each section of a pineapple was an individual fruit from an individual flower, but they have fused to form the pineapple.

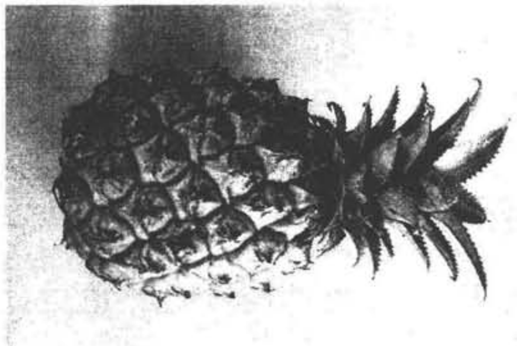

Figure 8. Pineapple: A Multiple Fruit

There are many dry multiple fruits, e.g.

- Tuliptree, multiple of samaras.
- Sweet gum, multiple of capsules.
- Sycamore and teasel, multiple of achenes.
- Magnolia, multiple of follicles.

ANATOMY OF FRUITS

In fleshy fruits, the outer, often edible, layer is the pericarp, which is the tissue that develops from the ovary wall of the flower and surrounds the seeds. If seeds are considered to be akin to eggs developing in the ovary of a fowl, the pericarp would be the female bird's uterus. However, there are a large number of fruits which are not adequately described by that analogy; for example in most nuts and legumes the edible part is the seed and not the pericarp. Many edible vegetables are actually stems, leaves, and even roots of the plant, but others like the cucumber, squash etc. are the common pericarp and are botanically considered to be fruits. Finally, in some seemingly pericarp fruits the edible portion is actually an aril.

In berries and drupes, the pericarp forms the edible tissue around the seeds. In accessory fruits, other tissues develop into the edible portion of the fruit instead, for example the receptacle of the flower in apples and strawberries.

Pericarp layers

The pericarp itself is typically made up of three distinct layers: the exocarp which is the most outside layer or peel, the mesocarp the middle layer or pith, and the endocarp the inner layer surrounding the hollowed ovary or the containing seeds.

Exocarp

Exocarp (Gr. "outside" + "fruit"), is a botanical term for the outermost layer of the pericarp (or fruit). The exocarp forms the tough outer skin of the fruit which bears oil glands and pigments. The exocarp is sometimes called the epicarp, or, especially in citruses, the flavedo.

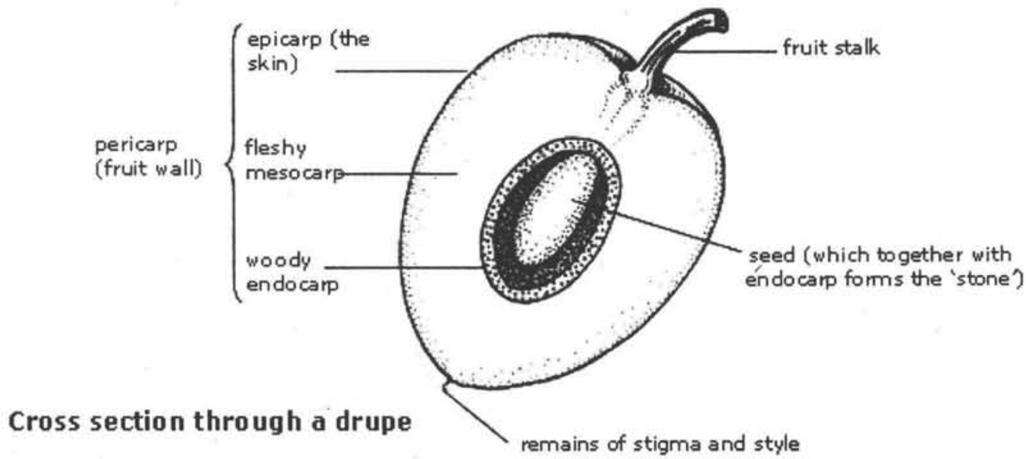

Figure 9. Diagram of a typical drupe (peach), showing both fruit and seed

Flavedo is mostly composed of cellulosic material but also contains other components, such as essential oils, paraffin waxes, steroids and triterpenoids, fatty acids, pigments (carotenoids, chlorophylls, flavonoids), bitter principles (limonene), and enzymes. In citrus fruits, the flavedo constitutes the peripheral surface of the pericarp. It is composed of several cell layers that become progressively thicker in the internal part; the epidermic layer is covered with wax and contains few stomata, which in many cases are closed when the fruit is ripe. When ripe, the flavedo cells contain carotenoids (mostly xanthophyll) inside chromoplasts which, in a previous developmental stage, contained chlorophyll. This hormonally controlled progression in development is responsible for the fruit's change of color from green to yellow upon ripening. The internal region of the flavedo is rich in multicellular bodies with spherical or pyriform shapes, which are full of essential oils.

Mesocarp

Mesocarp (Grammer "middle" + "fruit") or Sarcocarp (Grammer. "flesh" + "fruit"), is the botanical term for the succulent and fleshy middle layer of the pericarp of drupaceous fruit, between the exocarp and the endocarp; it is usually the part of the fruit that is eaten. This term may also refer to any fruit which is fleshy throughout. In a hesperidium, the mesocarp is also referred to as albedo or pith because of its soft fiber. It is part of the peel which is commonly removed by hand.

Endocarp

Endocarp (Gr. "inside" + "fruit"), is a botanical term for the inside layer of the pericarp (or fruit), which directly surrounds the seeds. It may be membranous as in citrus where it is the only part consumed, or thick and hard as in the stone fruits of the subfamily Prunoideae such as peaches, cherries, plums, and apricots.

In nuts, it is the stony layer that surrounds the kernel of pecans, walnuts etc. and which is removed prior to consumption. In citrus, the endocarp is separated into sections which are most commonly called segments. The juicy pulp filling the segments is usually referred to as juice vesicles.

SEEDLESS FRUITS

Seedlessness is an important feature of some fruits of commerce. Commercial cultivars of bananas and pineapples are examples of seedless fruits. Some cultivars of citrus fruits (especially navel oranges), satsumas, mandarin oranges table grapes, grapefruit, and watermelons are valued for their seedlessness. In some species, seedlessness is the result of parthenocarpy, where fruits set without fertilization. Parthenocarpic fruit set may or may not require pollination. Most seedless citrus fruits require a pollination stimulus; bananas and pineapples do not. Seedlessness in table grapes results from the abortion of the embryonic plant that is produced by fertilization, a phenomenon known as stenospermocarpy which requires normal pollination and fertilization.

Seedless fruits can develop in one of two ways: either the fruit develops without any fertilization (parthenocarpy), or pollination triggers fruit development but the ovules or embryos abort without producing mature seeds (stenospermocarpy). Seedless fruits of banana and watermelon are produced on triploid plants, whose three sets of chromosomes prevent meiosis from taking place and thus do not produce fertile gametes. Such plants can arise by spontaneous mutation or by hybridization between diploid and tetraploid individuals of the same or different species. Some species, such as pineapple and cucumber, produce seedless fruit if not pollinated, but produce seeded fruit if pollination occurs.

Lacking seeds, and therefore the capacity to propagate via the fruit, the plants are generally propagated vegetatively from cuttings, by grafting, or in the case of bananas, from "pups" (offsets). In such cases, the resulting plants are genetically identical clones. By contrast, seedless watermelons are grown from seeds. These seeds are produced by crossing diploid and tetraploid lines of watermelon, with the resulting seeds producing sterile triploid plants. Fruit development is triggered by pollination and these plants must be grown alongside a diploid strain to provide pollen.

One disadvantage of most seedless crops is a significant reduction in the amount of genetic diversity in the species. As genetically identical clones, a pest or disease that affects one individual is likely to be capable of affecting every clone of that individual. For example, the vast majority of commercially produced bananas are cloned from a single source, the Cavendish cultivar, and those plants are currently threatened worldwide by a newly discovered fungal disease to which they are highly susceptible.

SEED DISSEMINATION

Variations in fruit structures largely depend on the mode of dispersal of the seeds they contain. This dispersal can be achieved by animals, wind, water, or explosive dehiscence.

Some fruits have coats covered with spikes or hooked burrs, either to prevent themselves from being eaten by animals or to stick to the hairs, feathers or legs of animals, using them as dispersal agents. Examples include cocklebur and unicorn plant.

The sweet flesh of many fruits is "deliberately" appealing to animals, so that the seeds held within are eaten and "unwittingly" carried away and deposited at a distance from the parent. Likewise, the nutritious, oily kernels of nuts are appealing to rodents (such as squirrels) who hoard them in the soil in order to avoid starving during the winter, thus giving those seeds that remain uneaten the chance to germinate and grow into a new plant away from their parent.

Other fruits are elongated and flattened out naturally and so become thin, like wings or helicopter blades, e.g. maple, tuliptree and elm. This is an evolutionary mechanism to increase dispersal distance away from the parent via wind. Other wind-dispersed fruit have tiny parachutes, e.g. dandelion and salsify.

Coconut fruits can float thousands of miles in the ocean to spread seeds. Some other fruits that can disperse via water are nipa palm and screw pine.

Some fruits fling seeds substantial distances (up to 100 m in sandbox tree) via explosive dehiscence or other mechanisms, e.g. impatiens and squirting cucumber.

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3

Principles of Fruit Tree Cultivation

A fruit tree is a tree bearing fruit that is consumed or used by people — all trees that are flowering plants produce fruit, which are the ripened ovary of a flower containing one or more seeds. In horticultural usage, the term 'fruit tree' is limited to those that provide fruit for human food. Types of fruits are described and defined elsewhere, but would include fruit in a culinary sense as well as some nut bearing trees, like walnuts. The scientific study and the cultivation of fruits is called pomology, which divides fruits into groups based on plant morphology and anatomy. Some of those groups are: Pome fruits, which include apples and pears; and stone fruits which include peaches/ nectarines, almonds, apricots, plums and cherries.

FRUIT TREE FORMS

The shapes of most fruit trees can be manipulated by pruning and training in order to increase yield, or to improve their suitability for different situations and conditions. Pruning a tree to a pyramid shape means that trees can be planted closer together. An open bowl or cup form increases the penetration of sunlight, thus encouraging a high fruit yield whilst keeping the tree short and easy to pick from. Other shapes such as cordons, espaliers and fans offer opportunities for growing trees two dimensionally against walls or fences, or can themselves be trained as barriers.

Bush trees are the traditional open goblet shaped form, with a clear lower stem. Within this branch, several subforms are frequently used; these include the spindlebush-form; which was designed for dense orchards by Schnitz-Hubsh and Heinrichs in Germany in 1936, and is currently also the most popular training system for dwarf apple and pear trees.

Cordons are single stemmed trees with fruiting spurs planted at an angle. Any side branches are removed by pruning. cordons take less space and crop earlier than most other forms which means that more varieties can be got into a small space, but yields are smaller per tree. A special cordon set-up is the Bouché-Thomas system.

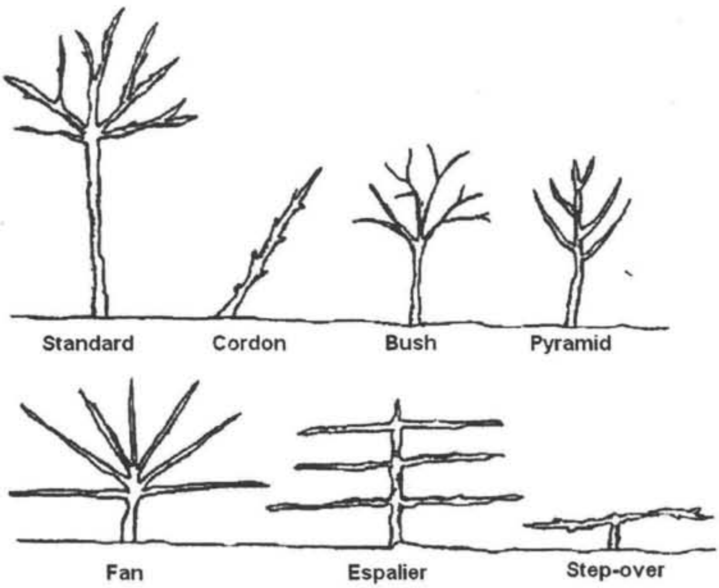


Figure 1. Fruit Tree Shapes

Espaliers have a central vertical trunk with three or four horizontal branches each side. A special espalier in this group is the LePage-system. Fans have a short central trunk with several radiating branches growing from the crown. Step-over espaliers have single horizontal branches at 30 cm from the ground and make a novel and productive border to the vegetable plot.

All of these shapes require training by tying the branches to the required form, and pruning to retain the desired structure. This is usually carried out in autumn for major cutting back and late summer for light trimming. Autumn pruning encourages woody growth whilst late summer pruning encourages fruiting. Not all trees will accept all of the shapes above- apples and pears do well as cordons and espaliers for example, whereas cherries prefer to be fanned.

PLANNING BEFORE PLANTING

Fruit Selection

Selecting the type of fruit to grow is the first step in tree fruit production. To begin, you need to know which tree fruit can be grown in your region. Your region's climate determines the type of fruit you can grow successfully. The climate must be compatible with the growing requirements of the selected fruit crop. To take an extreme example, a tropical fruit such as the banana simply cannot survive in Amercia. Bananas require a warmer climate and a longer growing season. Different crops require different levels of management. Low-management crops such as pecans, figs, and persimmons require little attention to training, fertility, or insect and disease control. On the other hand, peaches and plums require intensive management.

Plant Quality

Purchase well-grown, heavily rooted, one-year-old plants of all fruits except blueberries and brambles. Two-year-old blueberry plants are recommended. Nursery plants listed as "certified" (true to name) and "virus tested" or "virus indexed" are recommended. Brambles and stone fruit trees (peaches, nectarines, plums, cherries) are especially prone to virus infection in the nursery. Infected plants are not very vigorous and may produce little fruit, so it is worth the additional cost to buy virus-tested plants. Micropropagated ("tissue-cultured") brambles should be multiplied and grown in a greenhouse in steam-sterilised soil. Any bramble plant that has been grown outside in a nursery may be infected with several diseases, all of which will result in poor plant growth and yield.

Site Selection

Selecting a good site for your fruit trees is crucial to their success. A number of factors should be considered (Figure 2a and 2b).

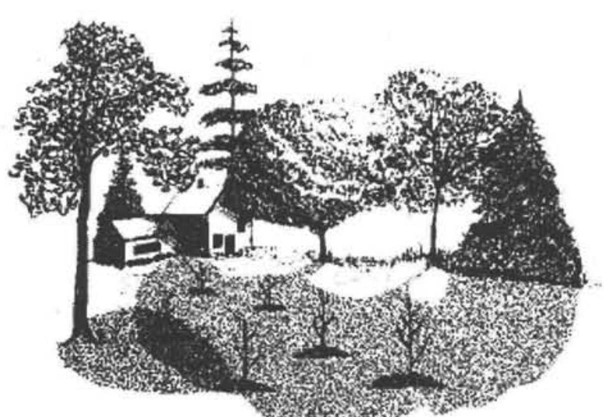


Figure 2a: Poor site selection. Fruit trees should not be planted in areas shaded by houses, buildings, or other trees. They also should not be planted near fences or hedges, as these keep cold air trapped around young trees.

Figure 2b: Well-selected site. All fruit trees are planted away from barriers and in areas that receive sufficient light.

Plenty of sunlight is a key to maximising fruit production. While some fruit plants can survive in partial shade, most require direct sunlight to fuel the energyintensive fruit-production process. Choose a planting area in your yard that will be in the sun most or all of the day. Rapid drying of the plant canopy reduces the need for fungicides and is important in preventing disease. The more quickly the plants dry off after rain or dew, the less chance they have of contracting disease. Early morning sunshine is particularly important for drying dew from the plants.

Choose an area that is large enough to permit adequate plant spacing within and between rows. Less crowded plants will dry more quickly.

Choose a location with good air and water drainage and some protection from prevailing winds. Northern exposures are less subject to late spring frosts and are likely to have the most snow cover, which protects plants from soil heaving caused by alternate freezing and thawing of the soil surface.

Avoid planting within the root zone of black walnut trees since these trees produce a natural herbicide (juglone) that inhibits the growth of other plants. Do not plant brambles or strawberries where any Solanaceous crop (tomatoes, peppers, eggplant, potatoes) has been grown for the last five years. A soil fungus called Verticillium can inhabit plant debris from Solanaceous crops. If strawberries or brambles are infected, the entire planting may be lost within one season.

Lack of space in full sunlight often discourages the home gardener from planting fruit in the backyard. Fruit plants can be planted in ways that do not require large areas. The following list provides some suggestions for planting in smaller spaces.

- Use dwarfing rootstocks for apple trees. These reduce the apple tree size by as much as 60 percent and are readily available from most nurseries.
- Use the fruit plants as a property screen or divider. Fruit trees, grapes, and brambles are ideal for this.
- Grow espaliered apple or pear trees or vining plants such as grapes or thornless blackberries on a fence or against a wall.
- Grow strawberries in pots or as a pyramid.
- Grow currants or gooseberries in partial shade.

Good internal water drainage in the soil is a more important consideration than soil fertility. Avoid soils and sites that are not well drained. If water stands for more than 24 hours after a spring rain, the soil is probably not drained well enough for fruit production. Wet soils result in oxygen-starved roots and a microenvironment conducive to disease development.

Soil Type and Drainage

Plant fruit trees in well-drained and fairly fertile soil. Avoid poorly drained soils. A tree's root system grows throughout the year. Water that remains standing in the root zone (18 to 24 inches deep) at any time during the year can drown the tree. During the growing season, standing water can drown some types of fruit trees in just three days. Poorly drained soils also promote the growth of root rot organisms.

When poorly drained soils cannot be avoided, problems may be alleviated by planting the trees in raised beds.The beds are formed by shaping well-drained topsoil into beds 18 to 24 inches high and 4 to 5 feet wide. Raised beds have been used successfully in both backyard and commercial orchards. Trees grown in raised beds must be irrigated more frequently during the growing season because the beds present a larger exposed surface area from which water can evaporate.

Soil Fertility

It is also important to consider soil fertility and acidity. Acidic soils reduce the amount of nutrients available to the trees. When this happens, fertilisation does not benefit the trees but results in runoff or leaching. To alleviate the problem, it will be necessary to add lime to the soil to reduce the soil pH.

Before planting, collect soil samples for analysis. Soil samples should be taken from two depths; the first from the top 8 inches of soil and the second from the 9- to 16-inch depth.

The soil in which our plants grow is a complex material. Its consistency and makeup have a marked influence upon plants. Soil provides support for the plant and is also the storehouse for plant nutrients, water, and oxygen for root growth.

Not all soils have the same ability to produce plant growth. The productive capacity of a soil must be considered in terms of both its fertility and physical condition. Even if the correct nutrients are present, they must be released in a form readily available to the plant. Soil fertility should then be considered as the soil's nutrient-supplying capacity, and not strictly as the amount of any one nutrient. Therefore, maintaining soil fertility involves adjusting the supply of available nutrients to levels conducive to the desired growth. To determine the fertility of your soil, collect samples on which to have a soil test performed. Obtain a soil test kit from your county extension office. There is a small cost for the kit, which includes soil analysis and fertilizer/lime recommendations for your particular soil. When you submit the soil for analysis, be sure to specify the crop that you intend to grow since nutritional and pH requirements vary somewhat among fruit types.

You will receive a soil test report back from the laboratory. The Penn State report shows phosphate, potassium (also called potash), magnesium, and calcium levels, as well as soil pH. Suggested fertilizer application rates are provided along with the levels. The report has three sections. First, the pH adjustment shows the amount of calcitic limestone (0 to 3 percent Mg) needed to raise the soil pH to the desired level for your particular crop. Second, the magnesium and calcium section shows the amount of Epsom salts (magnesium sulfate) and gypsum (calcium sulfate) needed by the crop. Finally, the plant nutrient needs section indicates the amount of other fertilizer materials to be used. Before planting, fertilise and lime the soil (or acidify it for blueberries) according to the soil test results.

Air Drainage

Adequate air drainage is as important as proper water drainage. Remember that cold air is heavier than warm air and settles in low areas, so choose a site that allows cold air to flow downhill away from the trees. Select higher sites with an unobstructed, gradual slope. Avoid low sites, which are commonly known as frost pockets.

Sunlight

Plant fruit trees in areas that receive full sunlight. Avoid areas shaded by taller trees, houses, or buildings. Most fruit tree buds require 30 percent sunlight to produce high-quality fruit. Although the exterior of a tree may receive full sun, sunlight can be reduced by one-half just 12 inches inside the canopy of the tree. Eighteen inches into the tree canopy, light may be reduced nearly 75 percent, which is below the level needed for successful fruit production. Partially shaded trees can also have increased disease problems.

Variety Selection

After selecting the fruit and the planting site, you must choose the variety of fruit to plant. Novice growers often try to plant the same varieties that they see at their local grocery stores. Many times, however, these fruit are produced in areas with different climatic conditions. The result, at best, is fruit that looks much different than expected. At worst, the variety will fail to produce a crop. Plant varieties that are known to grow well in your region.

Rootstock Selection and Tree Spacing

Almost all commercially available fruit trees have been budded or grafted; that is, the top portion, or scion, of the desired fruit variety is attached to the root system, or rootstock, of a different variety. Trees are grown this way because some popular varieties grow and crop better on rootstocks other than their own. In some cases, the rootstock is more resistant to certain troublesome diseases. In the case of apple trees, the rootstock can be chosen to limit growth, producing trees that crop well and are easier to manage than full-sized trees. The choice of rootstock is very important for some fruits, such as apples, but not of much consequence for others. Apple trees are grown on a wide variety of rootstocks. These are called size-controlling rootstocks because they control the size of the tree; however fruit size is not reduced. In general, the smaller the tree, the sooner it will bear fruit after planting. Table 1 lists the rootstocks commonly used for apple trees and indicates their effect on tree size, using the "seedling" or standard rootstock as the basis of comparison.

Table 1. Commercially Available Apple Rootstocks and Their Characteristics

Rootstock	Tree Size as Percentage of Seedling (Nonspur)	Tree Size as Percentage of Seedling (Spur)	Fruit Bearing Age (Years)	Resistance to Crown Rot	Resistance to Fire Blight
Seedling	100	80	6-10	Medium	High
MM.111	85	70	4-6	Medium	Low
MM.106	80	70	3-4	Very Low	Low
M.7a	70	60	3-4	Medium	High
M.26	50	40	2-4	Medium	Very Low
Mark	45	35	2-3	Medium	Low
M.9	35	20	2-3	Medium	Low

Thus, for example, the M.9 rootstock will produce a nonspur-type tree that is only 35 percent as large as it would be if grown on a seedling rootstock. The table also lists the time required for the trees to reach bearing age and the degree of rootstock resistance to two important diseases. Two categories of growth habit are included in the table: spur and nonspur. Trees with a spur-type growth habit bear the majority of their fruit on very short branches called spurs. Nonspur varieties produce fruit on longer branches. Since spur-type varieties have fewer long branches, the trees are more compact.

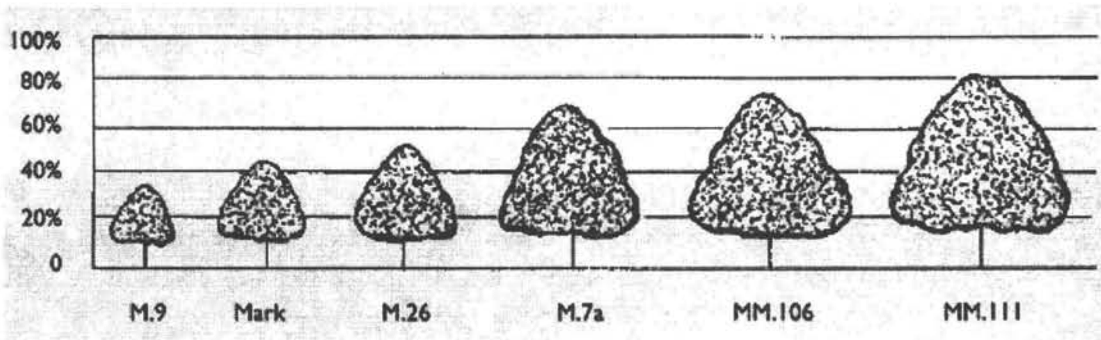


Figure 3. Tree size shown as a percentage of the size the tree would reach if grown on a seedling, or standard, rootstock.

Because the choice of rootstock affects the size of the trees, it also affects the optimum spacing between the trees. Table 2 gives the recommended distance between trees for both spur and nonspur varieties. Note that very vigorous varieties should be spaced farther apart.

Table 2. Recommended Planting Distances for Apple Trees Grown on Size-Controlling Rootstocks

		Distance Between Trees (feet)	
Rootstock	Nonspur Varieties	Spur Varieties	Very Vigorous Varieties
Seedling	18-25	12-16	25-35
MM.111	14-18	9-12	20-25
MM.106	12-16	8-11	17-22
M.7	10-14	7-9	14-20
M.26	8-12	5-8	11-17
Mark	6-8	4-5	8-11
M.9	4-8	3-5	6-11

Apple trees on rootstocks of a size class smaller than M.7 bear fruit while they are still very young. They should be supported by stakes to promote optimum growth and to help support the fruit load in the early years. Use 10-foot stakes and drive them 2 feet into the ground. Stakes are commonly made from 1-inch-diameter aluminum electrical conduit or 3-inch-diameter wooden posts. Tie the tree loosely to the above-ground portion of the stake. Strips of plastic or heavy-duty canvas or cloth can be used as ties. Do not use materials that will restrict tree growth or girdle the tree.

Peaches, nectarines, and plums are also affected by choice of rootstock. In the Southeast, trees are susceptible to peach tree short life (PTSL), a condition that causes sudden death of the tree after only four or five years of growth. With proper rootstock selection, nematode suppression, and cultural practices, the threat of this condition can be minimised. Spacing recommendations for other fruit trees are given in Table 3.

Table 3. Spacing Requirements for Other Tree Fruits

Fruit Crop	Minimum Spacing Between Trees (feet)
Asian Pears	20
Chestnuts	40
Figs	10
Pears	20
Pecans	70
Persimmons	15

CULTURAL PRACTICES

Planting

To plant a tree, dig a hole twice the size of the root system. The sides of the hole should be loose, not packed down by the force of the shovel. Cut off damaged roots at the point of injury. Shorten roots that are especially long and will not fit in the hole. Roots that are not shortened will wrap around the tree hole and eventually girdle the root system, reducing tree growth in later years (Figure 3).

When planting a grafted tree, be sure that the graft union is 2 inches above the soil. If the graft union is below the soil surface, the top portion or scion will grow roots and negate the effect of the grafted root system.

After the tree is in place, fill the hole with native soil, not potting soil. Adding organic matter or mulch to the soil can promote growth if these materials are mixed well with the soil. NEVER add fertilizer to the planting hole. Fertilizers are very caustic and can burn and kill the roots of young trees. After you have filled the hole, be sure to water the area well.

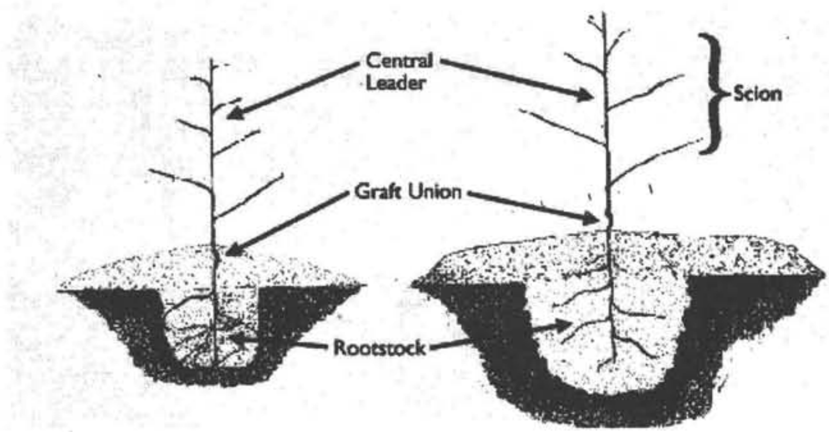


Figure 3. Proper tree planting. The figure on the left shows an improperly planted fruit tree. The hole is too narrow and shallow, forcing the roots to be wrapped in the hole, which may eventually girdle the tree. The graft union is also planted below the soil surface, which will negate the effect of the rootstock. The raised bed is not wide enough or deep enough to be of much benefit. The figure on the right shows the correct way to plant fruit trees.

During shipping, handling, and planting, roots are damaged. After planting young trees, prune the top of each tree. Pruning the tree top balances the root system and promotes vigorous growth in the spring. When working with unbranched trees, cut the tree off approximately 32 inches above the ground. For larger trees, remove 1/3 of the top of the tree.

The following suggestions will help you to successfully plant fruit trees.

- Time of planting: Dormant fruit trees can be planted in the spring as soon as the ground can be worked without fear of damaging the soil structure. In most parts of Pennsylvania this can occur anytime from March through mid-May. The later the trees are planted, however, the slower they will begin to grow.
- Handling the trees: As soon as the plants arrive, open the package. Report any signs of damage or poor handling to the nursery immediately.
- Holding the trees until planted: Trees to be held for several days should be heeled-in, or placed in cold storage with the roots covered with moist soil, sawdust, or sand. Never permit the roots to become dry.
- On the day before planting, place the trees in water so that all of the roots are covered. Allow the trees to absorb water for up to 4 hours.
- The hole in which each tree is to be planted should be wide enough to accommodate all of the tree's root system without excessive bending or bunching of the roots. It should be deep enough so that the bud union will be no more than 2 to 3 inches

above the ground after the soil settles. Grafted or budded trees should always be planted so their union is above the soil line.

- Clonal rootstock trees: Observe which side of the root system has the most roots. Set the tree so that the side of the root system with the most roots is pointed into the direction from which the prevailing winds come. This will afford added anchorage.
- Planting the tree: Add 4 to 6 inches of soil to the hole, while at the same time gently jiggling the tree up and down. This will cut down on the possibility of air pockets and help the soil to surround all of the roots.
- Fill the hole to within 3 to 4 inches of the ground line. Tramp the soil firmly, then add the remaining soil up to the ground line.
- Apply 5 gallons of water to each tree after planting. It is important to use at least 5 gallons to ensure complete wetting of all soil and roots in the hole.
- In the absence of a soil test, a reliable rule of thumb is to use the equivalent of 1/2 pound of 10-10-10 fertilizer per tree except for pears, in which case 1/4 pound per tree will be adequate. Sprinkle the fertilizer in a 12-inch-wide band. Keep the fertilizer at least 6 inches away from the tree trunk. Do not apply any dry granular fertilizer near the tree until after the ground has settled and no cracks in the soil are evident.
- After the water has moved into the soil, add a tree guard. A 15-by-18-inch piece of 3/8-inch hardware cloth makes an excellent guard. Bury the bottom of the guard 1 to 2 inches into the soil or into finely crushed stone, which helps to reduce weeds and rodent damage when it is spread around the base of the tree.
- When planting bare-root trees, remember that approximately one-quarter of the root system was removed when the tree was dug. To compensate, remove about one-quarter of the top part of the plant to reestablish a 1:1 shoot-to-root ratio. Trees that come balled and burlapped do not need as much pruning; remove only broken or low-hanging branches.
- If less than 4 to 5 inches of rain have fallen since the trees were planted, apply 5 gallons around the base of each tree. You might have to hoe a small ridge of soil around each tree to prevent the water from running off.

Weed Control

Weeds or grass growing between or under fruit trees compete for soil nutrients and moisture, reducing tree growth. Keep all vegetation under the trees controlled up to the drip line (the circle formed by the outermost branches of the tree). Avoid using mechanical cultivation to eliminate weeds because tree roots near the surface will be destroyed in the process. Weed whips are especially harmful. If the cutting line strikes the bark of the tree, it can crush layers of cells under the bark and girdle the tree without any visible signs, such as broken tree bark.

Herbicides are an effective alternative, but be careful to follow the label directions and keep the herbicides off the tree. Another alternative is to mulch around the tree. A layer of mulch 4 to 6 inches deep will control weeds and conserve soil moisture. Note, however, that mulch can provide cover for voles or mice. These rodents burrow under the mulch and frequently gnaw tree trunks or roots, girdling the tree and killing it or impeding its growth. When using mulch, check for rodent pests. Prevent problems by placing guards around the base of the trees or use traps to control these pests. It may also be beneficial to pull the mulch back 1 foot around the tree trunk in the early fall.

Insects and Disease Control

Unless properly managed, insects and diseases can seriously damage fruit trees and their crops. Pests can be controlled with commercial pesticides, and moderate control may be achieved using organic controls. Garden centers offer many materials, including multipurpose insect and disease control products. Treatment must be started before problems become severe, causing serious damage or crop loss. It is important to identify pests and diseases accurately so an effective treatment can be selected.

Nematodes are microscopic worms that live in the soil. Several types of fruit trees, including peach, plum, and figs, can be damaged or destroyed by nematodes. An inexpensive soil test can be conducted to check for nematodes. Avoid soils with high nematode populations. Soils with unacceptable nematode populations can be treated with a soil fumigant. However, most fumigants must be applied by a licensed pesticide applicator and can be costly.

Pest problems can also be reduced through proper sanitation. Remove and burn or bury dead, diseased, and damaged wood and fruit as soon as possible. Also, remove the leaves after they have fallen in autumn. Do not use the leaves as mulch. The infected leaves, wood, and fruit can provide a habitat in which insects and disease-causing organisms can overwinter. By taking time to maintain orchard sanitation, you can reduce insect and disease problems significantly.

Fertility

Tree fertility requires attention throughout the life of the tree, not just at planting time. However, applying fertilizer routinely without knowing whether it is needed can result in poor fruit quality and excessive tree growth. It can also waste money and contribute to environmental pollution.

Annual soil analyses can keep you informed about the nutrients in the soil and the soil acidity. In addition to soil analyses, simple observation of the amount of vegetative growth can help in managing soil fertility. Trees with less than 10 inches of current season's growth on lateral branches may need fertilizer. On the other hand, trees with greater than 18 inches of growth may not need fertilizer for several years. Excessive tree growth can promote some pest problems.

If you must fertilise without benefit of a soil test or other information, a useful rule of thumb is to apply 3/4 to 1 pound of 10-10-10 fertilizer for each year of tree age. When fertilizer is used, it is usually applied in late winter. Fertilizer should be broadcast on the soil surface both inside and outside the drip line of the tree. Keep fertilizer at least 6 inches away from the trunks of young trees.

Although the total amount of nutrients in the soil is important, the balance among them can be even more critical. Too much of a nutrient can be just as bad as too little. Excess magnesium may lead to calcium deficiencies, for example. Fertilisation, or the addition of nutrients to the soil and plant, is the main method of adjusting the available nutrients. The degree of fertilisation will depend upon the type of growth desired. Fertilisation often is thought of in terms of greatest response, which might not always be the optimum response. Generally, in commercial crops, when the cost of fertilisation is equal to or greater than the value of increased growth, there is little reason for continued fertilisation.

When a fertilizer material contains nitrogen, phosphorus, and potassium, it is known as a complete fertilizer. The fertilizer analysis is the percent by weight of these three elements in the final preparation. For historical reasons, the nitrogen is expressed as elemental, phosphorus as P_2O_5 and potassium as K_2O. A fertilizer analysis makes it easy to determine the exact amount of each element in a given quantity of complete fertilizer.

Since the needs of various crops differ, the plant requirements are expressed as a specific fertilizer ratio. If a plant needs twice the amount of phosphorus as it does nitrogen and potassium, using a material with a 5-10-5 analysis would be advisable since this fertilizer would have the needed 1-2-1 ratio. According to the analysis, 5 percent of the material by weight is nitrogen, 10 percent is phosphorus, and 5 percent is potassium. Therefore, when you apply 1 pound of the material to the soil you are applying 0.05 pounds of nitrogen, 0.10 pounds of phosphorus (as P_2O_5), and 0.05 pounds of potassium (as K_2O).

Gardeners have the option of using two major groups of fertilizers: natural organic and synthetic chemical. Natural organics include dried blood, manure, fish scraps, and cottonseed meal. These compounds are derived from living organisms. The nutrients in most organic fertilizers generally undergo gradual chemical transformations into plant-available forms after they have been applied to the soil; thus nutrients from them are more slowly available to the plant than from chemical fertilizer sources. When applying most organic fertilizers to the soil, timing must be adjusted to account for the slower release of nutrients. For example, June-bearing strawberries have a high nutrient demand in the fall as they produce flower buds for the crop the following season. When using compost, it may need to be applied in the late summer so it will have sufficient time to decompose and release nutrients in time to meet plant needs in the fall. Chemical fertilizers such as ammonium sulfate or superphosphate are prepared from inorganic minerals. The nutrients in most of the natural organic fertilizers generally undergo gradual chemical transformations into available forms after they have been applied to the soil. Most chemical preparations, on the other hand, are available for the plant as soon as they are applied to soils containing adequate moisture levels.

Chemical and organic fertilizers can be purchased at local garden centers or through gardening catalogs. To locate organic fertilizers in garden centers, ask personnel which products are used in organic production. Gardening catalogs will typically identify a product as allowable in organic production.

Composts can be obtained through various sources. Many local municipalities have composting facilities where composts can be obtained for a nominal fee or, in some locations, for free. Composts can also be purchased from garden centers. Making your own compost is a great option because you control what the compost is made from in addition to reducing the amount of waste sent to landfills.

The nutrient content in compost varies depending on what materials make up the compost and on the composting protocols used. Therefore, it is recommended that composts are tested, particularly those that you make or obtain from local municipalities, to determine the amount of nutrients they contain (kits for doing this are available through local extension offices). Finished compost typically contains 0.5 to 2.5 percent total nitrogen. As a general rule, about 10 percent of the nitrogen will be available to the plant each year.

Compost generally contains very little phosphorus for plant use, so phosphorus from alternate sources is typically needed to meet plant requirements. Potassium in composts is in a form that is readily available for plant use, but this form is also water soluble and, therefore, can leach out of compost piles. Placing a cover over a compost pile can help reduce the amount of potassium lost to leaching. In addition to determining the nutrient content of compost, the pH of the compost should be measured because it can be unsuitably high for fruit production, particularly for blueberries, which grow optimally in low-pH soils. When using compost to fertilise brambles, be aware that primocanes have difficulty emerging through large clumps; therefore, breaking up large clumps is necessary when applying compost.

Fruit Thinning

Apples, nectarines, peaches, pears, and Asian pears must be thinned early in the season to prevent overproduction, which can result in smaller fruit, increased tree breakage, and in-creased insect and disease problems. A heavy crop also reduces the chances for an adequate crop the following year.

Fruit should be thinned when they are about the size of a nickel. Remove enough fruit so that the remaining ones are spaced about 4 to 6 inches apart along the branch (Figure 4). Even though it may look like very few fruit remain, the increased fruit size at harvest plus reduced risk of tree breakage and improved prospects for next year's crop will more than compensate for the reduced number of fruit.

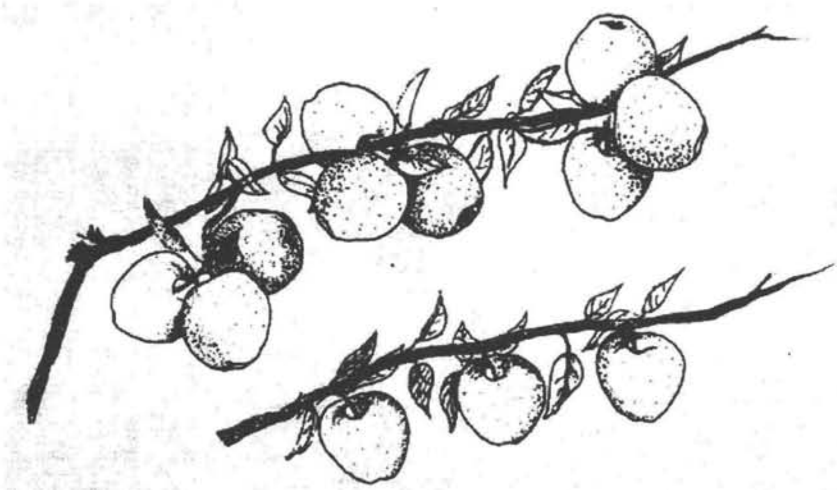


Figure 4. Fruit thinning. Top drawing: unthinned apple branch. Apples, pears, peaches, nectarines, and Asian pears should be thinned so that they are approximately 4 to 6 inches apart, as shown in the lower drawing.

FRUIT TREE PROPAGATION

Fruit tree propagation is usually carried out through asexual reproduction by grafting or budding the desired variety onto a suitable rootstock. Perennial plants can be propagated either by sexual or vegetative means. Sexual reproduction occurs when male pollen from one tree fertilises the ovules (incipient seeds) of the flower of another, stimulating the development of fruit. In turn this fruit contains a seed or seeds which, when germinated, will become a new specimen. However, the new tree will inherit many of the characteristics of both its parents, and it will not grow 'true' to the variety from which it came. That is, it will be a fresh individual with many unpredictable characteristics of its own. Although this is desirable in terms of increasing biodiversity and the richness of the gene pool (such sexual recombination is the source of most new cultivars), only rarely will such fruit trees be directly useful or attractive to the tastes of humankind. A tendency to revert to a wild-like state is common.

Therefore, from the orchard grower or gardener's point of view, it is preferable to propagate fruit cultivars vegetatively in order to ensure reliability. This involves taking a cutting (or scion) of wood from a desirable parent tree which is then grown on to produce a new plant or 'clone' of the original. In effect this means that the original Bramley apple tree, for example, was a successful variety grown from a pip, but that every Bramley since then has been propagated by taking cuttings of living matter from that tree, or one of its descendants.

Methods

The essentials of our present methods of propagating of fruit trees date from pre-Classical times. Grafting as a technique was first developed in China from where it was imported to Greece and Rome. Classical authors wrote extensively about the technical skills of fruit cultivation, including grafting techniques and rootstock selection. The oldest surviving named varieties of fruits date from classical times.

The simplest method of propagating a tree asexually is rooting. A cutting (a piece of the parent plant) is cut and stuck into soil. Artificial rooting hormones are sometimes used to assure success. If the cutting does not die of desiccation first, roots grow from the buried portion of the cutting to become a complete plant. Though this works well for some plants (such as figs and olives), most fruit trees are unsuited to this method.

Root cuttings (pieces of root induced to grow a new trunk) are used with some kinds of plants. This method also is suitable only for some plants.

A refinement on rooting is layering. This is rooting a piece of a wood that is still attached to its parent and continues to receive nourishment from it. The new plant is severed only after it has successfully grown roots. Layering is the technique most used for propagation of clonal apple rootstocks.

The most common method of propagating fruit trees, suitable for nearly all species, is grafting onto rootstocks. These are varieties selected for characteristics such as their vigour of growth, hardiness, soil tolerance, and compatibility with the desired variety that will form the aerial part of the plant (called the scion). For example, grape rootstocks descended from North American grapes allow European grapes to be grown in areas infested with Phylloxera, a soil-dwelling insect that attacks and kills European grapes when grown on their own roots. Grafting is the process of joining these two varieties, ensuring maximum contact between the cambium tissue (that is, the layer of growing plant material just below the bark) of each so that they grow together successfully. Two of the most common grafting techniques are 'whip and tongue', carried out in spring as the sap rises, and 'budding', which is performed around July and August.

Bud grafting

- Cut a slice of bud and bark from the parent tree.
- Cut a similar sliver off the rootstock, making a little lip at the base to slot the scion into.
- Join the two together and bind.

In time, the scion bud will grow into a shoot, which will develop into the desired tree.

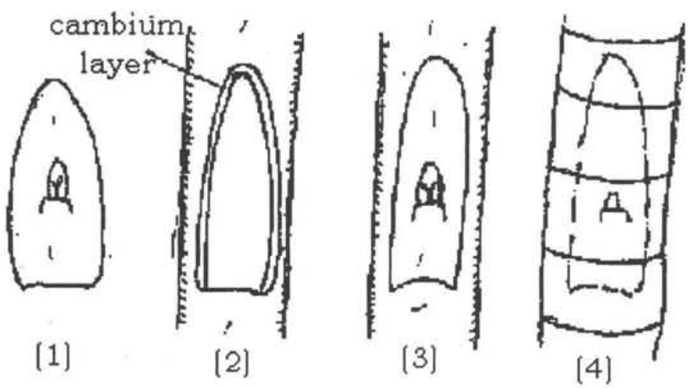


Figure 5. Diagram illustrating the bud grafting technique

Whip and Tongue grafting

- Make a sloping cut in the rootstock with a 'tongue
- Make a matching cut in the scion wood with a 'tongue' pointing downwards.
- Join the two, ensuring maximum contact of the cambium layers. Bind with raffia or polythene tape and seal with grafting wax.

Apple Rootstocks

Another reason for grafting onto rootstocks is that this enables the grower to determine the tree's eventual size. Apple tree size classes number one to ten in increasing height and breadth. A "1" is a dwarf which can be productive and as short as three(3) feet with proper pruning. A "10" is the standard sized tree with no dwarfing and will grow to twenty or more feet tall and wide, dependent upon the variety chosen. In general the class range is (1) 10-20% of full size, (2) 20-30%, (3) 30-40% and so forth to size 10 which is 100% of full size.

Apple tree rootstocks are referred to by numbers prefixed by letters indicating the developer of the rootstock. "M" designates Malling series developed stocks. East Malling Research is a pioneer in the development of dwarfing rootstocks. East Malling Research Station in Kent, England collected clones of the Paradise stocks from France in 1912 from which 24 "M" were designated with no particular order to the rootstock characteristics other than where they were located in the garden at the time the numbers were assigned. In other words, M.2 is larger tree than M.9 while M.27 is smaller than M.26.

"MM" designates Malling—Merton stocks developed from joint breeding programme by John Innes Institute, in Merton, England, & East Malling Research Station in the early 1950s. The "MM" series was developed primarily to provide resistance to Woolly Apple Aphid(Eriosomatinae) infestation.

"EMLA" designates East Malling / Long Ashton research stations who took the "M" stocks and developed virus free versions. E.g., EMLA 7 is M 7 with a guaranteed virus free stock. EMLA characteristics are often different from the parent "M" rootstock. Note that nearly all the apple rootstocks in the industry are now virus free.

"CG" or "G" designates Cornell-Geneva stocks which are those developed via the Cornell & USDA collaboration at the New York Agricultural Experiment Station in Geneva, NY. The "G" is the old designation. All newer stocks are "CG" followed by numbers that actually provide some information about the stock. As one might surmise, this is a huge improvement in the classical naming scheme which has no identification method at all.

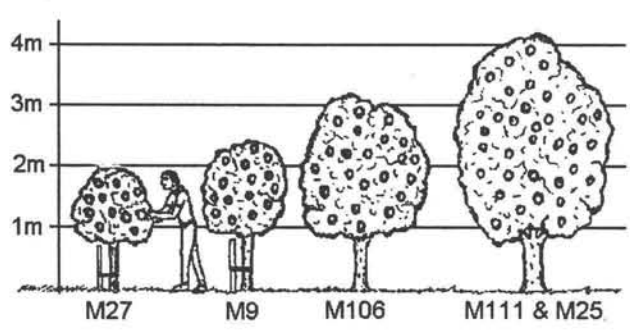


Figure 6. Diagram illustrating comparative sizes of apple trees depending on rootstock grafting

M.27 Malling 27: A very dwarfing rootstock. Unless the central leader is supported, the tree will be very small. Often only used as an intermediate stem piece on MM.106 or MM.111. If handled and spaced properly, it can be a very productive stock for a vertical axe system. Trees can be grown three to four feet tall and produce about 45 fruit, roughly 2 pecks, depending on fruit cultivar.

M.9: Very dwarfing—Reaches a height of 8 to 10 ft (3 m), coming into fruit after 3-4 years, reaching full capacity of 50 to 65lb (20 kg) after 5 to 6 years. It will grow under average soil conditions, but needs a good rich soil to thrive. A good choice where space is limited and fertility is high. Permanent staking is required, as is routine feeding and watering.Trees on this rootstock always require leader support. The rootstock is very susceptible to fire blight and can develop burr knots.

G.41 Geneva 41, released in 2005, produces trees the size of M.9. The rootstock was developed from a cross between M.27 and Robusta 5 made in 1975. Resistant to Crown | Collar | Root rot(Phytopthora) and fire blight.

M.26: Dwarfing—Similar to M9 in effect, although somewhat more vigorous and generally stronger, with a higher expected eventual yield of 65-75 lb (35 kg) and height of 8 to 10 ft (3 m). A good choice where soil quality is average and compact growth is required. Comes into fruit after 3-4 years, reaching full cropping capacity after 5 to 6 years. Staking needed for first five years of its life.It is susceptible to collar rot and fire blight and should not be planted in a wet site. Certain varieties when grafted onto this rootstock may exhibit signs of graft union incompatibility(i.e., the union breaks).

G.11 Geneva 11 is the second release of the Cornell breeding programme similar in size to M.26(Class 4) but more productive. Has the advantage of being resistant to fire blight and crown rot as well as only rarely producing suckers or burr knots.

G.202 Geneva 202(CG 5202) is a semidwarfing rootstock that produces a tree in class 5 slightly larger than M.26(Size Class 4) and is more productive than M.26. It was developed from a cross of M.27(Size Class 1) and Robusta 5 to be fire blight and Phytopthora resistant as well as having resistance to woolly apple aphids. In a 9-year study with the scion cultivar of the "Liberty" apple, G.202 was about 50 percent smaller than M.7 but had much greater production efficiency.

M.7 Malling 7 rootstock produces a semidwarf tree of Class 6 that is freestanding in deep well drained soils but in rocky, steep, or shallow soils, it tends to lean. The rootstock may sucker profusely and is susceptible to collar rot(Phytopthora).

MM.106: Semi-dwarfing—Sometimes referred to as semi-vigorous, this is the most widely used of rootstocks.It is probably the best choice for the average garden under average conditions, being tolerant of a wide range of soils, and producing a tree with an eventual size of 14 to 18 ft (5 m).Trees on this stock begin producing fruit within three to four years, and yield up to 90 to 110 lb (50 kg) after some seven or eight years.MM106 is very suitable for use with weaker varieties that would produce under sized bushes with more dwarfing rootstocks. Can be trained as a half standard tree, but is rather too vigorous for cordons unless the soil is poor. Requires staking for the first five years or so of its life. Trees on MM.106 are highly susceptible to collar rot especially when planted in soils that remain wet(poor percolation).

M.111 : Vigorous—Not generally suitable for garden scale growing, being both too large and spreading (18-25'), and too slow to come into cropping. They are however suitable for growing as specimen standards in the large garden, or for producing medium sized bushes on poorer soils. Begins to fruit after six or seven years, reaching full capacity of 160 to 360 lb (80 to 180 kg) after eight to nine years.It is the most cold-hardy rootstock readily available. Planting depth of this rootstock is critical. The union should be no higher than 1 to 2 inches above the final soil line.

M.25: Very vigorous—Suitable for a grassed orchard, and to grow on as a full standard. Plant 20 ft (7 m) apart, makes a tree of 15 to 20 ft (5 m) or more height and spread, eventually yielding 200 to 400 lb (100 to 200 kg) per tree.This rootstock is primarily used in UK and is rarely seen in USA where M.111 is used for this size tree.

Seedling: Very vigorous trees produced on a rootstock grown from seed. There is greater variability than with the vegetatively propagated rootstocks. Apples used for production of seedling rootstocks include 'Dolgo' and 'Antonovka', which are both extremely hardy and vigorous. That is only a sample of some of the more important current apple rootstocks that are available. There are at least a hundred more that have been developed to either provide enhancement or prevent potential damage from one kind of pest or another.

The problem with growing fruit trees, especially apple trees, is that they are subject to many different types of damage from bacteria, fungi and insects. The general approach of the commercial industry has been to use as many chemicals as necessary to insure attractive and marketable fruit. The attitude, still prevalent, has been "Who cares? Nobody eats a tree!" but as environmental problems increase and the general public pushes for low or no-spray fruit, there has become a commercial need for fruit that does not require such intensive spray programmes. This is being achieved, albeit slowly, by rootstocks and trees that are bred to have natural disease and pest resistance.

The Malling series and clones have been standard rootstocks for apples for many years and remain the standard "workhorses" for the commercial industry. However, since most of them are susceptible to disease some Malling rootstocks are being replaced by new breeds, including the Cornell-Geneva series. One of the newest rootstocks, only released commercially in 2004, is CG5202(G.202) which adds resistance to the woolly apple aphid(WAA) for the "CG" series of stocks which already has resistance to the major problems preventing quality production of apples utilising organic control systems. Combined with highly resistant trees such as "Liberty" it is showing great potential.

That leads to another characteristic of rootstocks that is or can be bred into them: environmental adaptability. This may be tolerance to wet|dry soil conditions, acidity|alkalinity of soil or even hot|cold air temperature.

The ability of rootstocks to modify or augment characteristics of fruit trees is limited and often disappointing in the final results. It takes ten years to get a full picture of the effects of any one rootstock so a rootstock that appears promising in the first five years of a trial may fail in the last five years. The Mark (apple) rootstock was such a stock and has now fallen mostly into disfavor. Another, the G.30, has proved to be an excellent stock for production but it was only after a number of years of trials that it was found to be somewhat incompatible with "Gala" apple(and possibly others) so that it is now recommended to be staked and wired.

To get a clear picture and push the industry forward, a consortium was founded and the so-called "NC-140" trials of rootstocks began. These test many pome rootstocks in many different sites across the USA and thereby provide growers, be they backyard or commercial, a clearer picture of what to expect when growing fruit trees on specific stock, in specific planting methods in their specific area of the USA. As one can imagine, this has the potential for a large economic benefit to both growers and consumers as well as going a long way to eliminating the need to spray pesticides as frequently as is currently required.

Pear Rootstocks

Pears are usually grafted onto quince rootstocks, which produce small to medium sized trees. Some varieties however are not compatible with quince, and these require double working. This means that a piece of pear graft-work compatible with both the quince rootstock and the pear variety is used as an intermediate between the two. If this is not done the pear and the rootstock could eventually separate at the graft. Varieties that require double working include 'Bristol Cross', 'Dr Jules Guyot', 'Doyenné d' été' and 'Williams Bon Chrétien'.

Quince C: Moderately vigorous—Makes a bush pear tree about 8 to 18 ft (3 to 6 m) tall, bearing fruit within four to eight years. Suitable for highly fertile soils and vigorous varieties, but not where conditions are poor. Used for bush, cordon and espalier growing. Old stocks of Quince C may be infected with a virus, so care should be taken to obtain certified virus free stock. If in doubt, use Quince A as there is not a great amount of difference in vigour between the two.

Quince A: Medium vigour—Slightly more vigorous than Quince C, this is the most common variety upon which pears are grafted. Bears fruit between four to eight years, making a tree of some 10 to 20 ft (3 to 7 m) in height and spread. Suitable for all forms of pear trees except standards.

Pear stock: Very vigorous—Pears grafted onto pear rootstocks make very large standard trees, not suitable for most gardens.

Cherries

Until the 1970s, cherries were grown of the vigorous Malling, Mazzard (Prunus avium), or Maheleb (P. maheleb) rootstocks, which required much space and time before cropping began, thus the growing of cherries was not a realistic option on a garden scale. The introduction of the rootstock 'Colt' enables trees reaching a maximum height of 12 to 15 ft (4 to 5 m) to be grown, and if trained as a pyramid it is possible to restrict growth to about 10 ft (3 m). The popular sweet variety 'Stella' could even be grafted onto a 'Colt' rootstock and successfully grown in a pot on the patio.

Plums

Plum rootstocks include:

- Pixy-A dwarfing rootstock, suitable for bush trees planted 8-10 (3 m) apart.
- St. Julien A-A semi vigorous rootstock suitable for bush and half standards planted 12 to 15 ft (4 to 5 m) apart. Also suitable for peaches, nectarines and apricots.
- Brompton or Myrobalan B- Suitable for half standards planted 18 to 22 ft (6 to 7 m) apart. Also suitable for peaches, nectarines and apricots.
- Myro-29C-Semi-dwarf rootstock. Shallow, vigorous, good choice for hard soils. Somewhat drought tolerant.
- Citation-Semi-dwarf rootstock. Shallow, vigorous, good choice for hard soils. Prefers a wetter soil.

Own-Root Fruit Trees

Some species of fruit are commonly grown on their own roots; new plants are propagated by rooting, layering, or modern tissue-culture techniques. In these cases there are may be no great advantages to using a special rootstock or improved rootstocks are not available. Fig, filbert, olive, pomegranate, gooseberry, bramble, and other fruits are commonly grown without any special rootstock.

FRUIT TREE PRUNING

A community apple orchard originally planted for productive use during the 1920s, in Westcliff on Sea (Essex, England), illustrating long neglected trees that have recently been pruned to renew their health and cropping potential

Pruning fruit trees is a technique that is employed by gardeners to control growth, remove dead or diseased wood or stimulate the formation of flowers and fruit buds. The most economical pruning is done early in the season, when buds begin to break, and one can pinch off the soft tissue with one's fingers (hence the expression "nipped in the bud"). Many home fruit growers make the mistake of planting a tree, then neglecting it until it begins to bear. But careful attention to pruning and training young trees will ultimately determine their productivity and longevity. Good pruning and training will also prevent later injury from weak crotches that break under snow or fruit load.

An apple tree sprout being converted to a branched fruit bearing spur by an Arborist. Numbers show the sequence of cuts, which occurred during 2 years. To obtain a better understanding of how to prune plants properly, it is useful to have some underlying knowledge of how pruning works, and how it affects the way in which plants grow.

Plants form new tissue in an area called the meristem, located near the tips of roots and shoots, where active cell division takes place. Meristem growth is aimed at ensuring that leaves are quickly elevated into sunlight, and that roots are able to penetrate deeply into the soil. Once adequate height and length is achieved by the stems and roots, they will begin to thicken to give support to the plant.

On the shoots, these growing tips of the plant are known as apical buds. The apical meristem (or tip) produces the growth hormone auxin, which not only promotes cell division, but also diffuses downwards and inhibits the development of lateral bud growth which would otherwise compete with the apical tip for light and nutrients. Removing the apical tip and its suppressive hormone allows the lower dormant lateral buds to develop, and the buds between the leaf stalk and stem produce new shoots which compete to become the lead growth.

Manipulating this natural response to damage (known as the principle of apical dominance) by processes such as pruning (as well as coppicing and pollarding) allows the horticulturist to determine the shape, size and productivity of many fruiting trees and bushes.

The main aim when pruning fruit trees is usually to obtain a decent crop of fruit rather than a tree with an abundance of lush yet unproductive foliage. Unpruned trees tend to produce large crops of small, worthless fruit often damaged by pests and diseases, and much of the crop is out of reach at the top of the tree. Branches can become broken by the weight of the crop, and the cropping may become biennial (that is, only bearing fruit every other year). Overpruned trees on the other hand tend to produce light crops of large, flavourless fruit that does not store well. Pruning is therefore carried out to achieve a balance between shoot growth and fruit production.

Formative Pruning of Bush Trees

Formative pruning of apple (Malus pumila) and pear (Pyrus communis) trees (the pome fruits; the stone fruits such as cherries, plums, gages, etc., have different requirements and should not be pruned during the dormant months) should be carried out during the dormant winter months between November and March (or June and September in the southern hemisphere) and during the early years of the tree's life to develop a strong framework capable of bearing the weight of the crops that will be borne in later years. This involves hard pruning, although in later years pruning will be lighter and carried out to encourage fruiting.

Maiden tree

A maiden whip (that is, a one year old tree with no side shoots) should be pruned to a bud with two buds below it at about 80 cm from the ground immediately after planting to produce primary branches during the first growing season. A feathered maiden (that is, a one year old tree with several side branches) should have its main stem pruned back to three or four strong shoots at 80 cm from the ground. Side shoots should be shortened by two thirds of their length to an upward or outward facing bud. Lower shoots should be removed flush with the stem.

Two year

Remove any lower shoots and prune between three and five of the best placed shoots by half to an upwards or outwards facing bud to form what will become the tree's main structural branches. Remove any inwards facing shoots.

Three year

Prune the leading shoots of branches selected to extend the framework by half to a bud facing in the desired direction. Select four good laterals to fill the framework and shorten these by a half. Prune any remaining laterals to four buds to form fruiting spurs.

Four year

The tree will have begun to fruit and only limited formative pruning is now required. Shorten leaders by one third and prune laterals not required to extend the framework to four buds.

Five year and onwards

The tree is considered to be established and should be annually pruned.

Pruning the Cropping Tree

Spur pruning

Before pruning it is important to distinguish between spur bearing and tip bearing varieties. The former, which is the most common type, bear most of their fruit on older wood, and include apples such as Cox's Orange Pippin, James Grieve and Sunset, and pears such as Conference, Doyenne du Commice and Williams Bon Chretien.

Tip bearers on the other hand produce most of their fruit buds at the tips of slender shoots grown the previous summer, and include the apples Worcester Pearmain and Irish Peach, and the pears such as Jargonelle and Josephine de Malines. There are basically three types of pruning that are applied once the main shape of the tree has been established. These are:

- *Renewal pruning*: This also depends on the tendency of many apple and pear trees to form flower buds on unpruned two year old laterals. It is a technique best utilised for the strong laterals on the outer part of the tree where there is room for such growth. Pruning long neglected fruit trees is a task that should be undertaken over a lengthy period, with not more than one third of the branches that require removal being taken each year.
- *Regulatory pruning*: This is carried out on the tree as a whole, and is aimed at keeping the tree and its environment healthy, eg, by keeping the centre open so that air can circulate, removing dead or diseased wood, preventing branches from becoming over crowded (branches should be roughly 50 cm apart and spurs not less than 25 cm apart along the branch framework), and preventing any branches from crossing.

Pruning of Tip Bearers

Tip bearers should be pruned lightly in winter using the regulatory system (see above). any maiden shoots less than 25 cm in length should be left untouched as they have fruit buds at their tips. Longer shoots are spur pruned to prevent over-crowding and to stimulate the production of more short tip bearing shoots the following year. Branch leaders are 'tipped', removing the top three or four buds to a bud facing in the desired direction to make them branch out and so produce more tip bearing shoots.

Pruning vs. Training

Growers often neglect the annual training and pruning of fruit trees. Without training and pruning, however, fruit trees will not develop proper shape and form. Properly trained and pruned trees will yield high quality fruit much earlier in their lives and live significantly longer.

A primary objective of training and pruning is to develop a strong tree framework that will support fruit production. Improperly trained fruit trees generally have very upright branch angles, which result in serious limb breakage under a heavy fruit load. This significantly reduces the productivity of the tree and may greatly reduce tree life. Another goal of annual training and pruning is to remove dead, diseased, or broken limbs.

Proper tree training also opens up the tree canopy to maximise light penetration. For most deciduous tree fruit, flower buds for the current season's crop are formed the previous summer. Light penetration is essential for flower bud development and optimal fruit set, flavor, and quality. Although a mature tree may be growing in full sun, a very dense canopy may not allow enough light to reach 12 to 18 inches inside the canopy. Opening the tree canopy also permits adequate air movement through the tree, which promotes rapid drying to minimise disease infection and allows thorough pesticide penetration. Additionally, a wellshaped fruit tree is aesthetically pleasing, whether in a landscaped yard, garden, or commercial orchard.

Historically, fruit tree form and structure have been maintained by pruning. Tree training, however, is a much more efficient and desirable way to develop form and structure.

Pruning is the removal of a portion of a tree to correct or maintain tree structure. Training is a relatively new practice in which tree growth is directed into a desired shape and form. Training young fruit trees is essential for proper tree development. It is better to direct tree growth with training than to correct it with pruning.

Pruning is most often done during the winter, commonly referred to as dormant pruning. Training includes summer training and summer pruning as well as dormant pruning. The goal of tree training is to direct tree growth and minimise cutting.

Dormant Pruning vs. Summer Pruning

Trees respond very differently to dormant and summer pruning. Dormant pruning is an invigorating process. During the fall, energy is stored primarily in the trunk and root system to support the top portion of the tree. If a large portion of the tree is removed during the winter, while the tree is dormant, the tree's energy reserve is unchanged. In the spring, the tree responds by producing many new vigorous, upright shoots, called water sprouts, which shade the tree and inhibit proper development. Heavy dormant pruning also promotes excessive vegetative vigor, which uses much of the tree's energy, leaving little for fruit growth and development.

Historically, much of the vigorous, upright vegetative growth has been removed during the dormant season; heavy dormant pruning results in a yearly cycle with excessive vegetative growth and little or no fruit production.

Timing of dormant pruning is critical. Pruning should begin as late in the winter as possible to avoid winter injury. Apple and pecan trees should be pruned first, followed by cherry, peach, and plum trees. A good rule to follow is to prune the latest blooming trees first and the earliest blooming last. Another factor to consider is tree age. Within a particular fruit type, the oldest trees should be pruned first. Younger trees are more prone to winter injury from early pruning.

Summer pruning eliminates an energy or foodproducing portion of the tree and results in reduced tree growth. Pruning can begin as soon as the buds start to grow, but it is generally started after vegetative growth is several inches long. For most purposes, summer pruning should be limited to removing the upright and vigorous current season's growth; only thinning cuts should be used. To minimise the potential for winter injury, summer pruning should not be done after the end of July.

Types of Pruning Cuts

Thinning Cut—removes an entire shoot back to a side shoot. Thinning cuts do not invigorate the tree in comparison to some of the other pruning cuts.

Heading Cut—removes only the terminal portion of a shoot. This type of cut promotes the growth of lower buds as well as several terminal buds below the cut. When lateral branches are headed into oneyearold wood, the area near the cut is invigorated. The headed branch is much stronger and rigid, resulting in lateral secondary branching. Older trees can be held in their allotted space by mold and hold cuts, which are devigorating heading cuts made into twoyearold wood. Young trees and branches where heading cuts are made will be referred to as headed.

Bench Cut—removes vigorous, upright shoots back to side branches that are relatively flat and outward growing. Bench cuts are used to open up the center of the tree and spread the branches outward. This is a major cut and should only be used when necessary.

When making pruning cuts, it is important to use techniques that will allow the cut surface to heal quickly. Rapid healing minimizes the incidence of disease and insect infection. Pruning cuts should be flush with the adjacent branch without leaving stubs.

Also, when large horizontal cuts are made, they should be slightly angled so that water does not set on the cut surface, allowing the growth of rot and disease organisms.

Many compounds are available as wound dressing or pruning paints. But the best treatment is to make proper pruning cuts and allow the tree to heal naturally. If preferred, tree paints and wound dressing may be used for aesthetic reasons, but they will not promote healing.

Training Systems

One of the most frequently asked questions is, "To what shape should I train my fruit tree?" It is difficult to give one answer. You can choose from many different training shapes and forms with multiple variations on each form. This bulletin focuses primarily on the central leader and open center training systems for mediumdensity orchards. A list of fruit trees conventionally trained to each system is also included. A fruit tree may be trained to any system. Depending on the form and function of the desired shape, you may want to train a tree to a nontraditional system. Whatever system is chosen, keep in mind that the objectives of training and pruning are to achieve maximum tree life and productivity.

Central Leader Training

A central leader tree is characterised by one main, upright trunk, referred to as the leader. Branching generally begins on the leader 24 to 36 inches above the soil surface to allow movement under the tree. The first year, 3 to 4 branches, collectively called a scaffold whorl, are selected. The selected scaffolds should be uniformly spaced around the trunk, not directly across from or above one another. Above the first scaffold whorl, leave an area of approximately 18 to 24 inches without any branches to allow light into the center of the tree. This light slot is followed with another whorl of scaffolds. Alternating scaffold whorls and light slots are maintained up the leader to the desired maximum tree height.

The shape of a properly trained central leader tree is like that of a Christmas tree. The lowest scaffold whorl branches will be the longest and the higher scaffold whorl branches will be progressively shorter to allow maximum light penetration into the entire tree.

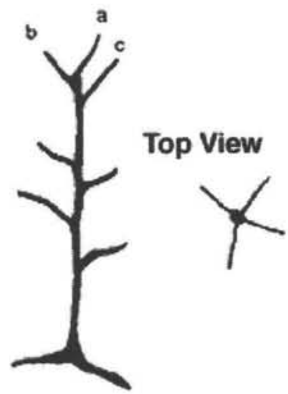
Developing a Central Leader Trained Tree At Planting

Fruit trees are frequently purchased as whips, which are unbranched trees ranging from 1/2 to 3/4 inch diameter. The tree should be planted in early winter with the graft union 2 inches above the soil surface. Just before the buds start to grow in the spring, the tree should be headed, or cut off, at 30 to 34 inches above the soil surface. The height at which the tree is headed depends upon where you want the first whorl of branches. Once the tree is headed, permanent branches will be selected from buds growing within 4 to 12 inches below the heading cut (Figures 7 and 8).

At Planting: As the buds begin to swell, head the tree at 30 to 34 inches above the soil surface.

Dormant Pruning: Head the tree at 24 to 30 inches above the highest branch of the first scaffold whorl.

Top View



First-Year Summer Pruning: Summer prune when new growth is 3 to 4 inches long. Leave a as the new leader, and remove b and c. Select four uniformly spaced laterals for the first scaffold whorl, and remove the remaining lateral branches.

After pruning the third year: Three scaffold whorls have been developed with three to four branches uniformly spaced around the tree in each whorl. A light slot of 18 to 24 inches is left between each scaffold whorl. Note the Christmas-tree shape that allows light penetration to lower branches and interior of the tree.

Figure 7. Pruning a central leader tree

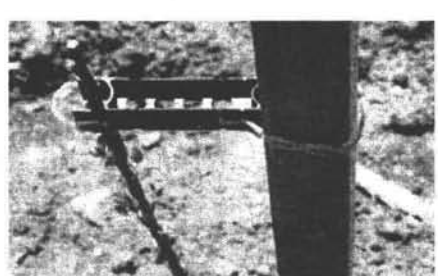


Figure 8. Newly planted apple tree headed back

Summer Pruning

After the new vegetative growth has reached 3 to 4 inches in length, summer pruning should begin. The first step is to select one upright shoot near the top of the tree to be the leader. After selecting the leader shoot, remove all other competing shoots for approximately 4 inches below it; rehead the tree above this leader. See Figures 9 and 10.

Figure 9. Left: Heading an apple tree at planting results in several competing shoots below the cut. Right: For central leader tree, a single leader needs to be selected by removing the undesired shoots.

Figure 10. Central leader plum trees must also have competing shoots removed.

At this time, side shoots (laterals) should be spread out to form an angle of 60 to 70 degrees between the leader and the side shoot. This angle is referred to as the branch or crotch angle. Branches that do not have a wide branch angle are overly vigorous and have a weak point of attachment to the leader. These branches frequently break under a heavy fruit load. Spreading the lateral branches will also slow the growth of the branches to a manageable level and promote the development of secondary or side shoots on the scaffolds. When growth is only 3 to 4 inches, toothpicks or spring clothespins can be used to spread branches (Figure 11). After a proper branch angle is attained, clothespins can be moved to the ends of longer limbs to weigh down the branches as they start to grow upward.

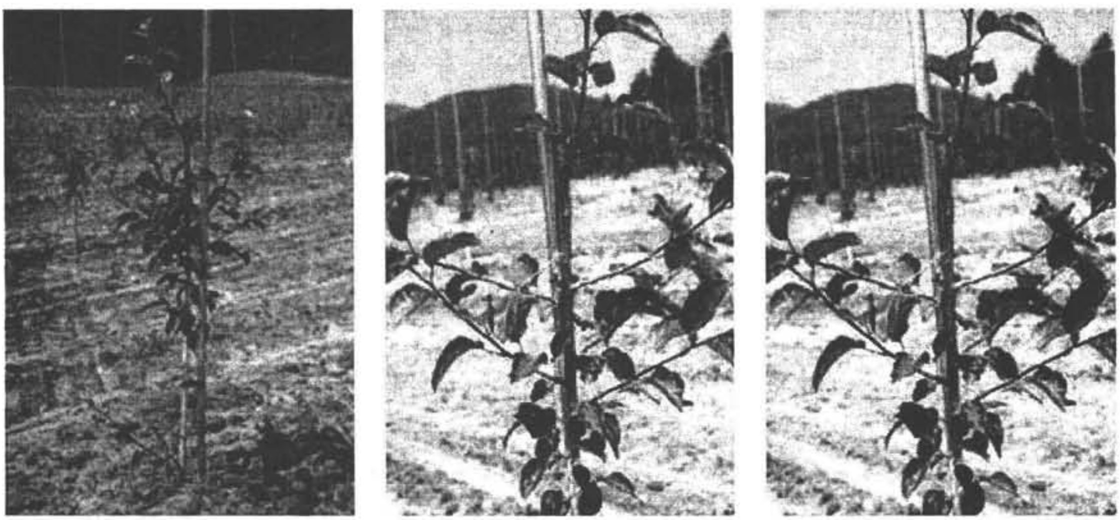


Figure 11. Central leader apple trees. Toothpicks are used to spread the lateral branches outward during the first growing season.

During the first year, minimise further summer pruning. Limit it to the removal of shoots growing upright or downward. Summer is the optimal time to select the leader and scaffold branches and remove undesirable growth. Branches lower than the desired height should also be removed. A young orchard or tree should be summer trained and pruned once a month through July to remove unwanted growth and to properly orient young branches. Summer pruning will greatly reduce the amount of dormant pruning needed.

Failure to summer prune the first year will result in an improperly trained tree, and drastic dormant pruning will be required to correct tree structure.

Succeeding Years

Managing the central leader is one of the most important aspects of dormant pruning. The leader should be headed at approximately 24 to 30 inches above the highest whorl of scaffolds to promote continued branching and scaffold whorl development. Dormant pruning should also eliminate dead, diseased, and damaged wood. Unwanted growth, such as upright growing shoots and laterals with sharp branch angles not removed during summer pruning, should also be removed at this time. Unbranched lateral branches should be headed back by approximately 1/4 of their length to encourage side branches and to stiffen lateral branches.

Summer pruning in succeeding years should eliminate competing shoots where dormant heading cuts were made (on the central leader and laterals) as in the first year. Summer is also the optimal time to remove unwanted side shoots and excessive growth. All laterals should have a wide branch angle, and spreading of lateral branches is essential for many varieties. Lateral branches will need to be spread for about the first five years, using a larger spreader each year.

Spreaders can be made with 1inchsquare wood pieces with a finishing nail driven in the end and cut off at an angle. Spreaders are frequently made in lengths of 6, 12, and 18 inches (Figure 12).

Figure 12. Wooden limb spreaders can be made from wood and finishing nails in various lengths.

Spreading branches in later years reduces vigor and promotes fruit development on the lateral branches. The reduced growth rate and the weight of the crop load will also help pull the branches down to a proper angle. However, it is important that the young tree is not allowed to crop too early where the weight of the fruit pulls the branches below horizontal. Once the branches are below horizontal, they are weak and nonproductive and need to be removed and replaced.

Another objective of dormant pruning is to control the length of the lateral branches. In order to maintain the Christmastree shape , lateral branches need to be cut back. Once the tree has reached its desired height and lateral spread, it will be necessary to mold and hold the lateral branches and the central leader with heading cuts. This can be done by cutting the laterals and leader back into twoyearold wood to a sidegrowing shoot. It is a good rule to cut back to a side shoot that is close to the same diameter as the lateral or leader being cut.

Mature Trees

Mature trees that have been properly trained and summer pruned will require minimal pruning. The first step would be to remove dead, diseased, and damaged wood and then upright shoots and shoots below horizontal. To prevent shading, it is important to maintain the Christmastree shape by heading lateral branches with mold and hold cuts. For quality fruit production, it is also essential that the light slots between the scaffold whorls be maintained.

Mature fruit trees that have not been properly trained frequently do not have a true central leader shape. For those trees, the objectives of training and pruning as discussed earlier must be considered. In many cases, too many lateral branches and upright limbs (some may be 6 or more inches in diameter) have been left and need to be removed to allow proper light penetration. This pruning needs to be done during the dormant season.

Neglected trees often have overgrown tops that act as an umbrella, shading the rest of the tree. The tops of these trees need to be cut back or removed. Remember, if the principles of pruning are followed, there are no perfect cuts and no incorrect cuts. However, do not remove more than 30 percent of the tree top to avoid shifting the tree into an excessively vegetative state with little fruit development.

Pecan Tree Consideration

Pecan trees should be trained to a central leader. The lateral branches, however, should be spiraled up the leader. Approximately 12 to 15 inches should be left between branches for adequate light penetration initially. As the tree matures it will be necessary to remove branches to prevent crowding and allow light penetration.

Multileader Tree

A multileader tree is the goal of another training system and an ideal option for pear varieties that are susceptible to fireblight. With a multileader tree, if one leader is infected with fireblight, it may be removed without loss of the major portion of the tree.

The multileader tree uses the same concept as the central leader tree except there are several leaders in the center of the tree. Each leader is maintained the same as an individual central leader tree. The only difference in training a multileader from the central leader is that in the first and second year instead of removing the competing leaders, several should be left and maintained.

HigherDensity Central Leader Training Systems

In the commercial apple industry, there is much interest in higherdensity orchards with 1,000 or more trees per acre. The first requirement for higherdensity systems is smaller trees, which is accomplished with sizecontrolling rootstocks. Two of the betterknown higherdensity training systems are the slender spindle and vertical axe. Both are modified central leader trees with branches continually along the central leader to the top of the tree. Light penetration is not a problem as the maximum height of the tree is limited to approximately 6 to 12 feet, with a canopy spread of 3 to 4 feet outward from the leader.

There are many other types of higherdensity training systems, some with elaborate trellis systems. The slender spindletype tree is the most popular highdensity training system. Highdensity training systems, however, will not be discussed in this bulletin because of the differences in management practices.

Open Center or Vase Training

With the opencenter system, the leader is removed, leaving an open center. Instead of having a central leader, the opencenter tree has 3 to 5 major limbs, called scaffolds, coming out from the trunk. This training system allows for adequate light penetration into the tree, which minimizes the shading problem prevalent in highervigor trees such as peach.

At planting

At planting, peach trees should be set so that the graft union will be 2 inches above the soil surface. As the buds begin to swell, the unbranched trees (whips) are generally headed approximately 30 to 34 inches above the soil surface. As discussed with the central leader system, new branches will come from the buds that are 6 to 9 inches below the heading cut.

Trees that are branched at planting are handled differently than the whips. The work that needs to be done under the tree determines the appropriate height for branching, which is usually 24 to 32 inches. Remove branches that are too low. If there are 3 to 4 uniformly spaced branches around the tree that can be selected as scaffolds, the tree is headed just above the highest selected scaffold. Any remaining branches not selected as scaffolds should be removed. However, if there are less than 3 scaffolds the tree should be cut back to a whip and the side branches removed.

Summer pruning

After the new vegetative growth is approximately 3 to 4 inches long, it is time to select the shoots that will become the major scaffolds. The lowest scaffold should be 24 to 32 inches above the soil surface to avoid interfering with cultural work under the tree, such as harvesting and weed control. It is best to select 3 to 4 scaffolds that are uniformly spaced around the tree, with wide branch angles, and not directly across from another scaffold.

During the summer, these shoots should be spread out to a 45 to 60 degree angle and held in place with a toothpick or clothespin. All other upright growth should be removed. It is best to come back through every month during the summer to remove upright growth that is shading the primary scaffolds and to make sure that the scaffolds have been spread to a proper angle. Many times the crotch angle is proper initially, but as the scaffolds grow, they turn upright. A spring clothespin placed on or near the end of a shoot will pull the scaffold down to a proper angle. Extreme care must be taken when using the clothespins as weights. Periodic checking is essential to assure that the scaffolds are not too flat.

Succeeding Years

After the first year of growth, the primary scaffolds should be selected and properly trained outward. Scaffolds should be headed during the dormant season of the first three years to promote continued lateral branching on the scaffolds and to stiffen and strengthen the scaffold. Scaffolds should be headed to outwardgrowing shoots similar in angle to those being removed. Bench cuts should be avoided.

If summer pruning is being practiced, undesirable shoot growth can be removed as soon as growth is 4 to 6 inches long. Summer pruning can also be used to direct scaffold growth outward to the desired growing points instead of waiting until the dormant season. For bearing trees, the goal of dormant pruning is to remove vigorous upright growth on the scaffolds and trunk that was not removed during the summer.

The upright growth left in the tree during the growing season may shade out lateral growth near the trunk. This shading causes lateral fruiting wood only on the ends of the scaffolds, which results in broken scaffolds under a heavy fruit load. It is best to keep the fruiting wood on the scaffolds as close to the tree trunk as possible to reduce tree breakage and to produce the highestquality fruit. Also, during the dormant season, damaged, dead, and diseased wood, such as cankers, should be removed from the tree. Shoots with shriveled and dried fruit from the previous season, called mummies, should also be removed from the orchard to reduce disease pressure for the coming season.

FRUIT TREE POLLINATION

Pollination is the process that transfers pollen grains, which contain the male gametes (sperm) to where the female gamete(s) are contained within the carpel; in gymnosperms the pollen is directly applied to the ovule itself. The receptive part of the carpel is called a stigma in the flowers of angiosperms. The receptive part of the gymnosperm ovule is called the micropyle.

The study of pollination brings together many disciplines, such as botany, horticulture, entomology, and ecology. The pollination process as an interaction between flower and vector was first addressed in the 18th century by Christian Konrad Sprengel.

Pollination is a necessary step in the sexual reproduction of flowering plants, resulting in the production of offspring that are genetically diverse. It is important in horticulture and agriculture, because fruiting is dependent on fertilisation, which is the end result of pollination.

Most fruit crops require pollination to ensure that fruit sets. Pollination is the transfer of grains of pollen from the anthers to the stigma of a flower (figure 1). Pollen grains get caught on the sticky surface of the stigma, germinate and produce a tube that grows down the style and unites with the female cell in the ovary. This union is called fertilisation. After fertilisation occurs, seeds develop and the fruit enlarges.

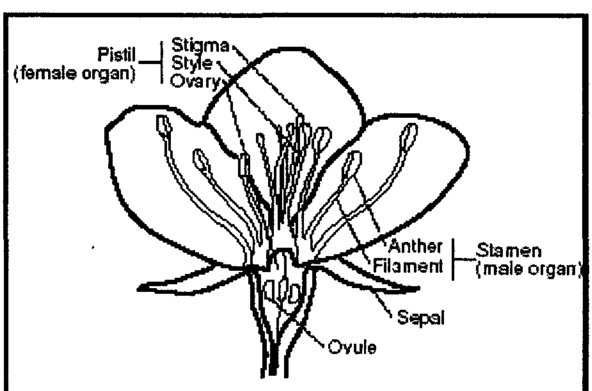


Figure 13. Diagram of Apple Flower

Pollination also requires consideration of pollenizers. The terms "pollinator" and "pollenizer" are often confused: a pollinator is the agent that moves the pollen, whether it be bees, flies, bats, moths, or birds; a pollenizer is the plant that serves as the pollen source for other plants. Some plants are self-fertile or self-compatible and can pollinate themselves (e.g., they act as their own pollenizer). Other plants have chemical or physical barriers to self-pollination and need to be cross-pollinated: with these self-infertile plants, not only pollinators must be considered but pollenizers as well. In pollination management, a good pollenizer is a plant that provides compatible, viable and plentiful pollen and blooms at the same time as the plant that is to be pollinated.

Honeybees are the most important natural carriers of pollen. As the bee flies from flowers on one tree to those on another in the orchard, pollen sticks to its body hairs. The bee rubs off the pollen onto the stigma and transfers additional pollen from the anthers as it visits the flowers. A honeybee may visit 5,000 flowers a day. Home plantings of fruit crops generally have enough wild bees for adequate pollination. However, in commercial orchards, beehives are generally placed in the orchard when the trees are in bloom to enhance pollination and fruit set. In some fruit crops, pollen is also transferred by the wind. Each fruit crop, and even specific varieties within individual fruit crops, has distinct requirements for pollination. The following terms are used to describe the pollination characteristics of fruit crops:

Cross-pollination — the transfer of pollen between two different species or varieties

Self-pollination — the transfer of pollen within a single plant or among several plants of the same variety

Self-unfruitful or self-sterile — plants in which very little fruit will set

Self-fruitful — varieties that set fruit with their own pollen

Cross-unfruitful — varieties that will not set fruit even when cross-pollinated

Intersterile — neither of two varieties will fertilise the other

Pollinator — an agent (bees, insects, people) of pollen transfer

Polliniser — the plant species or variety that produces the pollen.

To ensure that fruit sets, the pollination requirement of the varieties of a given fruit crop should be evaluated before planting.

To be an effective pollinizer, a variety must

- have a bloom period that overlaps that of the variety to be pollinated,
- have a diploid chromosome makeup,
- produce viable pollen, and
- be grown in close proximity to the variety to be pollinated.

Several environmental factors affect pollination. Temperatures below 55 to 60°F reduce bee flight and activity, as do windy conditions. Temperatures above 85 to 90°F dry the flower's stigmatic surface and prevent pollen grains from germinating. Because bees naturally seek out the best nectar-producing flowers, other blooming flowers in the area can attract bees away from fruit plants, which generally are poor nectar producers. In the early spring, dandelions in bloom can attract bees away from the flowers of fruit plants. Finally, applying insecticides during bloom can harm bees or other pollinating insects.

The best time to plan for pollination is when you order your plants. Most nurseries have charts or tables recommending varieties that will serve as pollinizers for each other. You should also be aware of your neighbors and what fruit plants they have. To be effective, a pollinizer does not have to be directly next to your plant. Also remember that some ornamental plants, such as crab apples, flowering pears, and plums, can be effective pollen sources if their bloom overlaps that of the planted fruit.

The pollination characteristics of several fruit crops are listed below. Those fruits listed as "self-fertile" will set fruit with their own pollen, and therefore require you to plant only one variety or plant. In general, however, all plants produce more fruit when two or more varieties are planted close to each other. You should also consider closely related ornamental plants as good pollinizers. For example, crab apples can pollinate apples, and the ornamental Bradford pear can pollinate pears.

- Apple: Cross-pollination is always needed to produce an adequate fruit crop.
- Apricot: All varieties are self-fertile, but cross-pollination is helpful.
- Blackberry: Most are self-fertile, but a few require crosspollination.
- Blueberry: Fruit set and crop size are improved by crosspollination.
- Cherry, Sweet: Most older varieties are self-unfruitful. Recently, however, a number of new self-fertile varieties have been developed.
- Cherry, Red Tart: The commercial varieties are self-fertile.
- Currants: Self-fertile.
- Gooseberry: Most varieties are self-fertile.
- Grape: A variety of flower types (perfect, male only, and female only) exist. To assure good crops, consult an extension specialist to determine the proper variety mix to assure fruit set.
- Nectarine: Self-fertile.
- Peach: All commercial varieties, except J. H. Hale, are self-fertile.

- Pear: Some varieties are partially self-fertile, but planting at least two varieties is best to ensure cross-pollination.
- Plum: A wide diversity occurs in the plums; about half of the varieties are self-fertile and half are not. To be on the safe side, provide pollinizers.
- Quince: All varieties are self-fertile.
- Raspberry, Black: Most are self-fertile.
- Raspberry, Purple: Self-fertile.
- Raspberry, Red: Most are self-fertile, but crop size is improved by cross-pollination.
- Strawberry: Some known varieties produce imperfect flowers, but most are self-fertile.

Types of Pollination

Abiotic Pollination

Abiotic pollination refers to situations where pollination is mediated without the involvement of other organisms. Only 10% of flowering plants are pollinated without animal assistance. The most common form, anemophily, is pollination by wind. This form of pollination is predominant in grasses, most conifers, and many deciduous trees. Hydrophily is pollination by water and occurs in aquatic plants which release their pollen directly into the surrounding water. About 80% of all plant pollination is biotic.

Biotic pollination

More commonly, the process of pollination requires pollinators: organisms that carry or move the pollen grains from the anther to the receptive part of the carpel or pistil. This is biotic pollination. The various flower traits (and combinations thereof) that differentially attract one type of pollinator or another are known as pollination syndromes.

There are roughly 200,000 varieties of animal pollinators in the wild, most of which are insects. Entomophily, pollination by insects, often occurs on plants that have developed colored petals and a strong scent to attract insects such as, bees, wasps and occasionally ants (Hymenoptera), beetles (Coleoptera), moths and butterflies (Lepidoptera), and flies (Diptera). In Zoophily, pollination is done by vertebrates such as birds and bats, particularly, hummingbirds, sunbirds, spiderhunters, honeyeaters, and fruit Bats. Plants adapted to using bats or moths as pollinators typically have white petals and a strong scent, while plants that use birds as pollinators tend to develop red petals and rarely develop a scent (few birds have a sense of smell).

Pollination in Apple

Most Apples are self incompatible and must be cross pollinated. A few are described as "self-fertile" and are capable of self-pollination although they tend to carry larger crops when pollinated. A relatively small number of species are "Triploid", meaning that they provide no viable pollen for themselves or other apple trees. Apples that can pollinate one another are grouped by the time they usually flower so cross-pollinators are in bloom at the same time. Pollination management is an important component of apple culture. Before planting, it is important to arrange for pollenizers—varieties of apple or crabapple that provide plentiful, viable and compatible pollen. Orchard blocks may alternate rows of compatible varieties, or may plant crabapple trees, or graft on limbs of crabapple. Some varieties produce very little pollen, or the pollen is sterile, so these are not good pollenizers. Good-quality nurseries have pollenizer compatibility lists.

Growers with old orchard blocks of single varieties sometimes provide bouquets of crabapple blossoms in drums or pails in the orchard for pollenizers. Home growers with a single tree and no other variety in the neighborhood can do the same on a smaller scale.

During the bloom each season, apple growers usually provide pollinators to carry the pollen. Honeybee hives are most commonly used, and arrangements may be made with a commercial beekeeper who supplies hives for a fee.

Orchard mason bees are also used as supplemental pollinators in commercial orchards. Home growers may find these more acceptable in suburban locations because they do not sting. Some wild bees such as carpenter bees and other solitary bees may help. Bumble bee queens are sometimes present in orchards, but not usually in enough quantity to be significant pollinators.

Symptoms of inadequate pollination are small and misshapen apples, and slowness to ripen. The seeds can be counted to evaluate pollination. Well-pollinated apples are the best quality, and will have seven to ten seeds. Apples with fewer than three seeds will usually not mature and will drop from the trees in the early summer. Inadequate pollination can result from either a lack of pollinators or pollenizers, or from poor pollinating weather at bloom time. It generally requires multiple bee visits to deliver sufficient grains of pollen to accomplish complete pollination.

All varieties of apple trees should be crosspollinated with another apple or crabapple variety. To attain the best fruit set on apple trees, the king blossom in the flower cluster must be pollinated. Thus, the bloom periods of the polliniser and the king blossom of the apple tree must overlap. In backyard plantings, two semidwarf apple varieties that bloom at the same time should be planted within 50 feet of each other. Two dwarf apple varieties with similar bloom periods should be spaced less than 20 feet apart to ensure the transfer of pollen between trees.

Although some apple varieties, such as Lodi, Liberty, Empire, Winesap, Jonathan, Jonagold, Gala, Golden Delicious, Rome and Granny Smith may be listed as self-fruitful, they will set more fruit on an annual basis if they are cross-pollinated. Additionally, some apple varieties, such as Winesap, Stayman, Mutsu and Jonagold, produce sterile pollen and therefore cannot be used to pollinate other apple varieties. Many nursery catalogues include pollinisation compatibility charts or recommend good apple varieties to use as pollinisers.

Manchurian crabapple, with profuse white flowers, is commonly used to pollinate early- to mid-blooming apple varieties, while Snowdrift crabapple is used for mid- to late-blooming apple varieties. When using a crabapple tree as a polliniser, it should be planted within a similar distance to an apple tree as listed above. In situations where a solitary apple tree is planted, branches of open fresh blossoms of another apple or crabapple pollinating variety can be placed in buckets of water and hung in the tree.

Another way to ensure pollination where a single tree is planted, is to top-work or graft another apple variety onto the existing tree. To top-work an apple tree, 6- to 8-inch sections of branches of one apple variety are cleft-grafted onto terminal branches of another variety.

In commercial apple plantings, a row of polliniser trees is often planted between every four rows of the main variety of trees. If pollinisers are placed within the row, every fifth semidwarf tree is a polliniser and each polliniser is offset in adjacent rows to stagger them throughout the orchard block. In high-density plantings of dwarf trees, apple or crabapple pollinisers may be planted between eight to ten trees of another variety in the row.

Beehives are generally placed in commercial apple orchards as the king flowers open. If hives are brought in before this time, bees may forage flowers of other broad-leaved plants instead of the apple blossoms. For this reason, dandelion flowers should be removed by mowing or by herbicide treatment before hives are placed in the orchard. In orchards where semidwarf trees are planted, one hive of a mediumstrength colony is generally sufficient per acre. Two hives per acre are used in highdensity orchards where dwarf apple trees are planted. Extra strong colonies of as many as 50,000 bees have been effective in pollinating four acres of semidwarf trees under ideal climatic conditions.

Pollination in Pear

Pears are similar to apples, with the notable exception that pear blossoms are much less attractive to bees, due to lower sugar content than apple or contemporaneous wildflower nectar. Bees may abandon the pear blossoms to visit dandelions or a nearby apple orchard. There are two possible methods used to compensate. One is saturation pollination, that is to stock so many bees that all area blossoms are worked regardless of the attractiveness to the bees. The other is to delay the movement of the beehives into the orchards until there is about 30 per cent bloom. The bees are moved into the orchard during the night and will usually visit the pear blossoms for a few hours until they discover the richer nectar sources. The recommended number of hives per acre is 1.

Most pear varieties are self-unfruitful. However, nearly all pears are suitable pollinisers for other varieties that bloom at the same time. One exception is Seckel, which is not a good polliniser for Bartlett. Even though Anjou, Bartlett and Kieffer are partially self-fruitful, they should be cross-pollinated to produce heavy and regular crops. Pear flowers produce only a small amount of nectar, which is low in sugar. For this reason, more pollinisers and bees are needed for pears than for any other tree fruit.

Pollination in Citrus

Many citrus varieties are seedless and are produced parthenocarpically without pollination. Some varieties may be capable of producing fruit either way, having seeds in the segments, if pollinated, and no seeds if not. Citrus that requires pollination may be self compatible, thus pollen must be moved only a short distance from the anther to the stigma by a pollinator. Some citrus, such as Meyer Lemons, are popular container plants. When these bloom indoors, they often suffer from blossom drop because no pollinators have access. Hand pollinate by a human pollinator is a solution, though it is important to learn whether the variety is self fertile or self incompatible.

A few citrus varieties, including some tangelos and tangerines are self incompatible, and require cross pollination. Pollenizers must be planned when groves are planted. This last group generally requires the addition of managed honeybee hives at bloom time for adequate pollination.

Peach Pollination

Nearly all common varieties of apricot, peach, nectarine and sour cherry are self-fruitful. However, the J.H. Hale peach is not self-fruitful but can be pollinated by almost any other peach variety with a synchronous bloom period except Elberta. Self-unfruitful varieties of apricots include Perfection, Riland and Rival. These self-unfruitful varieties can be pollinised by any other apricot variety.

Sweet Cherry Pollination

Stella, Lapins and Starkrimson are selffruitful. Most other varieties of sweet cherries require cross-pollination. Several varieties are intersterile and cannot fertilise each other.

For example, Bing, Lambert and Royal Ann will not pollinate each other. In commercial plantings, beehives should be placed in the orchard on the first day of bloom.

Plum pollination

Most European plums either benefit from or require cross-pollination from another European variety. However, European or prune-type plums, such as Stanley and Damson, are self-fruitful. Japanese plums, such as Santa Rosa, Burbank, Redheart, Shiro, Methley and Ozark Premier, require pollination from another Japanese or an American-Japanese hybrid. Follow nursery recommendations for suitable pollinisers.

Pollination of Small Fruit Crops

Grape, strawberry, raspberry, blackberry, gooseberry and currant plants are all self-fruitful. However, blueberry varieties require cross-pollination for fruit set. Thus, varieties that bloom at a similar time should be placed within rows or planted in adjacent rows.

Pollination Failures

Poor fruit set or low yields are often caused by poor pollination or frost during the period when trees are in bloom. Some of the common reasons for pollination problems can be the lack of a suitable variety for cross-pollination. Pollination failures also occur when bloom periods of two varieties used for cross-pollination do not overlap. Poor climatic conditions during bloom can also adversely affect pollination.

Bees travel shorter distances during cool, rainy or windy weather. In areas where native bees have been infected with tracheal or varroa mites, growers should rent beehives from commercial beekeepers that have strong colonies. Do not spray carbaryl or any other insecticide that could harm bees during the bloom period. To prevent bees from foraging flowers of dandelions or other weeds, mow the orchard or control the weeds with a herbicide before the fruit plants bloom. Wait to move the beehives into the orchard until the fruit crop has started to bloom and remove the hives as flowers stop blooming. Beehive inserts can also enhance pollination in commercial orchards. Inserts are placed at the hive entrance and filled with pollen from a polliniser variety. Pollen can be purchased from a commercial supplier and should be kept cool and out of the sun until it is placed in an insert. Use a teaspoon of undiluted pollen every several hours. A total of 1.4 ounces (40 grams) of pollen per acre is usually recommended.

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4

Cultivation of Tropical and Subtropical Fruit Crops

Tropical and subtropical fruits, in contrast with temperate fruits, can be broadly defined as those meeting all of the following criteria: crops that have their origin and commercial growing areas (when such exist) in the tropics or subtropics, plants that are evergreen and perennial, crops with a limited degree of frost resistance, and plants whose growth is practically nonexistent below 50°F (10°C) (with some exceptions according to species and individual age).

A distinction between tropical and subtropical is possible if one considers that tropical species are not only sensitive to temperatures below 68°F (20°C) but indeed require a climate with average mean temperatures higher than 50°F (10°C) for the coldest month. Additionally most tropicals require humid environmental conditions.

Examples of truly tropical crops are traditional fruits native to Southeast Asia, like mangosteen, durian, and rambutan. A good example of a typical subtropical fruit crop is the cherimoya, which when cultivated in cold subtropical areas may suffer some foliage loss during the winter with regrowth in spring. However, some fruit crops can be cultivated equally well in either the tropics or the subtropics, of which the banana and the avocado are the most outstanding examples.

Strictly speaking, the tropics extend between the Tropics of Cancer and Capricorn, at 23° north and south of the equator. But, agronomically speaking, these boundaries are too rigid. Not only do they contain areas, especially at higher altitudes, that do not conform to the climatic characteristics generally assigned to the tropics, but regions outside this belt have coastal areas or insular climates that may exhibit climatic conditions fitting properly in the tropics. This is the reason why some climatologists have extended the region to the thirtieth parallels. In any event the main feature associated with the tropics is not so much that of heat but rather steady warm temperatures throughout the year.

J. A. Samson gave a good working definition of the tropical climate: temperature averages around 80.6°F (27°C), with the warmest month being only a few degrees higher than the coldest and temperature differences between night and day, at any given time, being greater than those between winter and summer, and, finally, little variation in day length, with the longest day being less than thirteen hours long. In comparison, the subtropics have hotter summers and cooler winters. Humidity is also generally lower. Day length differences become greater with increased latitude. The limit for the subtropics is the isotherm of 50°F (10°C) average for the coldest month.

Hundreds of tropical and subtropical fruits exist, but only some fifty are well known throughout most of the world. These are important production crops, although a considerable gap exists between world per capita consumption (54.9 kilograms per year) and estimated consumption saturation (about 100 to 120 kilograms per year). Production and trade figures allow the division of tropicals and subtropicals into three main categories with some overlapping. Major fruits, such as banana and plantain, citrus, coconut, mango, and pineapple.

Minor fruits, such as abiu, atemoya, avocado, breadfruit, carambola, cashew nut, cherimoya, durian, guava, jaboticaba, jackfruit, langsat, litchi, longan, macadamia, mangosteen, papaya, passion fruit, pulusan, rambutan, sapodilla, soursop, and white sapote.

Wild fruits belonging to diverse botanical families. These are not cultivated commercially in any country and are much in need of characterisation, conservation (both in situ, including on farm, and ex situ), selection, and breeding.

Major-category fruits are cultivated in most tropical (and subtropical) countries and are well known in both local and export-import markets. Minor fruits are not so extensively cultivated, and consumption and trade tend to be more limited, both geographically and quantitatively. However, many are of considerable economic importance in their respective regional markets, as is the case with carambola, durian, and mangosteen, which are major fruits throughout Southeast Asia.

BOTANICAL ASPECTS

Tropical and subtropical fruits include not only woody plants, such as the mango or the orange, but also herbaceous crops like the banana and vines like the passion fruit. Most botanical families can lay claim to at least one species of tropical or subtropical fruit.

From the botanical point of view, a fruit is the structure developed from flowers or inflorescences. In most cases the fruit consists only of the developed ovary, but it may include other parts of the flower, such as the pedicel, sepal, or receptacle, or even a portion of the seed stalk. As with temperate crops, many different fruit types appear among the tropicals and subtropicals, from single fruits, including berries, such as the avocado or orange; drupes, such as the mango; pomes, such as the loquat; capsules, such as the durian; nutlets, such as the litchi and the longan; to compound fruits, as in the typical syncarpium of the pineapple; or even a bunch of individual berries, as in the banana. To differentiate fruit crops from perennial vegetables whose fruits are also eaten, it is necessary to keep in mind that in a horticultural sense a fruit is something that is normally eaten fresh and out of hand. A number of exceptions exist, like the breadfruit and the plantain, considered fruits by all but only palatable when cooked, as if they were vegetables. Nuts, obviously not eaten out of hand, and some tree crops whose seeds are the only part eaten, are also included among tropicals and subtropicals in most horticultural books and as such are included in this entry.

ORIGIN AND SPREAD

Although most of the continents, including the islands throughout the Pacific, have contributed tropical and subtropical fruits, most of the best-known ones came from the tropical and subtropical regions of America (for example, papaya, avocado, pineapple, guava) and Asia (for example, orange and most citrus fruits, mango, banana, litchi). Only two commercially important fruits originated in Oceania, the macadamia in Australia (specifically Queensland) and the coconut in the Pacific, the latter to the extent that its origin is considered pantropical. The only important fruit native to the African continent is the date. Europe, with no tropical and limited subtropical areas, has none.

Spread to the regions surrounding their areas of origin probably began early, as soon as humans realised their value in terms of nutrition and the variety they could add to the primitive diets of the time. The potential of some species to provide not only food but also shelter or clothing (some types of banana), wood, and medicine hastened distribution. An outstanding example is the mango. Native to the Indo-Burman region, by the end of the fourth century C.E. it had spread to all the tropical countries of Southeast Asia. The Arabs were apparently responsible for its spread to the east coast of Africa around 700 C.E. as an adjunct to their slaving ventures. Just as Malaysians introduced the banana to Madagascar some two centuries earlier, Islamic domination brought the orange to the Mediterranean and southern Europe. Crops from the Americas are not as well documented, but archaeological findings have shown connections between the cultures of Mexico and Peru dating as far back as 1000 B.C.E. giving a solid opportunity for some tropical and subtropical fruits to spread around the warmer American lands.

Soon after the European discovery of America, the Old and New Worlds rapidly exchanged crops. The sixteenth-century monk Bartolomé de las Casas mentioned that orange seeds were carried from the island of La Gomera to Haiti on Christopher Columbus's second voyage in 1493. It is similarly well documented that the banana was carried to Santo Domingo from the Canary Islands in 1516 (the Canaries were a routine last port of call for European ships facing an Atlantic crossing). After Columbus's voyages, a veritable avalanche of expeditions explored all corners of the world, and where the ships went, food went also, to say nothing of tasty fruits and easily propagated species. Between 1500 and 1650 Portuguese sailors connected Brazil and the Cape of Good Hope, touching Goa, Malacca, the Moluccas, Canton, and Macao, trading from there with Japan and Formosa. The Spanish Manila galleon route dominated shipping from 1565 to 1815, plying the seas between the Philippines and Mexico. Dutch, British, and French voyagers were also important in spreading tropical fruits around the world.

No hard and fast rule explains why some fruits spread quickly throughout the world while others remain limited in scope even in the twenty-first century. Several factors may be involved, among them crop adaptability, shelf life, ease of propagation (including the capacity to survive long voyages), size of the plant, multiplicity of uses (that is, other than as fresh fruit), and taste acceptance.

The excellent taste of the pineapple, the long-lasting viability of the plant's suckers as planting material, and the rapidity with which it produces fruit all account for its prompt appearance in Europe—albeit in glasshouses—and India as early as 1548. Similar considerations apply to the banana and the papaya and even to woody perennial trees like the mango or the guava, which soon spread throughout the tropics and subtropics, even though their size precluded cultivation in greenhouses outside these areas. On the other hand true tropical trees are usually demanding in climate and in some cases are difficult to propagate. The mangosteen, rambutan, and durian (this last deemed by many people to have a peculiar taste) have remained confined almost exclusively to their area of origin in Southeast Asia. The mangosteen is notable among tropical fruits in that it has proven particularly intractable to most attempts to establish it outside of its area of origin via the usual method, which is selection or breeding of cultivars capable of adapting to environments different in climate or edaphic conditions. The species consists of a single genotype, which in essence means no genetic variation exists with which to breed or improve stock, and it is entirely possible that its evolution has ceased.

NUTRITIONAL AND MEDICINAL VALUE

Despite the relatively low caloric values of tropical and subtropical fruits (banana and plantain and avocado are the notable exceptions), they play an important role in human diet mainly because of their high and diverse vitamin and mineral content. This has been of capital importance in the tropics, where people have been consuming them since ancient times, either by collecting fruit from the wild or by cultivating plants in kitchen gardens. They have become an important part of the diet of people in the developed countries of the world, especially among the health and fitness conscious. In a properly balanced diet, tropical and subtropical fruits may be an excellent component for the sports-oriented person. This is not to say that one can live by tropical fruits alone or that they can be considered staple fruits within the diet (again the banana and especially its relative the plantain are the exception in some tropical areas). But nutritionists have long recommended a minimum of one hundred grams of fruit per day and that it be as varied as possible. Toward the end of the twentieth century market campaigns commonly recommended consumption of five fruits per day, which, while it may have more to do with commerce than with science, does reinforce the value of fruit as a part of the human diet.

Tropical and subtropical fruits also have some medicinal properties. Many tropical fruits, notably the mango and the papaya, are a good source of carotene (provitamin A). An indication of the high content of this vitamin is the orange-yellow color of the flesh. Others, like all citrus fruits and the guava, are well known as good sources of ascorbic acid (vitamin C). In general they are not a good source of the B group of vitamins (thiamine, riboflavin, and niacin) except for nuts, which are also a good source of vitamin E, proteins, and fats. Tropical and subtropical fruits are also rich in pectin, fiber, and cellulase, which promote intestinal motility. In common with other fruits, they are good sources of antioxidants, and some are also good sources of organic acids, which stimulate appetite and aid digestion.

Values for the chemical composition of tropical and subtropical fruits are widely available in many texts, some of which are included in the bibliography cited here, but the salient points related to general nutritional value follow. Banana is a good source of vitamins A, B, and C and riboflavin. Together with the tropical and subtropical nut fruits, the banana has the highest calorie content. It is low in protein and fat and rich in potassium. Easy to digest, it constitutes an excellent food for young and old alike and is recommended for athletes. Avocado has a good oil content (of the different avocado races, the West Indian types have the lowest) composed of highly digestible unsaturated fatty acids, and it is rich in folic acid. Some cultivars contain good quantities of proteins, vitamin A, riboflavin, and phosphorus.

All citrus fruits have fairly high amounts of vitamin C, as does the guava, which in turn contains fair amounts of niacin and iron. The papaya has high quantities of vitamins C and A as well as potassium and calcium, and it is low in carbohydrates. However, its outstanding feature, which distinguishes the papaya from all other fruits, is the fact that it contains papain, an enzyme that promotes digestion (although papain content does decrease as the fruit ripens). It is highly recommended for people with certain digestive disorders. The mango is rich in provitamin A and carbohydrates and is an acceptable source of vitamin C. The same is true of the passion fruit, which additionally has acceptable quantities of niacin. The pineapple is also rich in vitamin C and carbohydrates and is a good source of calcium, phosphorus, iron, potassium, and thiamine.

The litchi and the longan, most of the Annonaceae, and the durian are all good sources of carbohydrates and vitamin C. The durian also has fair amounts of iron and niacin. The mangosteen is considered by many to be one of the finest tasting fruits of all, according it the title of "queen of fruits". It is one of the lowest in nutritive value, but even so it can boast moderate quantities of calcium, phosphorus, ascorbic acid, and carbohydrates. The carambola is low in calories and rich in vitamin C, and it is an adequate source of vitamin A. It is prohibited for people with kidney problems (specifically stone formation) due to its high oxalic acid content, but new cultivars have been selected for lower oxalic content while maintaining sugar and vitamin levels.

The macadamia nut is rich in protein, oil, iron, calcium, thiamine, riboflavin, and niacin. The subtropical date also has a high nutritive value. Rich in carbohydrates, it is a good source of vitamin A, potassium, and iron but is low in oils and sodium. The coconut is high in phosphorus, iron, proteins, and oils—in this case all saturated fatty acids, the consumption of which should be limited according to health recommendations. Coconut milk aids in balancing pH in the body due to its alkaline reaction.

The medicinal value of tropicals and subtropicals, both the fruits themselves and their actual plant parts (bark, roots, and even pollen), has long been acknowledged by the diverse peoples in and around their areas of origin. These regions are rich in recipes for preparing infusions, decoctions, syrups, pastes, jellies, juices, and so forth for myriad purposes. All the citrus fruits and several others rich in vitamin C are obviously useful to prevent colds and similar infections, while fruits rich in vitamin A prevent dietary deficiencies, such as those leading to blindness.

The date has a high tannin content that is reportedly useful as an astringent in intestinal complaints and is good for sore throats, colds, and bronchial catarrh. Breadfruit is reported to reduce high blood pressure. Carambola fruit and pineapple juice are reportedly useful diuretics, while the flesh of the very young fruit of the pineapple is reputedly an abortifacient. The skin of the avocado and extracts of ripe and unripe fruits and seeds of the papaya reportedly have antibiotic properties. In traditional medicine a decoction of young mango leaves is recommended as a remedy for asthma, blenorraghia, and bronchitis.

The roots, bark, leaves, and immature fruits of many tropical fruit crops are widely used in the tropics as astringents to stop gastroenteritis, diarrhea, and dysentery. A decoction of the boiled fruit of the sapodilla has also been reported useful in treating diarrhea. The flesh of the longan has been recommended for its febrifuge and vermifuge properties and as an antidote against some types of poisons. The infusion of passion fruit leaves, rich in the glycosid passiflorine, is reported to have sedative properties.

TROPICAL AND SUB-TROPICAL FRUITS IN INDIA

Banana

Banana (*Musa paradisiaca* L.) occupies over 1,64,000 hectares, mainly in Tamil Nadu, West Bengal, Kerala, Maharashtra, Gujarat, Karnataka, Assam, Andhra Pradesh and Bihar. Though some inferior types of banana are found growing as far north as the Himalayas, its commercial importance is mainly limited to the more tropical conditions, such as those prevailing in central, southern and north-eastern India. It is a moisture- and heat-loving plant and cannot tolerate frost or arid conditions.

Figure 1. Banana Plant

Varieties

Cultivated varieties are broadly divided into two groups : table and culinary. Among the former are 'Poovan' in Madras; 'Mortaman', 'Champa' and 'Amrit Sagar' in West Bengal; 'Basrai', Safed Velchi', Lal Velchi' and 'Rajeli' in Maharashtra; 'Champa' and 'Mortaman' in Assam and Orissa; and 'Rastali', 'Sirumalai', 'Chakkarekeli', 'Ney Poovan', 'Kadali' and 'Pacha Nadan' in southern India. 'Basrai', which is known under different names, viz. 'Mauritius', 'Vamankeli', 'Cavendish', 'Governor', 'Harichal', is also grown in central and southern India. Recently, the 'Robusta' variety is gaining popularity in Tamil Nadu and Karnataka. The 'Virupakshi' variety is the most predominant variety in the Palni Hills of Tamil Nadu. Among the culinary varieties, Nendran bananas, 'Monthan', 'Myndoli' and 'Pacha Montha Bathis' are the leading commercial varieties in southern India. 'Gros Michel' is a recent introduction into southern India; it is suitable for cultivation only under garden-land conditions and is generally fastidious in its cultural requirements. It is not, therefore, in favour with the cultivation.

Propagation and planting

Propogation is by suckers or off-shoots which spring at the base of a banana-tree from underground rhizomes. Vigorous suckers, with stout base, tapering towards the top and possessing narrow leaves, are selected for plant. Each sucker should have a piece of underground stem with a few roots attached to it. Banana suckers can be planted throughout the year in southern India, except during summer, whereas in the rest of the country, the rainy season is preferred. They are planted in small pits, each just enough to accommodate the base of a sucker. The planting-distance varies from 2m X 2m in the case of dwarf varieties to 4m X 4m in the case of very tall varieties.

Manuring

An application of 20 to 25 kg of farmyard manure, together with about 5 kg of wood-ashes per plant is given at planting time. In southern India, ammonium sulphate is applied one month, five months and nine months after planting 20 kg per hectare each time. In western India, a little over 2 kg of oilcake per stool is applied during the first three months after planting. A complete fertiliser mixture may be applied to supply 100 to 200 kg of N, 100 to 200 kg of P_2O_5 and 200 to 400 kg of K_2O per hectare.

After-care

The removal of suckers, dry leaves and pseudostems, from which the fruits have been harvested, constitute the main after-care. Daughter-suckers should be removed promptly until the mother-plant flowers, when one daughter-sucker may be allowed to take its place. The removal of dry leaves and useless pseudostems requires to be done in time. After all the fruits are formed, the pendant portion of the remaining inflorescence along with the heart should be removed.

The propping of plants with bamboo poles, especially those which have thrown out bunches, is necessary wherever damage by wind is apprehended. Where the wind damage is recurring, dwarf varieties should be preferred.

Irrigation

The banana-plants require very heavy irrigation. Irrigation is given in most places once in seven to ten days. Stagnation of water in the soils is not very congenial to the proper growth of banana and, hence, the drainage of soil is also essential.

Harvesting

Early varieties commence flowering in southern and western India about seven months after planting, and the fruits take about three months more to ripen. In the Andhra Pradesh delta areas, the fruits are ready for harvesting about seven to eight months after planting. The first crop of the 'Poovan' variety matures in 12 to 14 months and the second in 21 to 24 months after planting. In other parts of India, the first crop is usually gathered a year after planting, whereas the succeeding crop may be ready in six to ten months thereafter. The bunch is harvested just before it attains the ripening stage. When the fruits have reached the full size, they become plump, and mature with a distinct change in colour. For long transport, the bunch may be harvested somewhat earlier. The bunch is cut, retaining about 15 cm of the stem above the first hand. The yield varies considerably from 26,000 to 55,000 kg per hectare.

Curing and Marketing

The ripening of banana is done in several ways, e.g. exposing the bunches to the sun, placing them over a hearth, wrapping them in closed godowns or smoking them in various ways. One of the common ways is to heap the fruits in a room and cover them with leaves, after which fire is lit in a corner and the room is closed and made as air-tight as possible. Ripening takes place usually in 30 to 48 hours. In a cool store, the bunches ripen well at about 15° to 20°C. The application of vaseline, a layer of clay or coal-tar to the cut-ends of the stalks prevents rotting during ripening and storage. Wrapping up the fruits and packing them in crates help to reduce the damage during transport.

Mango

Mango (*Mangifera indica* L.) occupies nearly half of the total area under fruits in the country. It is adaptable to a wide range of soil and climatic conditions and grows well right from Assam to the southern-most limits of the country and from the sea-level up to about 1,500 metres. It withstands both fairly dry conditions and heavy rainfall, provided severe and recurring frosts in winter do not endanger the young trees.

Varieties

The number of varieties is very large. Each variety has its own peculiar taste, flavour and consistently of pulp. Some of the important commercial varieties grown in different regions are : 'Bombay yellow', 'Alphonso', 'Gopal Bhog', 'Zafran' (all early), 'Langra', 'Desheri', 'Safeda Lucknow', 'Safeda Malihabad', 'Fajrizafrani' (all mid-late). 'Fajri', 'Same Bihisht', 'Chausa', 'Taimura' (all late). In Uttar Pradesh; 'Bombai', 'Alphonso', 'Hemsagar', 'Krishna Bhog', 'Aman Dasheri', 'Gulab Khas' (all early), 'Langra', 'Aman Abbasi', 'Khasul-Khas' (all mid-late), ' Sinduri', 'Sukal', 'Taimuria' (all late) in Bihar; 'Bombai' or 'Maldah', 'Gopal Bhog', 'Hemsagar' (all early), 'Krishna Bhog', 'Zardalu' (both mid-late), 'Murshidabadi', 'Fazli Maldah' (both late) in West Bengal; 'Alphonso', 'Pairi', 'Cowsji Patel', 'Jamadar' in Bombay; 'Swarnarekha', 'Benishan', 'Cherukurasan', 'Panchadarkalasa', 'Desavathiyamamidi', 'Sannakulu', 'Nagulapalli', 'Irsala' in Circars; 'Rumani', 'Neelum Benishan', 'Bangalore', 'Alampur Benishan' in Rayalaseema; 'Murshidabadi', 'Mulgoa', 'Goabunder', 'Benishan', 'Neelam', 'Totapuri' or 'Bangalora' in Telengana; 'Alphonso', 'Peter', 'Rumani' in central districts; 'Mundappa', 'Neelam', 'Alphonso', 'Olour', 'Bennet Alphonso', 'Kalepad', 'Peter', 'Fernandin' in Coorg and Karnataka; and 'Padiri', 'Alphonso', 'Peter', 'Neelum', 'Bangalore', 'Rumani' in Tamil Nadu. In Goa, some excellent varieties like 'Alphonso', 'Fernandin', 'Mankurad' and 'Moussorate' are under cultivation. The new mango variety, 'Mallika' evolved at the Indian Agricultural Research Institute is now gaining popularity.

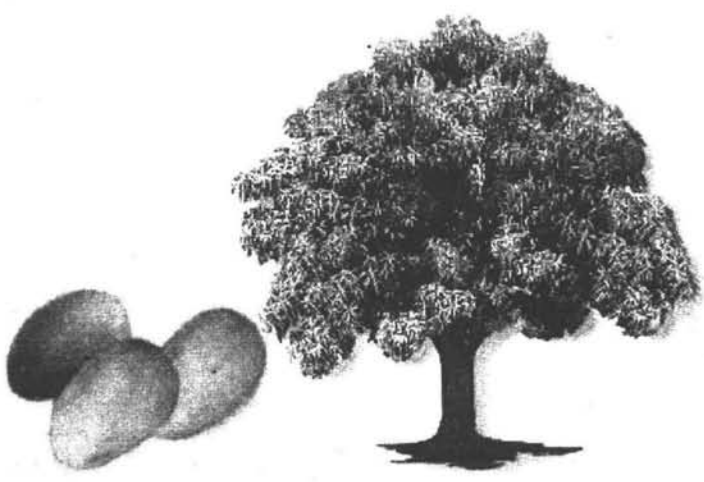

Figure 2. Mango Tree and Fruits

Other varieties, such as 'Jehangir' and 'Himayuddin', produce high-quality fruits, but are poor in yield and cropping tendencies. Attempts are being made to evolve hybrid progenies by crossing.

Propogation and Planting

Propogated vegetatively by inarching or budding in situ in the nursery, either by using Forkert or by using the T-method. The beginning of the monsoon in light-rainfall areas and the end of the monsoon in heavy-rainfall regions are the most suitable periods for inarching or budding. Recently, veneer-grafting has been found to be the best method of mango propagation. Grafted plant are ready for transplanting in the field after six to twelve months. Select straight-growing grafts and set them in pits filled with soil mixed with farmyard manure (45 kg) and a fertiliser mixture containing 0.225 kg of N, 0.45 kg of P and 0.225 kg of K per pit. The planting-distance is 7.5 to 9 metres in poor shallow soils and 15 to 17 metres in deep fertile soils. The beginning of the monsoon in low rainfall areas or the end of the monsoon in heavy rainfall tracts is the best time for planting. The graft-joint should be at least 15 cm above the ground.

Pruning

No systematic pruning is done. The removal of dead-wood and the thinning of over-crowded and mis-shapen branches after about four years is all that is necessary; flowers that appear during the first three or four years should be removed.

Culture

Before planting, the field is ploughed, harrowed and levelled. Thereafter, it is ploughed and harrowed twice a year, once in the beginning of the monsoon and again at the close of the rainy season or in the cold-weather. It is green-manured once every two or three years.

Short-season intercrops, like vegetables, may be taken during the first four to five years. Young plants require irrigation regularly. After five to six years, when they have established themselves, the trees are able to grow and fruit satisfactorily without irrigation in most parts of Peninsular India. In northern India, they have to be irrigated throughout their life. Irrigation is usually withheld during the cold weather before flowering, especially in deep retentive soils. Though the exact manurial requirement is not known, regular manuring is beneficial.

The dose recommended for the bearing trees is 45 to 70 kg of farmyard manure, 0.5 to 0.7 kg of N, 0.7 kg to 1.0 kg of P and 1.2 to 1.5 kg of K per tree. Nitrogen and half of potash may be given before the monsoon, and farmyard manure, phosphate and half of potash in October or before flowering starts.

Crop Irregularity

Grafted mango-trees bear fruits from the fourth or fifth year onwards and a full crop from the tenth or fifteenth year. The erratic bearing of mango is well known. It depends upon the variety , the weather and climatic conditions and cultural treatments. The selection of regular-bearing varieties, timely cultural practices and proper nutrition help to produce a regular crop. New growth in spring, on which flower-buds are produced during the next winter, can be encouraged by applying nitrogenous fertilisers (0.45 to 0.90 kg of N per tree). In the case of heavy late rains, an additional ploughing in winter helps to produce flower-buds in January-February. In the case of individual trees, ringing or girdling in August-September may also to help to force flower-buds the following winter. The application of Ethral (200 ppm) from September onwards has been found to induce flowering in mango in Karnataka by the Indian Institute of Horticultural Research.

Improvement of Old and Seedling-Trees

Mango-trees of inferior varieties, so also those raised from seeddlings, can be converted into choice varieties by grafting them in situ either by crown or side-grafting. In crown-grafting, the trunk of the tree is cut down to about half a metre from the ground and one or more scions of the selected variety are inserted into it between the bark and the wood by splitting open the bark. The scion should be a dormant, terminal shoot, about 12.5 mm in diameter, with a whorl of plump swollen buds at the top. In side-grafting, the procedure is the same as in crown-grafting, except that the trunk of the stock tree above the grafting joint is cut down after the scions have sprouted and have established themselves properly. Old trees, having several branches, can be similarly improved by crown-grafting on each branch at a suitable height. Sometimes, the grafting is done by inarching, but the process is cumbersome, expensive and not very satisfactory.

Harvesting and Marketing

The fruit takes five to six months to mature. Depending upon the onset of flowering, the mature fruits are ready for harvesting from April to May in western India, from May to June in the Deccan, from February to March in Malabar, from April to July in the coastal Andhra Pradesh, from May to August in Mysore and Rayalaseema, and from June to August in northern India.

The mature fruits are harvested by severing the stalks to which they are attached, when they are still green and hard. The signs of maturity vary with different varieties. As a mango tree usually bears flowers in three or four distinct flushes lasting over a month, it is preferable to harvest the fruits as they mature. The fruits, so harvested, can be transported after packing them in baskets or wooden crates, properly padded with straw, wood-shavings or wool, to long distances. For overseas markets, they are packed in a single layer in specially designed wooden crates.

For ripening, the fruits are spread out on rice straw in a single layer. Two or three such layers are built one above another in a well-ventilated room. The mangoes are ready for disposal after they change colour. Yield varies considerably with the variety, vigour of growth, flowering, etc. A grafted tree yields about 300 to 500 fruits in the tenth year, about 1,000 in the 15th year and 2,000 to 5,000 from the 20th year onwards.

Citrus

Citrus is grown in almost all the states of India. The total area covered is over 67,650 hectares, of which Madhya Pradesh, Madras and Maharashtra have the largest share. Citrus trees are grown in almost all kinds of soils, varying from heavy black soils to shallow open soils. Some of the varieties of citrus seem to adapt themselves to soil conditions better than others. They thrive in free-draining alluvial or medium black soil of loamy texture. A hard substratum or a sticky impervious layer is very injurious. Soils having a high water-table should be avoided. Though citrus trees on the whole do well in dry climate, with a rainfall between 75 and 125 cm, certain species, such as pummelo and certain mandarin oranges, thrive in heavy-rainfall areas of Konkan, Assam and Coorg.

Figure 3. Branch of a Lemon Tree

Grapefruit

The name grapefruit (*Citrus paradisi* Macf.) has been derived from the habit of bearing the fruit in clusters like grapes. In India, its introduction is comparatively recent, and its cultivation is confined mostly to Punjab, the western parts of Uttar Pradesh and to places around Poona in Maharashtra.

Climate and Soil

The climatic and soil requirements of the grapefruit are similar to those of the orange. High rainfall and humidity are harmful, as they encourage diseases.

Varieties

The popular varieties, which are all imported, are 'Marsh Seedless', pink-fleshed 'Foster' and yellow-fleshed 'Duncan'.

Propogation and Planting

Propogation is done by budding. However, owing to their polyembryonic nature, seedling trees have been frequently found to be quite satisfactory. The rootstock most successfully employed in the northern regions is kharna khatta. In the south and Bombay-Deccan, 'Jamburi' is commonly employed, whereas in Assam grapefruit does well on Rabab tenga. Planting, irrigation, manuring and interculture are the same as for the orange.

Pruning

Grapefruit trees require less pruning than orange-trees.

Harvesting and Marketing

The harvesting season is from January to March in the north and from September to November in the south. Picking, packing and other operations are the same as for the orange. Quality and flavour of the fruit is improved if it is stored before transporting.

Lemon (*Citrus limon* (L.) Burm.f) is not cultivation to any great extent in India, as it requires a comparitively cool climate for regular bearing. Its fruit is not so highly flavoured as that of sour lime.

Lime

The lime (*Citrus aurantiifolia* Swingle), both sour and sweet, known as *kaghzi nimboo* and mitha respectively, are more orized in India than lemon. Sour lime is propagated mainly from seed.

Budding on rough lemon rootstock, layering and morcotting are also practiced to some extent. The tree is susceptible to frost. It flowers twice a year in February-March and again in August. The main crop is obtained in August from the first flowering. The second crop is ready in the following February.

The propagation of sweet lime is done from mature wood cuttings which root readily. It can also be propagated from seeds and the seedlings, usually come true to type. Planting of limes and their pruning, manuring, etc. are the same as for the sweet orange.

Mandarin Orange

Climate and Soil

Santra or mandarin orange (Citrus *reticulata* Balanco) grows successfully in all tropical and subtropical parts of the country. It tolerates more humidity in summer and winter than the sweer orange. It is grown under rain-fed conditions in Coorg, Wynad tract, Palni Hills and the Nilgiris in the south between elevations of 600 and 1,500 metres. In Assam, the main centres of production are the Khasi, Jaintia and Lushai Hills. The region around Nagpur produces a superior quality of mandarins. It is mainly grown under irrigation. In Punjab, its cultivation is confined mainly to the submontane districts up to about 600 metres. It can be grown successfully on a wide range of soils, but the ideal soil is medium or light loam with a slightly heavier subsoil. Heavy black soil, underlain with murram and having good drainage, is also suitable. In the Khasi Hills of Assam, oranges are grown on sandy or gravelly soils.

Varieties

The important varieties cultivated on a commercial scale are the 'Nagpur' orange, the 'Khasi' orange, the 'Coorg' orange, 'Desi Emperor' and the 'Sikkim' orange.

Propagation

The propagation of mandarin orange is largely through seed, except the 'Nagpur' and 'Emperor' varieties which are propagated by budding. Like other citrus species, the seed is polyembryonic. Therefore, while propagating by seed, the sexual seedlings which are usually stunted and poor are rogued out and the rest that are produced from the cells of the nucellus are allowed to grow. The seedlings, thus selected, are more or less uniform in growth and production. They are, however, late in bearing and remain tall and slender. Budded plants do not suffer from these defects. The santra orange is usually budded on rough lemon (jambhiri, Soh-myndong or jatti khatti rootstock. The variety 'Emperor' is budded on the kharna khatta rootstock. Studies at the Citrus Experiment Station, Coorg, of the Indian Institute of Horticultural research, has shown that trifoliate, Rangpur lime, Kodakthuli and Troyer citrage are good rootstocks for mandarin.

Planting

In the hills and humid regions, where plantings are generally done on steep slopes, the land is properly terraced. In the plains, where the trees have to be irrigated, the land should be levelled. The trees are usually transplanted during the monsoon. In heavy-rainfall areas, the plantings is generally done at the end of the heavy rains. They are planted 4.5 to 6 metres apart.

Pruning

Prune young trees to build up a strong framework, as recommended for sweet orange. The bearing trees require little or no pruning. Undesirable growths, like water-shoots and crossing branches, should be removed once or twice a year. In Bombay-Deccan, root exposure or resting treatment is given to santra trees to make them flower to order. The treatment is the same as for the sweet orange.

Manuring

Farmyard manure, 20 to 25 kg per tree, is applied at planting, together with about half a kilo of ammonium sulphate. A mixture supplying 0.09 kg each of N, P and K per tree may be applied in the first year after planting, and the dose is gradually increased to 0.45 kg of each N and P and to 0.90 kg of K per tree in the seventh year and kept constant thereafter. The dose of farmyard manure is increased to 50 kg per tree. It may be replaced by green manuring. In northern India, manuring is generally done in winter, whereas in Bombay-Deccan it is done before the advent of the monsoon or at the time of root exposure.

Irrigation

When grown under irrigation, the method and frequency of application of water are the same as described under sweet orange.

Harvesting

Seedling trees bear their first crop in the eighth year and the full crop from the tenth year onwards. Budded trees start bearing from the fourth year and full crop is had from the seventh year onwards. The harvesting periods differ in different parts of the country. While picking the fruit, the stem-end should be cut close to the fruit without damaging rind. Packing is done by putting the fruits of different size grades in separate wooden crates.

Sweet Orange

Sweet Orange (*Citrus sinensis* (L.) Osbeck) is grown under both subtropical and tropical conditions. Dry and arid conditions, coupled with distinct summer and winter having low rainfall, are most favourable to the growth of the sweet orange. Rainfall seems to be unimportant if irrigation is provided, but atmospheric humidity exerts a great influence. The sweet orange can be grown on a wide range of soils, from heavy clays to very light sands, with pH ranging from 6.0 to 8.0. The tree is particularly sensitive to high concentrations of salts and cannot stand water-logging.

Varieties

The important varieties of sweet orange grown in each region are 'Blood Red', 'Pineapple', 'Hamlin', 'Jaffa' and Valencia Late' in northern India, mosambi in Western India and 'Sathgudi' and 'Batavian' orange in southern India.

Propagattion and Planting

Usually, propagated by budding. The most suitable rootstock is Jamberi or jatti khatti. For 'Pineapple', 'Hamlin', 'Jaffa' and 'Valencia Late' varieties, kharna khatta also provide a suitable rootstock. The trees are planted 6 to 7.5 metres apart each way in January or August-September in the north and in July-August in the south. The bud-union should be kept at least 15 cm above the ground while planting.

Pruning

The pruning of citrus-trees begins in the nursery. All branches that start within a few centimetres of the union are removed, leaving about a half a metre of clean straight stem with a few well-placed branches. All unwanted branches are removed once a month during the first year after planting, and once in two to three months in subsequent years. The bearing trees require little or no pruning. After the crop is picked, the branches touching the ground should be cut close total the laterals so that no stubs are formed. All diseased, injured and crossing branches, water-sprouts and dead wood should be removed periodically.

Root Exposure

In the Bombay-Deccan region, root exposure is given to the trees to bring them into flowering at a particular time of the year. Water is withheld for about two months in advance of the normal flowering season, and after about a month, the roots are exposed by removing about 10 cm of the soil in the case of light soils and about 20 cm in the case of heavy soils. After about 10 days, the soil is returned mixed with manure, and a light irrigation is given. After four or five days, a more copious watering is given, followed by 10 days later by the full dose of water. In the case of light soils, the withholding of water without root exposure is sufficient to check vegetative growth and force blossoming.

In southern India, no root exposure is given nor is it feasible. In the north, the root-exposure treatment is not necessary as the trees normally rest in winter and flower once a year. It should be mentioned that in most situations, the root exposure of citrus trees is a devitalising process and should be resorted to only under expert advice and direction.

Manuring

Manuring may be followed as in the case of the santra orange.

Irrigation

After the first heavy irrigation given soon after planting a second light watering follows in four to five days. Thereafter, irrigation is given at regular intervals, depending upon the source of water and the nature of the soil. Under well irrigation, water is given after every eight days in hot months and about 12 to 15 days in cold months. Where irrigation is from canals, the usual interval is about 14 days. A light soil requires irrigation more often than a heavy soil. Excess watering should be avoided, especially in heavy soils.

When the trees are young, irrigation water is applied in basins of about one-metre radius. The basins are enlarged as the trees advance in age. In the ring method of irrigation a bund is formed about three-fourths of a metre away from the trunk to prevent water from touching it. The furrow method ensures a more even distribution of moisture in the soil.

Harvesting

Trees begin to bear fruits from the fourth year onwards, but normal crops are borne from the seventh year. The main harvesting season in the north is December to February, whereas in the south, it is October to March. In the Bombay-Deccan region, there are two main seasons, November to January for ambe bahar, and March to May for mrig bahar

Picking may be done any time during the day, taking care that the stem is cut close to the fruit without damaging the rind. The fruits are washed, dried and graded for size and packed into wooden cases for disposal.

Grape

Grape (*Vitis vinifera* L.) is a subtropical fruit which grows well in dry climates having a short sharp winter and a long dry summer. The vines shed their leaves and rest in winter, put forth new growth in spring and mature in summer. Grape does not thrive in regions having humid summers. It tolerates frost during the resting period, but succumbs to it readily during its growing period.

Figure 4. Grapes in brach

In India, however, it grows under varying climatic conditions. In Punjab, Uttar Pradesh and Himachal Pradesh, it grows and fruits once a year in summer, and rests during winter. In southern India, where it is cultivation mainly in Maharashtra, Hyderabad-Deccan, parts of Karnataka and Tamil Nadu, the vine grows throughout the year and bears two crops, the first in April and the second in August-September. The grape grows best on light, friable loamy soils with free drainage. Heavy soils are unsuitable.

Varieties

Varieties suitable for different regions of the country are:

1. *Northern plains* : 'Black Prince', 'Bedana', 'Foster's seedling', 'Kandhari Dakh' and 'Muscat of Alexandria', 'Perlette'.
2. *Dry and temperate regions* : 'Thomson Seedless', 'Sultana' and 'Kishmish White'.
3. *Southern plains* : 'Bangalore Blue', 'Pachadraksha' and 'Anab-e-Shahi', 'Gulabi',.'Black Champa', 'Thompson Seedless'.
4. *Western plains* : 'Cheema Sahebi', 'Anab-e-Shahi', 'Thompson Seedless'.

Propagation and Planting

The vine is usually propagated by cuttings. In northern India, cuttings are made from one-year-old wood at the time of pruning in February, when the vines are dormant. The cuttings are tied in bundles and stored in moist sand for about a month for callusing.

The callused cuttings start well in the nursery. Elsewhere in India, they are obtained from the prunings in October and planted in nursery for rooting. The cuttings are ready for transplanting in January. It is also possible to raise a plantation by planting cuttings in situ in the field.

Planting

The rooted cuttings are transplanted in northern India in January and February when they are dormant. The planting-distance varies according to the method of training involved. It is 2.5m X 3.0m, if vines are trained on the head system and 6m X 6m, for the overhead pergola. In western India, it is 25m X 1m for the avenue system. in Karnataka, it is 4.5m X 6m and in Tamil Nadu 4.5m X 7.5m for the overhead arbour system.

Training and Pruning. The most popular systems of training are:

1. *Head system.* The vine is trained in the form of a dwarf bush. It is allowed to grow into an upright stem with the help of a support and the developing shoot is cut off at a height of 1 to 1.25 m in July. It is allowed to develop three to four lateral branches, each about 0.45 m long, arranged in the form of a vase or goblet. At the first dormant pruning in February, the lateral branches are shortened to spurs with one to two buds each. These spurs provide suitable arms for the framework during the succeeding summer. At the second dormant pruning, eight to ten arms, with one to two spurs on each arm, are retained for cropping in the third year. This system is cheap, but yields are poor. It is practiced in northern India on varieties which fruit on the first few buds of the cane.

2. *Cane system.* This system is suitable for training on a two-wire trellis. The trunk is headed back, as in the head system; four arms, two on each side of the trunk, are allowed to develop and are pruned to a 30-m length after a year. Fruit canes, each carrying 10 to 20 buds, develop on each arm which is tied to the trellis wire. A renewal spur is left on each arm just below the cane for the next year's crop.

3. *Cordon system.* After the vine has reached a height of 0.5 to 1 m, the stem is bent and is trained along the single-wire trellis. On each arm that develops from the trunk, short fruiting spurs, each carrying two to four buds, are allowed to remain at the time of pruning. The replacing spurs are also provided close to the base of the fruiting spurs.

4. *Pergola system.* In the pergola, arbour or bower system, the vine is allowed to develop into two or three branches, about 1 m from the ground. The branches are fastened to the horizontal wires of the pergola and allowed to grow and spread on the roof. The branches that grow on the arms are pruned each year according to the mode of bearing of the variety planted.

Pruning is usually done in northern India once a year in spring before the new growth starts. In Peninsular India, grapevine is pruned twice a year, once in summer and again in October, the exact period being decided by the distribution of rainfall. Sometimes, the girdling or ringing of a caneis carried out to hasten maturity and to improve the size and quality of berries.

Irrigation

The grapevine should be regularly irrigated. It is necessary to regulate the water-supply carefully both when the vine is in flower and when the bunches are ripening. Too wet a soil during those periods is not desirable.

Manuring

In addition to the farmyard manure (25 to 30 kg), a dose supplying 0.07 to 0.09 kg of N, 0.54 to 0.57 kg of P and 0.135 to 0.18 kg of K per vine at pruning is recommended. Green-manuring may be done whenever feasible.

Tips for Successful Grape-growing. (1) The cuttings for planting should be selected from one-year-old dormant wood from healthy bearing vines. (2) Pruning of the vines should be regulated to suit the bearing habit of each variety. The timing of pruning should be so regulated as to avoid the vines coming into blossom when the days are characterised by dewfall. (3) A portion of the berries at the tip of each bunch may be thinned to ensure more effective spraying against diseases.

Harvesting and Marketing

The fruit is ready for picking after the berries near the tip have changed colour and have become sweet. The picked fruit should not be exposed to the sun and, if it is to be sent to a distant market, it should be packed in sawdust. Yields vary largely, depending upon the variety, the locality and upon a host of other factors. Yields even up to 40,000 kg per hectare have been obtained, though 15,000 kg may be considered an average. A single vine at Coimbatore has been known to yield more than 800 bunches in a single season.

Guava

The total area under guava in the country is about 30,000 hectares, of which Uttar Pradesh has the largest area (9,840 hectares), followed closely by Bihar (4,800 hectares). It is a very hardy tree, withstanding heat and prolonged droughts, but is susceptible to frost. A cool winter induces heavy fruiting. It grows in all types of soils having pH ranging from 4.5 to 8.2. Its fruit is rich in vitamin C (35 to 100 mg per 100 g) content.

Figure 5. Guava

Varieties

'Lucknow-49', 'Allahabad Safeda' and 'Seedless' are white-fleshed varieties. Several types having pink flesh and white flesh with bright red skin are also known.

Propagation and Planting

Guava is propagated through seed, and also vegetatively. Inarching, layering and air-layering are commonly practiced. Propagation through root suckers, root cuttings and budding is sometimes successful. Propagation is generally done during the rainy season. The new plants are ready to be set out after a year. The usual distance for planting is 5.5 to 6 metres.

Culture

The growing of a green-manure crop during the rainy season, and clean cultivation during the rest of the year are recommended. One or two irrigations between the end of the monsoon and the harvesting (winter) are given in northern India. In southern India irrigation throughout the year is necessary. In addition to bulky organic manures, the use of 45 to 60 kg of N, 77.5 kg to 90 kg of P and 100 kg to 110 kg of K per hectare is recommended.

Pruning

Young trees require pruning several times a year to prevent the formation of long and slender branches. As the fruit is borne on new growth, heavy pruning of the bearing trees increases fruiting. All flowers should be removed until the framework becomes strong enough.

Harvesting

Fruits must be plucked as they ripen. Plucking extends over several weeks. For long-distance marketing, it is necessary to harvest the fruit somewhat earlier. Yields of 22,000 kg per hectare have been reported.

Papaya

Papaya occupies a very small area, yet its cultivation is widespread in the country. It grows well almost everywhere, except at altitudes higher than 1,500 metres. It cannot tolerate low temperatures. A dry warm climate is necessary. Strong winds are highly detrimental to the trees as the hollow stems break easily. Even though the tree is adapted to a wide range of soils, it grows best in the loamy soil. Deep clayey soils that are prone to water-logging should be avoided. In heavy-rainfall areas, a prolonged stagnation of water near its stem is highly injurious.

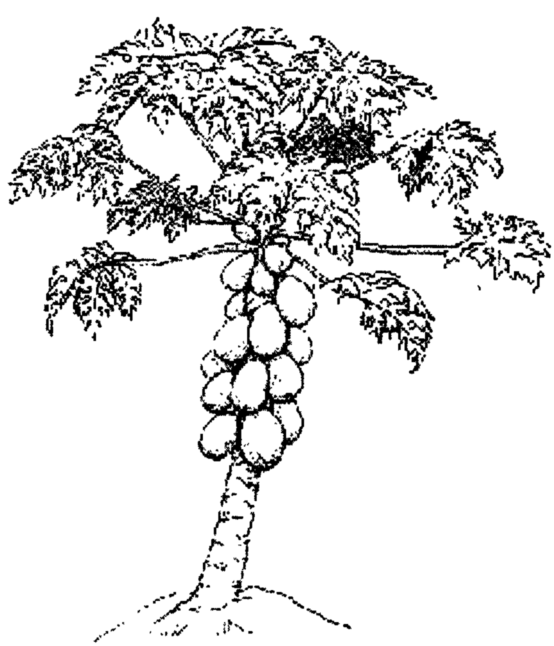

Figure 6. Papaya plant with fruits

Varieties

'Washington', 'Honey Dew' (Madhubindu), 'Coorg Honey Dew', 'Singapore' and

'Ceylon' are important varieties. C.O.I., an improved strain of the Ranchi type has been evolved at Coimbatore. The varieties do not remain pure under the existing state of cultivation and give rise to varieties, both in tree and fruit characteristics.

Sex Variation

The papaya plant is normally unisexual. Some plants bear male flowers and some female. Occasionally, a plant with hermaphrodite flowers may occur. The proportion of plants with male, female and hermaphrodite flowers varies with the variety. The proportion of fruit-bearing female plants of any variety varies from 40 to 60 per cent. The plants of 'Coorg Honey Dew' are either female or hermaphrodite and, hence, every plant yields fruits.

Propagation and Planting

Papaya is propagated through seeds. About 100 to 200 grammes of seed is required for an acre of plantation. Seeds obtained from mature large fruits, borne on female plants, are usually the best. The best time for raising seedlings is the monsoon period. The seedlings are ready for transplanting in four to six weeks, when they are 20 to 30 cm tall. They are lifted with a ball of earth around the roots; most of their leaves are clipped off, and they are planted in small holes made in the field 2.5 to 4 metres apart. Four seedlings may be planted in each hole about one-third metre apart from one another. After the plants have flowered, all male plants, except a few required for fertilising the female plants, are pulled out. One male tree for every 10 to 20 female trees is sufficient. Transplanting is best done in the monsoon. The practice of planting four seedlings in one hole is not required for varieties, e.g. 'Coorg Honey Dew', which do not produce any male plants.

Culture

Papaya plants are irrigated once in every 10 to 12 days in winter and six to eight days in summer. To avoid stagnation of water near the trunks, the basin may be made to slope away from it. Nine kg of farmyard manure per pit is applied at the time of planting, followed by 35 to 45 kg of it every six months, once at the beginning of the monsoon and again in winter. A fertiliser mixture to supply 25 to 50 kg of N, 50 to 100 kg of P and 50 to 100 kg of K per hectare may be given in two equal doses every six months. The removal of weeds and a light or shallow ploughing or harrowing once or twice a year are necessary. Low-growing vegetables of short duration may be taken as intercrops. An occasional thinning of fruits is necessary to prevent overcrowding. Papaya may itself be grown as a 'filler' or in plantation of other crops where spacing is wide enough.

Harvesting and Marketing

Papaya flowers in about four months after planting and fruits are ready for harvesting in another six months. Except during winter, the trees continue to flower and fruit all the time. Fruits are picked when they are still hard and green, but show a distinct change in the colour of the rind. Yield varies from 30 to 150 fruits per tree. The packing of fruits in baskets in several layers should be avoided. A soft padding, such as of wood-shavings, wool or straw is recommended.

Pineapple

Pineapple (*Ananas comusus* (L.) Merr.) occupies about 12,000 hectares and is grown mainly in Assam, West Bengal, Tripura, Uttar Pradesh, Andhra Pradesh, Kerala and Karnataka. It is a humid tropical plant and grows well, both in the plains and also at elevations not exceeding 900 metres. It tolerates neither very high temperatures nor frost. It grows in almost any type of soil, provided it is free-draining.

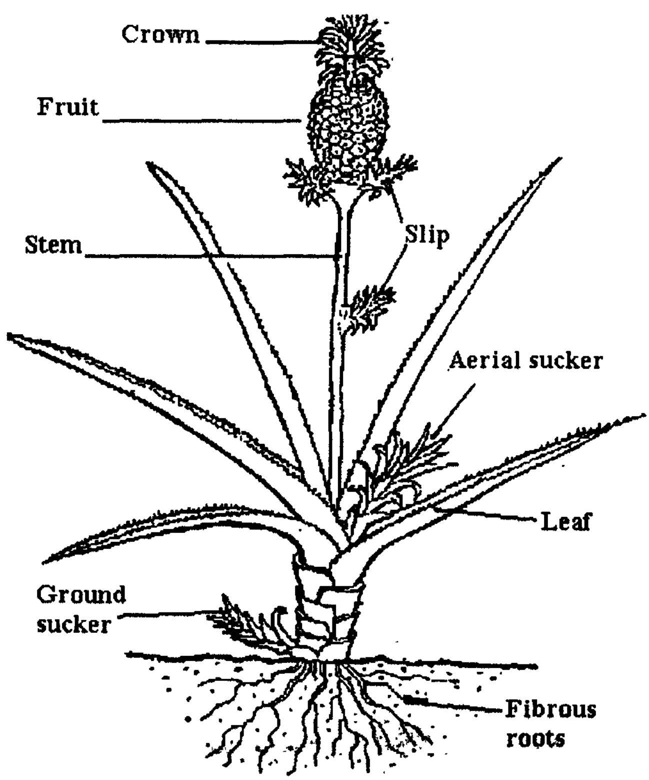

Figure 7. Pineapple plant with fruits

Varieties

'Kew', 'Queen' and 'Mauritius' are the three popular varieties. 'Kew' produces large fruits and is mostly used for canning. The other two have smaller fruits which are considered to be of superior quality. 'Kew' is a late-fruiting variety. 'Queen' is early, while 'Mauritius is intermediate.

Propagation and Planting

Pineapple is commonly propagated from suckers or slips. Suckers arising from the underground parts of the plant are commonly used. Slips arise from the fruiting stem and from the crown on top of the fruit. After the fruit is harvested, stalks are cut into discs and used for propagation. Plants grown from suckers produce fruits in about 18 months, whereas those from slips and suckers propagated from disc cuttings take over two years.

Suckers or slips are first cured by stripping off the lower leaves, followed by drying in the sun, or in partial shade for three to four days before planting. They are planted either in flat beds, where there is no danger of water stagnation, or in shallow trenches which are filled as the suckers grow and develop. Care should be taken to see that the bud or 'heart' of the suckers does not get buried. A planting density of 43,500 plants per hectare can be followed, keeping a distance of 30 cm between plant and plant, 60 cm between rows and 90 cm between beds. The rainy season is the best time for planting.

Culture

The field is prepared by ploughing, harrowing, etc., before planting. In the hills, proper terracing is a necessity. In dry regions, the crop requires regular irrigation. Even when rain-fed, irrigation during the dry weather is necessary every week or ten days. Twenty-five to 50 tonnes of farmyard manure per hectare is applied in two doses in the 6th and 12th month after planting. Sixteen grammes of N and 2.5 g of K_2O per plant should be applied. Of these, part of the nitrogen can be applied as foliar application as 4% urea. Only two suckers are retained on each plant for the ratoon crop. After harvest, the plants are earthed up to stimulate the rooting of the ratoon suckers.

Harvesting and Marketing

Pineapple usually flowers from February to April and the fruits are ready from July to September. Sometimes, off-season flowers appear, and they produce fruits in September-December. The fruits are harvested when they just begin to yellow and the eyes become full and the bracts wither. The fruit is cut clean, retaining with it about 5 cm of the stalk. The yield is 12 to 17 tonnes per hectare in the case of the two smaller varieties and 25 to 30 tonnes per hectare in the case of 'Kew' in the first year. With a high population density, even about 85 tonnes of fruit can be obtained. Fruiting decreased progressively in the case of the ratoon crops. For transport, the fruits are wrapped up in straw and packed in bamboo baskets or crates in one or two layers.

Sapota

Sapota (*Achras zapota* L.) known popularly as chiku in western and central India, is adaptable to a large variety of conditions of soil and climate. It flourishes in the heavy-rainfall areas of western and southern India and grows equally well in the drier parts of the Peninsular India. It is an evergreen, growing and flowering almost throughout the year. Rain or cloudy weather does not harm the setting of fruits. Young plants are easily injured by frost, but grown-up trees can withstand frost of a short duration. Its soil requirements are not very exacting, but it grows best in alluvial or sandy-loam soilshaving good drainage.

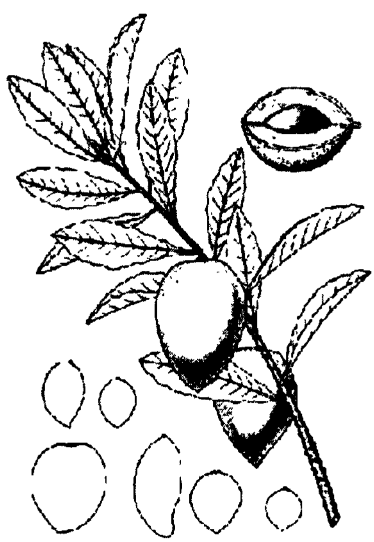

Figure 8. Branch of supota with fruit

Varieties

'Cricket Ball' and 'Dwaropudi', both with round fruits, are common in Tamil Nadu, whereas 'Bangalora', 'Vavila Valasa' (both oval-fruited), 'Jonnavalasa' (round-fruited), 'Kirtabarati' and 'Pot' (dwarf trees) are recognised in Andhra Pradesh. In western India, 'Kalipatti' and 'Chatri' (both oval-fruited) are well-known varieties. The variety 'Cricket Ball' does very well in Karnataka.

Propagation and Planting

Propagated by layering, gootees (air-layering) or inarching. Side-grafting and budding are also possible. Rootstocks employed are rayan or manikara (Manilkara hexandra) or mohwa (Bassia latifolia and B. longifolia). The second and third species are not recommended, as they are not compatible with the sapota scions. In northern India, the planting-distance is 4.5 to 6 metres, whereas in the south, it is 9 to 12 metres. In northern India, the young plant must be suitably protected against frost and hot winds after planting.

Culture

Before planting, the field is ploughed, harrowed and levelled. Irrigation is given every six to twelve days, except during the rainy season. The removal of weeds and the loosening of the soil by ploughing or harrowing are done once or twice a year. Manures and fertilisers are applied, as recommended for mango. For the bearing trees, half of the dose is applied in October-November and the other half in February-March or before the monsoon. Intercrops of vegetables may be taken for the first six to ten years. No pruning is necessary.

Harvesting and Marketing

Substantial fruiting starts from the fourth or fifth year. The fruit takes four months to mature. Flowers appear throughout the year, but the crop is available for harvesting in two to three seasons, i.e. northern and central India, March-April and August-September; in southern India, February-June and September-October and in western India, January-February and May-June. The yield varies from 200 to 300 fruits in the fourth year, from 700 to 800 in the seventh year, from 1,500 to 2,000 between the tenth and 15th year, and from 2,500 to 3,000 from the 20th to 30th year. Mature fruits show a yellow streak, whereas the immature fruits show a green streak when scratched with the fingernail.

For distant markets, the fruits are packed in bamboo baskets immediately after picking, using straw as padding. Oval and round fruits may be separately packed.

Pomegranate

The largest area under pomegranate (*Punica granatum* L.) about 500 hectares, is in Maharashtra, but there are small plantings in almost all parts. Where winters are cold, the tree is deciduous, but in the plains, it is evergreen. A hot, dry summer produces the best fruits. The presence of many seeds and of tannin in the rind and membranes detracts from its attractiveness. The tree can stand considerable drought.

Figure 9. Pomegranate

Climate

Pomegranate is sub-tropical fruit. It can adopt itself to a wide range of climatic conditions and can grow up to 1800 m above sea level. The fruit tree grows best in semi-arid climate where cool winter and hot and dry summer prevail. The tree requires hot and dry climate during the peroid of fruit development and ripening. The optimum temperature for fruit development is 38°C. The tree can not produce sweet fruits unless the temperature is high for a sufficient long period. Under tropical and sub-tropical climate, it behaves as an evergreen or partially deciduous. Under humid conditions, the sweetness of fruit is adversely affected. Therefore, it is considered that pomegranate is a hardy fruit and can thrive well under drought conditions, though yield is low. The plant bear well only under irrigation.

In areas of low temperature, the tree behaves as deciduous in nature and sheds its leaves during winter months. It is also rated as winter hardy fruit tree. Two years old shoots of hardy cultivers are not damaged even at 20C. When temperature falls below -140C, visible damage due to frost occurs. Aridity and frequent anomalies of the climate cause leaf shedding and fruit cracking.

Soils

It can be grown on diverse types of soil. The pomegranate is not very particular about its soil requirement. The deep loamy and alluvial soils are ideal for its cultivation. It can tolerate soils which are lomay and slightly alkaline. It can thrive well on comparatively poor soils where other fruits fail to grow. Pomegranate can also be grown in medium and black soils. It is rated as salt-hardy fruit plant.

Propagation

Pomegranate plants raised from seed vary widely and are undesirable. Thus, they must be raised vegetatively. Among the vegetative methods of propagation, cuttings are universally used for raising pomegranate plants on commercial basis.

Mature wood is used for making the cuttings and these are 8 to 10 cm long. The cuttings are planted in the nursery fields in such a way that not more than one-third of the cutting is exposed. The best time of making the cuttings is December-January when the plants shed leaves. The cuttings made during September-October can also root satisfactorily. The cuttings in the nursery field are planted directly after making them from the plants. They need not to be kept for callusing.

Pomegranate may also be propagated by air-layering or gootee. Treatment with 10000 ppm Indole Butyric acid in lanolin as carrier was found to improve rooting. Ground layering is another method used for multiplying the pomegranate plants.

Planting Operation

Land is prepared thoroughly and levelled prior to pit digging. The layout is done following square or hexagonal system. The size of the pit should be 60 × 60 × 60 cm. Pits should be filled with 22-25 kg of farmyard manure or compost, 1kg of superphosphate and good soil mixture.

The plants are planted at a distance of 6m × 6m apart in square system and it will accommodate 275 plants per hectare. In higher but deeper soil, the planting distance can be reduced to 5 × 5 m.

Planting density is the most important yield contributing factor which can be manipulated to attain the maximum production per unit area. The optimum spacing is important for the maximum utilisation of land and good income over a long period. At MPAU, Rahuri, it was observed that as the plant density was increased, yield per hectare also increased without affecting fruit quality. A density of 1000 plants per hectare gave 2-3 times higher yield and 2.44 times more profit as compared with normal plant population of 400 per hectare. It was also recommended that for higher yields for the first four to five years after planting, a distance of 5 × 2 m may be adopted and alternate plants may be removed afterwards maintaining a planting distance of 5 × 4 m. The best time of planting pomegranate in Northen India is dormant period, i.e. January to mid February and in South India during monsoon season.

Flowering and Fruiting

In evergreen pomegranate cultivers, the flower buds of the spring flush are borne on nature wood of one-year old shoot, whereas the flowers which appears during July-August are borne on the current year's growth. In deciduous cultivers, the flowers are borne on the current year's growth between July and August. The flowers are found mostly in clusters, either terminally or in axils of the leaves. The inflorescence in cyme and due to heavy drops of secondary and tertiary buds they appear to be solitary in clusters.

In Western India, three flowering seasons and in North India, two flowering seasons have been reported. The flowering period of different cultivers is also quite variable. Under Delhi condition, Dholka, Kandhari, Muskat and Patiala flowered only once in a year while Ganesh and Japanese Dwarf flowered twice.

Irrigation

The newly set plants require regular irrigation so that the roots become well established and the plants can start growth. The plants may be individually watered daily or about a week after planting. In northern India where planting is done during the spring, regular watering may be given every 7 to 20 days till the start of the monsoon. In areas where planting is done during the monsoon, irrigation may be given whenever there is no rain for a prolonged period of time. After the plants are well established, in about 6 months, they can stand considerable amount of drought and irrigation may be given at intervals of 2 to 4 weeks depending upon the soil, climate, weather conditions and intercrops grown. Regular irrigation is essential from flowering to ripening of fruits, as irregular moisture condition results in dropping of flowers and small fruits.

Intercropping

Intercropping is pomegranate orchard is highly desirable because it takes about 6-7 years to come to commercial bearing. Vegetables viz. cabbage, cauliflower, tomato, radish, cucurbits, moong, peas, beans or green manure crops can easily be followed in pomegranate orchard. The growing of intercrops should be carried out for the first four years of the life of the plantation. It is usually advisable to allow the intercrops to grow throughtout the year. Intercrops can be continued for another 3 to 4 years after the plants had started bearing. It is best to grow a green manure crop during the monsoon and burry, when it has completed its vegetative phase and started flowering.

Manuring and Fertilisation

In northern India, manures are applied during February, whereas in other areas, manuring may be done just before the start of monsoon in case of young plants. The one year old tree should be manured with about 10 kg of farmyard manure and 150 to 200 g of ammonium sulphate. The amount is increased by the same amount every year so that a five year old tree gets 50 kg of farmyard manure and one kg of ammonium sulphate.

CONSUMPTION AND OTHER USES

The main method of consumption of most tropical and subtropical fruits is as fresh fruit. The breadfruit is the most important exception, as it is only eaten cooked. Nuts can be eaten directly or processed (roasted, candied, and so forth). Salads, both savory and sweet types, are prepared with many fruits. Indeed consumption is virtually as unlimited as the chef's imagination. Jams, jellies, juices (made with fresh fruits, concentrates, or frozen pulp), sauces, ice cream and sherbets, and other desserts and diverse confectionaries are typical of the uses to which tropical and subtropical fruits are put, both industrially and domestically. Infusions as social beverages, not as medicinal remedies, are made from many different fruits.

A specific product is baby food, especially made with "healthy" fruits like the banana or the papaya, based on different kinds of puree (industrially known as aseptic, chilled aseptic, or simply chilled purees). Flour is also made from the durian and the banana. Pickles and chutneys are made from many fruits, the most famous of which is mango chutney, a staple in Indian cuisine and highly esteemed by gourmets. Dips are also popular in many countries, of which perhaps the best known is avocado-based guacamole. Guava paste or spread is consumed, usually with bread and cheese, in many countries, particularly Cuba, Brazil, and the Canary Islands.

Besides their edible and pleasant fruits, the actual plants of several tropical and subtropical fruit crops are also put to good use. Descriptions of the many properties of parts other than fruits—wood, leaves, flowers, roots, seeds—are frequently dealt with in older texts , but a clear dearth of in-depth studies on many of these aspects is apparent. The potential of leaves or flower extracts as biological products for use against pests and diseases is in much the same situation and is an issue relevant to organic produce, of increasing importance to concerned consumers.

TRADE OF TROPICAL AND SUB-TROPICAL FRUITS

In addition to citrus and the banana, four other tropical and subtropical fruits, pineapple, mango, avocado, and papaya, dominate the fresh fruit export trade. Pineapple clearly leads the ranking in processed fruits with a wide range of products, although juice and rings in syrup are the best known. Many other tropical and subtropical fruits are no longer exotic products in world markets, having become firmly established with guaranteed supply and reasonable prices. Carambola, guava, litchi, mangosteen, passion fruit, and rambutan have experienced notable development. The main importers of most of these tropical and subtropical fruits are the European Union, the United States, Japan, Canada, and China.

Exports of fresh fruits are mainly by ship or surface transport. Postharvest techniques for extending the shelf life of most tropical and subtropical fruits have been mastered, and refrigerated boats (some even providing controlled atmosphere installations) move these commodities from production countries to their ultimate markets with ease. A small proportion of the major fruits, particularly pineapple, mango, and papaya, are transported by air, either destined specially for gourmet or niche markets or for celebrations at certain times of the year, such as Christmas and New Year's, when they command higher prices. Some of the minor crops, still considered exotics, like the mangosteen and the rambutan, have a more difficult postharvest life and therefore are exported by air.

Many countries from virtually all the continents have designated specific areas for production of fruits destined purely for export. Those countries include India, Malaysia, Thailand, and China in Asia; the Philippines and Australia in Oceania; South Africa and Ivory Coast in Africa; Mexico, Brazil, the United States, Peru, Costa Rica, and Chile in North and South America; Spain in Europe; and Israel.

While banana, pineapple, and citrus have a long history of international trade, the avocado trade burst upon the scene in the 1970s. The mango did not become a well-known fruit (from a consumption point of view) until the 1990s, with Mexico as the leading exporter. The papaya and the litchi may still revolutionise trade.Of particular relevance for the development of tropical and subtropical fruit trade is the World Trade Organisation (WTO) agreement in Marrakech on 15 April 1994 following the conclusion of the Uruguayan round of General Agreement on Tariffs and Trade (GATT) talks. Basically these agreements established the principle of free trade not exposed to arbitrary market entrance taxes, and obligate signatory countries (in practice most of the world) to use only sanitary and phytosanitary quarantine measures based on solid scientific information, thus effectively halting the use of these measures as a loophole to arbitrarily restrict imports.

As in other commodities, an interesting market is developing for organically produced tropical and subtropical fruits, and organic pineapples and bananas are available in Western markets.

Many organisations and horticultural societies at national and international levels are dedicated to particular tropical or subtropical fruits (or a closely related group). Their members include amateurs, growers, researchers and academics, handlers, traders, and consumers. By reason of both magnitude and global concern, some of these merit special mention.

The International Society of Horticultural Science (ISHS), headquartered in Louvain, Belgium, has established a Commission of Tropical and Subtropical Horticulture with working groups in specific tropical and subtropical fruits. The ISHS meets regularly in different countries to discuss aspects of production, research, and trade of these fruits, and it holds an international congress every four years, which congregates a minimum of four thousand people.

The Interamerican Society of Tropical Horticulture was formerly known as the Tropical Region of the American Society of Horticultural Science. It holds annual meetings in different American countries with tropical crops to discuss the same issues mentioned above but including vegetables and ornamental plants.

The Intergovernmental Group on Bananas and on Tropical Fruits, under the auspices of the Food and Agriculture Organisation of the United Nations (FAO), meets every two years to discuss issues related to marketing and trade.

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5

Fruit Crops of Arid and Semi-arid Zones

Arid and semi-arid or subhumid zones are characterised by low erratic rainfall of up to 700mm per annum, periodic droughts and different associations of vegetative cover and soils. Interannual rainfall varies from 50-100% in the arid zones of the world with averages of up to 350 mm. In the semi-arid zones, interannual rainfall varies from 20-50% with averages of up to 700 mm. Regarding livelihoods systems, in general, light pastoral use is possible in arid areas and rainfed agriculture is usually not possible. In the semi-arid areas agricultural harvests are likely to be irregular, although grazing is satisfactory.

These zones exhibit ecological constraints which set limits to nomadic pastoralism and settled agriculture. These constraints include:

- rainfall patterns that are inherently erratic;
- rains which fall mostly as heavy showers and are lost to run-off;
- a high rate of potential evapotranspiration further reducing yields;
- weeds growing more vigorously than cultivated crops and competing for scarce reserves of moisture;
- low organic matter levels, except for short periods after harvesting or manure applications; and
- highly variable responses to fertiliser.

Indigenous peoples of these areas have lived within these constraints for centuries. They have existed on the productivity provided locally and have used their knowledge to devise coping and adaptive strategies.

In this chapter we will discuss about some of the important fruit crops grown in arid and semi-arid areas of India.

DATE-PALM

Some of the imported varieties of date-palm have been cultivated successfully in Punjab. This tree thrives in light as well as in heavy soils, provided the depth is adequate (2.5 to 3 metres) and the drainage is good. The plant is not affected by frost and requires intense heat in summer for the development and ripening of the fruits. The maxim 'head in fire and feet in water' indicates the conditions that are ideal for date-cultivation. If the water-table is within 3 to 3.5 metres from the surface, mature trees need no surface irrigation. A wet season during flowering and fruit-ripening is limiting factor in the successful cultivation of the date-palm. South-western Punjab, northern Rajasthan and Kutch offer suitable conditions for date growing.

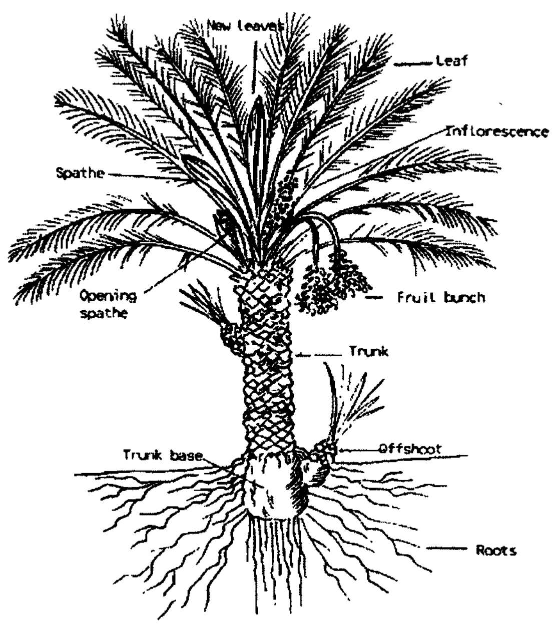


Figure 1. Date-palm

Climate

The date palm is a tree flourishes well under varied sets of climate. However, for proper maturity of fruit, the date requires prolonged summer heat without rain or high humidity during the ripening period. A light shower with prolonged periods of cloudy weather and high humidity may cause more damage than a heavy rain followed by clear weather and drying winds. The mean temperature between the period of flowering and ripening of the fruit should be above 21^0 C rising to 27^0 C or higher for at least one month. For successful fruit maturation, nearly 3000 heat units are required. The heat units available in most of the north-western districts of India, counted from the time of flowering, i. e. end February to July, indicate that these are suitable for date palm cultivation. Taking this into consideration, parts of Rajasthan extending from Sri Ganganagar to Anupgarh, Jaisalmer and Barmer and Kutch district of Gujarat will be suitable for date cultivation. The climate of Abohar (Panjab) should be considered marginal because of rainfall (30 cm) and high humidity at the time of ripening (July-August) being the limiting factor.

Soil

The date palm can be grown in soils containing more alkali or salts. It can tolerate such condition better than many other fruit plants. In view of the large investment required to bring a date garden into bearing and maintain it on profitable production, sandy loam soil, 2 or 3 metres deep with good water holding capacity and drainage is most desirable. Date palm can tolerate high soil salinity. In the soil having 4 per cent salt concentrataion, dates can survive well provided the root system does not come in contact with a stratum of soil where the sodicity is more than 1 per cent.

Varieties

Hillawi: It is soft date from Iraq. This variety is relished both in doka and dang stages. Total soluble solids range between 28 to 42% and astringency in the fruit at doka stage is low or almost absent. It is an early variety yielding good crops and is somewhat more tolerant to rains. Dry dates (Chhuhara) of good quality and cured soft dates (Khajoor) can be prepared. Its fruit at dang stage (fresh form) is very delicious. Average yield ranges from 50 to 80 kg per palm.

Khadrawi: It also originated from Iraq. This variety proved successful under Abohar conditions. The trees of this variety are comparatively less tall and and yield good crops. It can be used both for dry dates and soft dates. The yield ranges from 40 to 70 kg per palm.

Shamran: It is a mid-season cultiver tolerant to high humidity. The variety yielding prolific crops. The fruits can be cured into good quality. Chhuhara and also softened with salt treatment. Fruit is medium to large, oblong to oblong-oval and yellow at doka stage. Its yield per palm is 40 to 70 kg.

Medjool: The variety originated in Morocco and has large size fruits. It is late in ripening and has proved particularlt good in preparing dry dates of attractive bold size and good quality. Its yiled is 35 to 50 kg per palm.

Barhee: It is soft date from Iraq. The variety has proved extremly good for table use in fresh form (doka stage). The doka fruit contains about 32% TSS, has golden yellow colour and has a very pleasant taste because of low astringency and high pulp content. The trees of this variety are prolific in yields and the fruit is ready for eating late in the season i.e. first fortnight of August at Abohar. Its yield ranges from 60 to 110 kg per palm.

Hayany: It is soft date originated from the UAR. The berries have attractive deep colour. The fruits could be consumed as fresh in the doka stage as ripening does not proceed further under Abohar conditions. The yield per palm ranges from 30-40 kg.

Zaidi: It is a mid season variety, slightly tolerant to rain or high humidity. The fruit is small to medium, obovate and yellow at doka stage.

Propagation Techniques

The date palm are always propagated throughsuckers (offshoots) for commercial plantation. The suckers usually arise near the ground around the trunk. The offshoots arising at a higher level from the ground on tree trunk and with no roots give very poor survival. These are separated from the mother palms during March or August-September. The leaves are trimmed off 4-5 days before their detachment.

The inner leaves should be cut back by one-half and the outer ones by two-thirds. The tender young unopened leaves near the central bud and parts of the bare stalks of the old leaves necessary to protect the bud, should be kept on the offshoots. The outer whirl of leaves may be fastened to afford protection from heat and cold to the central bud also facilitate detachment and transport. The suckers weighing approximately 25 to 30 kg and well rooted should be removed. Expose the point of detachment and set a chisel sharpened at the face and welded to a 150 cm long handle of 4 cm diameter. Drive in the chisel by hammering at the other end. It is very important that no injury is caused to the mother palm. Cut surface should by coated with tarcol or some suitable material immediately and earthed up.

Planting Operation

The offshoots are planted 6 to 7 metres apart in the already prepared pits of 1 × 1 × 1 m size immediately after detachment. In this way 202 to 275 plants/hectare will be accomodated. If transported from long distance, the offshoots may be kept in the straight. The soil around the offshoots should be pressed firmly. The field is irrigated immediately after planting. Thereafter, frequent light irrigations are given to keep the soil always moist. At Abohar, the offshoots removed in March survived better in direct field planting than those removed in August-September. However, the separation could be done both in February-March and August-September.

Orchard Cultural Practices

Irrigation

Date palm is known as drought resistant fruit tree and is able to survive for long periods without irrigation. However, continuous drought condition retards the growth of the plant. If water is available, date palm uses it lavishly. Date palm is highly tolerant to excessive irrigation and floods. Continuous stagnation of water or waterlogged conditions are injurious for its growth. To maintain maximum growth, the root zone up to 2-3 m should be kept moist and not allowed to dry. Light but frequent irrigation should be given after planting. The full grown trees on the lighter soils are usually irrigated 7 to 10 days during mid-summer and every 15 to 30 days during winter. Such soils requires 2.75 to 3.75 acre-meters of water per year and 30 to 45 acre-centimeter per month is needed during summer. On heavy soils, half the amount may be enough. Each irrigation of 10-15 acre-centimeters is usually sufficient. Irrigation is withheld when ripening starts to facilitate harvesting, hasten fruit ripening and to reduce fruit drop caused by high humidity.

Manuring and Fertilisation

Generally the farmers do not apply manure to the date palm. The trees certainly respond to manuring as indicated by increased vigour and growth. The results of studies conducted at Abohar shows that 25 to 50 kg of farmyard manure and 1 to 2 kg ammonium sulphate per palm should be added. The quantities may be reduced if some leguminous crop has been grown in the date palm. Farmyard manure is applied during December-January. The nitrogen dose should be given a fortnight before flowering i.e.in the first week of February.

Intercropping

Intercropping in date palm with suitable crops bring good income and also improves the fertility of the soil. During the first few years, intercropping can be practised with no shortage of irrigation. Intercrops such as gram, peas, mash, moong, moth, senji and lentil can be sown during summer. Intercropping of some vegetables in plantation located near the cities, can be practised if sufficient irrigation and manuring facilities are available. The filler trees like grapes can be tried with good success.

Fruit Thinning

Excess load of fruit may cause shrivelling of berries, breaking of spathe stalks, more damage due to rain and humidity, delay in ripening and alternate bearing. It also reduced size and produce poor quality of fruit. It is, therefore necessary to keep only optimum quantity of fruit and thin out the rest. This is usually accomplished either by reducing the number of fruits on each bunch and or by removing some of the bunches. The number of fruit that a palm can safely carry depends on the cultivar, age, size and vigour of the palm and number of green leaves on it.

Under normal conditions, 1-2 bunches in the 4th year and 3-4 bunches in the 5th year may be left. Normally 8-10 bunches per palm are retained in India. Small, defective and broken bunches should be removed. In short-stranded varieties like Khadrawi, the strands are generally cut back to even up the bunch from the top. Most of the fruit thinning is done by the removal of half to two-third of strands from the centre. In the long stranded varieties like Deglet Noor, one-third to half strands are cut in similar way as in Khadrawi, in addition, strands are also cut back to remove about one-third of the flowers.

The desirable number of fruits to be left is between 1300 and 1600 per palm depending on the variety. The per cent thinning is generally done 40-50 in Khadrawi, 50-55 in Hallawi, 50-60 in Zaidi and Barhee. Ethephon 100-400 ppm after 10 to 30 days from fruit set was found effective in fruit thinning of cv. Hayany. The biennial bearing habit of the treated palms were found to reduce by ethephon treatment. It also advances the ripening of fruit.

Harvesting and Processing

Harvesting of dates generally depends upon the weather conditions. The rain and high humidity in the atmosphere at the ripening time is a limiting factor in its cultivation. When the climate is favourable, it is preferable to leave the fruit of most varieties on the palm until it reaches the stage of maturity at which it is to be consumed or stored. The changes associated with ripening and the period during which the fruit may be consumed extend from the peak of the khalal stage, when the fruit has its most intense red or yellow colour and maximum weight, to the final tamar stage, when it has lost the greater part of its moisture content and will keep without special attention to storage.

Most of the people like to eat the fruit in khalal stage. At least two varieties of dates Hillawi and Barhee, are liked most for eating in khalal stage. Dates are hand-picked at the stage of maturity. All the dates in the same bunch do not ripen at same time, it has been the practice to make several pickings to harvest the fruit during a season. Sometimes, when the season is favourable and more than 70 per cent fruit is ripe, the entire bunch is harvested. The research conducted on curing of dates in Panjab (Abohar) have revealed that the rain and high humidity in the atmosphere at the time of ripening (July and August) do not allow the ripening process on the tree to proceed satisfactorily beyond doka stage. If the fruit is retained on the tree, there is checking, splitting and rotting. High humidity and rainfall also cause the fruit to drop. Therefore, the crop has to be harvested at doka stage. Though in comparatively drier seasons partial crop on some trees may become dang (mellow and soft) but the quantity of such fruit is limited. The berries are removed and graded manually on the basis of size and colour.

Scientists working at Abohar (Panjab) have developed a technique to transform satisfactorily the date fruit at doka stage into dry dates (Chhuhara) of good quality. At least four varieties Hillawi, Khadrawi, Shamran and Medjool have yielded very good product. Chhuhara obtained from Medjool, which is a large-sized variety, compare very well with the high quality Chhuhara imported from Middle East countries.

The technique developed involves immersion of frut at doka stage in boiling water for 6 to 8 minutes and then drying either in temperature-controlled oven (air-circulation type) for 80 to 120 hours at 48^0 to 50^0 C or in the sun for 10-15 days if weather is dry. Thus, an average of 45 per cent fruit product is obtained. Fruits at advanced doka stage or when they attain one-fourth, one-half or full dang (the berries become mellow and soft starting from the distal end) can be converted into soft dates (khazoor) of good quality by drying either in the oven at 40^0 C or in the sun. Thus, for soft dates, only drying the berries at partial or full dang stage is required with no other treatment and this way a final product of soft Khazoor ranging from 50-60 per cent is obtained.

Hillawi and Barhee yielded 50-100 kg fruit per palm at doka stage. The average yield from Khadrawi and Shamran is obtained 40-70 kg fruit per palm. The yield from Medjool palm is upto 50 kg but its fruits are very large in size.

Artificial ripening of fruit at doka stage to transform it into dang stage was also attempted at Abohar. For these studies, berries were treated with 0.5 per cent to 2.0 per cent common salt (sodium chloride) and similar concentrations of acetic acid in combination with 1.0 per cent salt. The fruits to be treated with salt were spread on polythene sheet and requisite quantity of salt was applied by rubbing and smearing uniformly on the berries.

The fruits which were given acetic acid plus salt treatments, were first dipped in solutions of desired acetic acid concentrations for 2 minutes followed salt application by the method described above. Each treated lot was packed into wooden boxes lined with old newpapers and packed in laboratory at room temperature. The boxes were opened after 24 hours. From these studies, it was found that 2 per cent salt, 60 to 70 per cent of the doka fruit were transformed into dang. However, the dang obtained by this treatment was not as good in taste as that of naturally ripened on the tree, but still it was edible and generally acceptable on account of its having lost the astringency. But such products cannot be stored more than 24 hours and, as such, should be consumed to as early as possible.

Insect-pests

The most important pests of dates are follows:

(i) *Date Stone bettle (Coceotrypes dactyliperda F.):* It attacks unripe fruits and the adult penetrates the fruit and reaches the stone by constructing a direct circular hole through the pulp and both adults and grubs feed inisde on the pulp and results in the drop of unripe fruit. Hillawi and Khadrawi, which ripen early, are more suscepitble to this pest. Spraying the plants with 0.075% per cent Malathion has proved effective for its control.

(ii) *Nitiduled bettle (Haptoncus luteolus Ev):* The larve penetrate the fruit and eat the inner portion of the pulp. Their attack is followed by fungal decay. The adult is brownish yellow, oval, slightly oblong, 2.3 + or-0.13 mm long and 1.16 + or-o.21 mm broad. Initially, the dropped fruits are attacked. Then the peat spread to fruit bunches on the tree and cause the fruit to drop. The pest over winters as pupae in the soil. Spraying wiht Malathion (0.075 per cent) gave satisfactory results. Regular removal of dropped fruits and their destruction also helps in minimising the effect.

(iii) *Cigar hoeing bettle (Lasioderma testaceum Duft):* It is reported as pests of stored dates in India. For the control of these pests, fumigate the dates and keeping material with Methyl bromide at a dose of 1/2 kg/27 cubic meter giving an exposure of 24 hours.

(iv) *Termites:* They feed on the roots of the newly transplanted suckers which may ultimately cause them to wither and die. As a preventive measure, 10 per cent BHC mixed in each pit @ 30 g before planting is recommended.

Diseases

Much less work has been done for the investigation of diseases of date palm in India. Studies conducted at Regional Fruit Research Station, Abohar, have found two diseases.

(i) *Graphiola leaf spot (Graphiola phoneicis):* It is also called as false smut or palm leaf pustule. It is a serious disease. This disease is more acute in the areas where humidity is more. Numerous hard black smut like pustules are seen scattered developing epidermily on the upper and lower surfaces of leaflets and also on rachis. The pustules at maturity consists of round, hard, black cups about 0.50 * 0.25 mm. These cups contain yellow spores. Older leaves are more affected, they loose their chlorophyll and dry up. For its control, remove and burn the affected leaves to check further contamination and spray the trees with 2: 2: 250 Bordeaux mixture (2 kg copper sulphate + 2 kg unslaked lime mixed in 250 litres of water.)

(ii) *Fruit rot:* It often causes considerable loss when humid weather occurs during the ripening season. Under such conditions, various fungus may develop in the fruit and cause spotting, dropping and rotting. The damage may be reduced by better ventilations of the branches and protecting the fruit from rain. In addition, spray the bunches with a mixture of 5 per cent fahana (ferlic dimethyl dithiocarbamate) in sulpher.

PHALSA

Phalsa is a small bush which grows all over the country except at higher elevations. In Punjab, Haryana, Uttar Pradesh and Andhra Pradesh, it is grown commercially. The fruit is berry-like, globular, smooth, deep reddish brown and comes in the market in May and June.

Figure 2. A branch of Phalsa

Climate

Phalsa relish distinct winter and summer for best growth, yield and quality. In regions having no winter, the plant does not shed leaves and produce flower more than once, thus yielded poor quality fruits. Full grown plants can tolerate freezing temperature for a short period. The plants can tolerate temperature as high as 44^{0}C. High temperature during fruit development favours ripening of fruits. At flowering time, clear weather is needed, whereas rains at that time affect fruit-setting adversely. The phalsa is one of the hardiest fruit plants and can be grown successfully throughtout Punjab and Haryana. Being deciduous in habit, it can withstand frost quite well. However, care should be taken to select sites which are not subject to very low temperatures during winter. It can also grow successfully in hot and dry climatic conditions, such as those prevailing in the districts of Ferozepur, Bhatinda and Sangrur of Punjab. It can withstand occassional drought and water shortages better than fruit plants. However, for raising profitable crop of phalsa, satisfactory arrangements for irrigation need to be made.

Soil

The phalsa is not at all fastidious in its soil requirements and can grow quite successfully in almost every kind of soil. Around Amritsar (Punjab), where the soils are comparatively heavy, its plants grow well and bear bumper crops. At many other places such as Ludhiana, it yields well under lighter soil conditions. Though the ideal soil for growing phalsa is the rich loamy type. Under water logged conditions plants become chlorotic and make poor growth.

Proper soil drainage is another factor which should be kept in mind. However, soils where water stagnates for many days during the rainy season or those which have a poor sub-surface drainage and are water-logged should not be selected for commercial cultivation of phalsa.

Choice of Varieties

In phalsa, no distinct cultivar is identified. Some growers have, however, given names as Local and Sharbati. Two distinct types i.e. Tall and Dwarf were recognised at Hissar. Dwarf type was found to be more productive.

1. *Tall type:* Plant height is 4.5 m, leaf size 20 × 18 cm. Leaves are light green in colour. Average fruit size is 2.07 cm and weighing 0.48 g. Average yield per bush is 5.2 kg. Pulp is 81.5 per cent, juice 5.4 per cent. TSS 14 per cent and Acidity 4.64 per cent.
2. *Dwarf type:* Plant height is 3.4 m, leaf size 18 × 15 cm. Leaves greenish white in colour. Fruit size is 2.26 cm, weight 0.54 g. Average yield is 3.5 kg per bush. Pulp 60.3 per cent, juice recovery is 34.6 per cent. TSS 12.1 per cent with acidity 3.63 per cent.

Propagation

Raising of seedlings: For raising the phalsa seedlings, large sized, purple black coloured fruits are collected when the crop is ready in the end of May or beginning of June. After extracting from the fruits, the seeds should be washed and dried under shade. These seeds are sown in raised beds when there is sufficient humidity in the atmosphere. Rainy season (July-August) is the best time for sowing of seed.

The seeds on raised beds are sown in lines which are 10-15 cm apart from each other. In the rows, the seed should be sown 4-5 cm apart and 1.5 to 2 cm deep. The seeds should be covered with sand or light soil mixed with well rotten and dry farmyard manure. The beds should be watered regularly with water, but too much watering should be avoided as the excessive moisture conditions cause poor development of the plants. The beds should be kept free from weeds. Initially, one hand weeding is recommended, otherwise the roots of small plants get damaged if weeding is done with khurpa etc.

When the seedlings come out and have made 5-7 cm growth, light dressing of calcium ammonium nitrate or Ammonium sulphate at the rate of 50 g/sq metre of nursery area is applied. This encourage rapid growth of the seedlings. Seedlings are ready for transplanting in the following winter i.e. during January-February.

Propagation through cuttings: The phalsa plants can also be multiplied through hard-wood cuttings. The cuttings should be prepared during December-January and kept for callusing. The use of root promoting harmones such as Indole butyric acid @ 100 ppm enhances the success of rooted cuttings.

Planting Operation

Land is prepared well before the plants are set in the field. When there is enough time, a cover crop such as guara, jantar or senji may be sown in the soil. After these crops produce enough vegetative growth, they should be burried into the soil. Before planting, the orchard site should be properly laid out according to the square or the hexagonal system. Half metre deep pits or half metre diameter should be dug and refilled with a mixture of top-soil and well rotten farmyard manure in the ratio of 1: 1. To save the plants from possible attack of white ants add 30 g of BHC 10 per cent dust to each pit. After this, the field is thoroughly irrigated and transplanting is done when the soil is in friable condition.

The phalsa plants are spaced at various distances in different regions of India. Eight to twelve months old seedlings are better for planting in the field. The plants are spaced at 1.5 metres apart by which 4400 plants are accommodated in one hectare by the square system of planting.

The phalsa plants should preferably be transplanted in the field during January-February before they start new growth. The plants being dormant at that time, they can be lifted from nursery with bare roots. However, for transplanting during August-September, the seedlings have to be lifted from the nursery alongwith earth balls. Transplanting in the rainy season, is, therefore, a little more cumbersome and riskier than that done in the spring, when the plants are dormant.

Flowering and Fruiting

Flowering in phalsa starts from February-March and continues till May. The first flower to open is at the base. Flowers are borne in the axil of leaves. The flower are mostly cross pollinated and honey-bee seems to play major role in pollination.

The flower buds become plumpy before anthesis. The first sign of anthesis is the appearance of a slit in sepals at the base of the bud. The slit widens and at first only one sepal falls apart. The other sepals fall one by one and the whole process of flower opening is complete within half an hour. The dehiscence of anthesis in phalsa takes place before the flowers are completely open.

Orchard Cultural Practices

Irrigation

Phalsa is regarded a drought resistant fruit plant. However, it can be observed that in Punjab, Haryana and other neighbouring Northern Indian regions, irrigation is essential for securing high yield of better quality fruits. Its plants do not need any irrigations till January. Adequate supply of irrigation water at regular intervals specially during flowering and fruiting periods is very essential for ensuring better health of plants and more profitable yields. A light irrigation should be given after pruning and fertilisation of the plants. During the early part of the spring, when the new growth starts and the temperature is usually low, the irrigation interval may be kept at about 2-3 weeks. The demand for water increases a great deal after the middle of April and consequently the irrigation interval may be reduced to 7-10 days. At this time, the plants should not be allowed to suffer from water shortage; as it would adversely affect the yield and quality of fruit. Regular irrigation should be applied to the plants till the fruit is harvested and the monsoon sets in.

As the roots of the plants are active during winter, adequate soil moisture should be maintained in the root zone. During winter, one or two light irrigations may suffice if there are no rains.

Interplanting

Many fruit plants grown in the plains of North India such as mango, litchi and pear comes into bearing on commercial scale very late. These fruit plants have a slow rate of growth and the space between the tree rows remains unoccupied for several years. The growers can, therefore, utilise the empty space between the permanent fruit trees for raising some quick-growing fruit plants like phalsa. Phalsa has another advantage over other quick-growing fruits suitable for interplanting that it is kept low-headed by severe pruning every year and does not cause overcrowding in the orchard. Phalsa being a deciduous plant, does not require much water during the dormant period (winter months). Phalsa should be interplanted only in the middle of the permanent tree rows. As soon as the permanent trees come into bearing, the phalsa plants should be uprooted, so that the main fruit crop does not suffer.

Manuring and Fertilisation

Generally, phalsa is planted on comparatively poor soils. Some cover crop such as gurar, jantar or senji should be grown in the field where phalsa is to be planted. This practice adds sufficient quantity of organic matter to the soil and enriches it.

In order to get profitable crops of good quality, full grown phalsa plants should be given 10-15 kg of well rotten farmyard manure, soon after planting. Nitrogenous fertilisers should also be applied, preferably in two split dose-one at the time of flowering and second after fruit-setting. Higher yield of phalsa can be obtained by application of 100 kg N, 40 kg P and 25 kg K per hectare, respectively. Trials at Rajsthan Agricultural University, Udaipur revealed that application of NPK @ 100, 40, 25 kg per hectare gave higher yield.

Zinc and iron were found to influence berry size and juiciness in phalsa. $ZnSO_4$ @ 0.4 per cent at prebloom stage and after berry set improved the juice content. Ferrous sulphate at 0.4 per cent alone or in combination with zinc improved the berry size.

Pruning

The general practice of cutting back the phalsa plants to the ground level every year during the dormant period is not in order. Investigations carried out on this aspect have shown that the phalsa plnats pruned to a height of one metre during January-February produce a greater number of new shoots than those which are pruned to the ground level. The growers are, therefore, advised to prune their phalsa plants at a height of one metre from the ground level. The phalsa plants are rather slow in shedding their leaves winter. The best time for their pruning is when the plants have shed their leaves and in all cases the operation should finished well before the start of new growth.

Use of Growth Regulators

Growth regulators have proved effective in increasing the fruit set and yield in phalsa. GA_3 at 10 ppm increased the setting of fruit and yield appreciably. CCC at 250 ppm sprayed twice at an intervalof 7 days after 50 per cent fruit set increased the fruit size. Ethephon at 1000 ppm resulted in maximum ripening in 5 days after application. SADH 1000 ppm at early stage of plant growth reduced the plant height and brought improvement in yield and fruit quality. Spraying of GA_3 at 60 ppm once at the beginning of flowering, another after 15 days and ethrel at 1000 ppm when ripening of berries had just started, increased the fruit retention percentage and yield. They also reduced the harvesting span and increased the TSS of the fruit.

Harvesting of Fruit

The phalsa plants begins to bear fruits in the second year. A good commercial crop is usually obtained during third year. In the Punjab and Haryana, the harvesting season of phalsa fruit starts by the end of May and lasts till the end of June. The fruits should be picked when the colour has changed to a deep reddish brown and the pulp tastes sweet. Several pickings are necessary as all the fruits do not ripen at one time. The fruit-picking is usually done on alternate days. Under optimum conditions, a phalsa bush yields on an average about 4-5 kg of fruit.

Insect Pests

Psylla: A tiny insect causes severe damage to the phalsa foliage and young shoots. Its infestation over a long period of time results in the deformation of floral and vegetative parts. The plant growth is greatly arrested and gives a sickly appearance. Fruit set is severally reduced resulting in great financial loss to the growers.

The pest can be controlled by spraying one kg of carbaryl (Sevin 50% WP) in 500 litres of water or 300 ml Malathion 50 EC or 300 ml of Rogor 30 EC in 300 litre of water per acre as soon as new growth starts in March.

Diseases

1. *Brown spot:* The disease is caused by fungus Cercospora grewiae. The brown spot of phalsa is quite wide spread in the Punjab and is very severe from June to August. It results in premature leaf-fall when the attack is severe. The disease first appears as tiny lesions on the upper and lower surface of the leaf. In the beginning, these lesions are covered with a white mass of fungus. Gradually, the lesions enlarge and become reddish brown to dark brown. Many times, several lesions coalesce to form big spots which are very conspicuous and may cover a large part of the leaf.

   To control this disease, the leaves and prunings should be collected soon after removal and destroyed to check the fresh infection of the new leaves, the plants should be sprayed with Bordeaux mixture 2: 2: 250.

2. *Pinspot of phalsa:* The disease is caused by phyllosticta grewiae. The disease can appear any time during the growing season of phalsa and may cause considerable damage to the foliage. Small brown to dark brown, circular to irregular pinspot like lesions appear on the leaves.

CUSTARD-APPLE

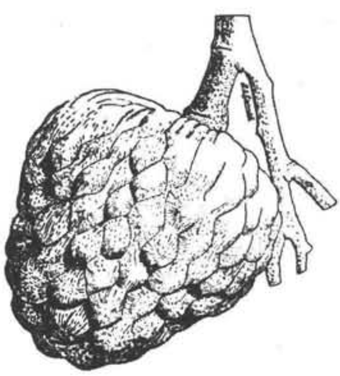
A small tree seldom more than 4.5 metres high and is both cultivation and found growing in a semi-wild state throughout Peninsular India. A dry-and-hot climate suits it most.

It flourishes in lighter soils, and grows well even on the slopes of hills, but cannot stand cold or frost.

This fruit-tree is propagated through seeds and by grafting. There is considerable variation in the fruit-trees when propagated from seeds. 'Bullock's-heart (*ramphal* provides a suitable rootstock for grafting by inarching or budding. Grafted plants give fruits earlier (in about two years) than seedlings which take three to four years. The plant flowers from April and November. The yield per tree varies from 25 to 30 kg. Fruits are mostly consumed locally, but they can be transported over long distances if they are picked before they are fully ripe and are packed in a single layer in well-ventilated wooden boxes with soft padding material.

BULLOCK'S-HEART

The Bullock's-heart is an allied fruit which is rarely cultivated. It prefers a heavier soil than custard-Apple and is less resistant to cold and frost. It is easy to propagate by inarching. It gives fruits from January to May and the yield goes up to 45 kg per tree. Cherimoyer is the best of the family and performs best in subtropical climate. It is propagated by inarching on Bullock's heart rootstock. The tree bears fruits from the sixth year onwards and gives about 100 fruits per year. Attemoya is a cross between custard-apple and cherimoyer and is similar to the latter in its growth requirement.



The bullock's heart alos known as custard-apple, is the fruit of the tree Annona reticulata. This tree is a small deciduous or semi-evergreen tree sometimes reaching 10 metres (33 ft) tall and a native of the tropical New World that prefers low elevations, and a warm, humid climate. It also occurs as feral populations in many parts of the world including Southeast Asia, Taiwan, India, Australia, and Africa.

The fruits are variable in shape, heart shaped, oblong or irregular. The size ranges from 7 centimetres (2.8 in) to 12 centimetres (4.7 in). When ripe, the fruit is brown or yellowish, with red highlights and a varying degree of reticulation, depending on variety. The flavor is sweet and pleasant.

In some regions of the world, "custard-apple" is another name for sugar-apple or sweetsop (Annona squamosa)', a different plant in the same genus. In Britain, "custard-apple" refers to cherimoya, the fruit of Annona cherimola, a third plant in the same genus.

The fruits are tasty and nutritious but all parts of this tree can be useful.The fruit is good to eat as is but also makes a sweet drink and can be used as a milk substitute.

The unripe fruit has been used to assist against diarrhea and dysentery. The tree bark is used for skin and mucosae medicines and the seed bark contains useful tannins and astringents. The leaves are believed to have healing properties and have been used against tumors and cancers.

The leaves also provide ingredients used to make dyes, stains, inks, tattoos and mordants. The whole plant is a source of hydrogen cyanide.

Cultivars

- Tikal: Is of excellent quality and medium yield; its flesh is bright-red, except in the white areas surrounding the seeds.
- Canul: Has a medium fruit with a waxy, shiny dark-red surface and purplish red flesh; it is very aromatic and deliciously sweet with few concretions of hard cells.
- Sartenaya: Has a medium fruit with a waxy, shiny red surface and pink flesh with a magnificent taste and texture. Although the fruit is not as attractive in appearance as that of the previous two cultivars. the tree is sturdier.
- San Pablo: : Has a long, large fruit with an opaque, light-red surface. The flesh is dark-pink with a good aroma and taste. It is a vigorous, productive cultivar.
- Benque: Has a big conical fruit with a dark-red surface and very tasty dark-pink flesh.
- Caledonia: Has a small fruit with a dark surface: it is very attractive to cochineal insects (Philophaedra sp.), which are not very common in other varieties. The flesh is pink and has an excellent taste.
- Chonox: Has a medium fruit with a red skin and juicy. very tasty pink flesh; it is very productive and, for this reason, often has low-quality fruit. It produces abundant flowers in groups of up to 16.

AONLA

It is indigenous to India and the tree is characterised by very small leaves which are attached to branchlets in such a way that each branchlet looks like a compound leaf. The tree attains good height. It is quite hardy and can be grown without much care in all types of soil, except very sandy.

The 'Banarsi' *aonla* is the most important cultivar which is propagated vegetatively. In the District of Pratapgarh of Uttar Pradesh, there are many commercial orchards. The important varieties grown are 'Banarsi', 'Chakiya' and 'Pink-tinged'. These are vegetatively propagated and highly valued unlike the seedling-trees which produce unmarketable fruits.

The commercial practice of propagating *aonla* is by shield-budding which is done in June. The two-year-old seedling *aonla* is used as rootstock. Budded *aonla* plants are planted in the fields during rains at a distance of 11 metres each way. It can also be planted as a windbreak around an orchard.

The budded plants will commence bearing from the 10th year. The vegetative growth of the tree continues from April to July. Along with the new growth in the spring, flowering also commences. The flowers are of two types: *i* male, and *ii* female. Fruits are fully mature by January-February. Under conditions in southern India, the fruits are found throughout the year at one place or another.

FIG

Fig has never been grown extensively in India. Maharashtra formerly had more than 500 hectares, but largely because of diseases, this figure has decreased to less than 125 hectares. Southern India reports somewhat less than this area, and there are a few fig-groves in Hyderabad and in other parts of the country. The types are not of the best quality and it is likely that they are hybrids between the European and other species. The climate of most parts of India seems to be suitable for the cultivation of fig. Rain at the time of fruit ripening is undesirable. Various tupes of soil are used successfully.

Varieties

There is as yet little basis for recommending specific varieties for different parts of India. The variety most commonly grown in Maharashtra and southern India is known as the 'Poona' fig.

Propagation and Planting

The plants are almost entirely grown from cuttings. Budding and grafting are easily done. Several species of *Ficus* are compatible as rootstocks. Cuttings made in winter are ready for planting out in the rainy season. Some prefer to plant the cuttings *in situ*. The spacing of fig-trees depends on the size they are to reach and this depends mainly on the type of pruning. Generally, a spacing of 4.5 to 5 metres is adopted.

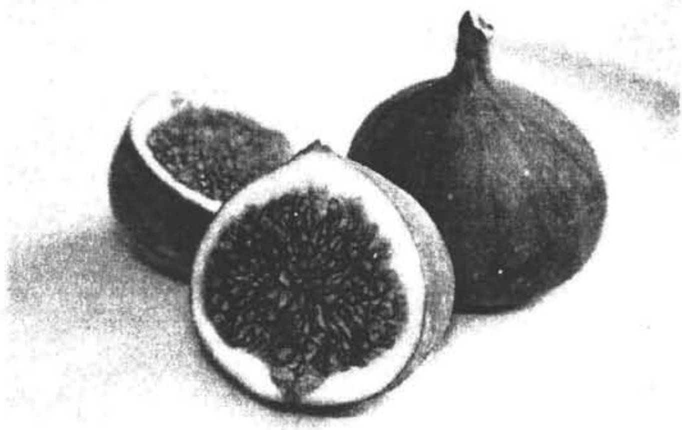


Figure 3. Figfruit

Culture

Tillage to keep down weeds is necessary and irrigation during the dry season when the fruits are growing and maturing is desirable. The tree is deep-rooted and drought-resistant, but does not bear well under conditions of water deficiency. A good supply of nitrogen is also required for heavy bearing, and the use of farmyard manure is also recommended. A fertiliser mixture containing 0.225 kg of N, 0.45 kg of P and 0.45 kg of K per tree may be applied.

Pruning

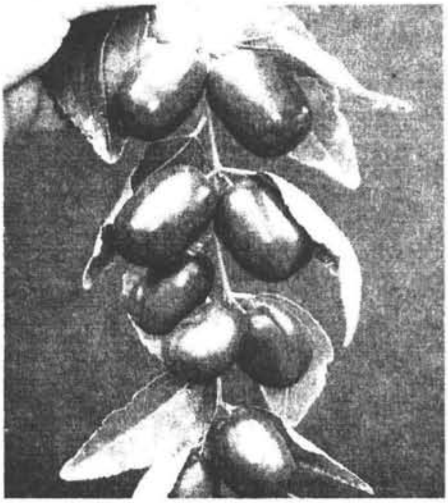
The fig-tree can stand very heavy pruning. Most of the fruit is borne on the growth of the current year. Some annual pruning seems desirable, but the most efficient type in each of the areas where the fig is grown in this country is not known.

Harvesting

The ripe fruit is delicate and must be harvested carefully and used within a few days. Where figs are grown for drying, they may be allowed to fall from the tree on clean dry ground.

JUJUBE

Jujube, *ber* or bor, is estimated to occupy about 4,000 hectares mainly in the northern, eastern and western parts of India. Almost any soil is suitable, even if it contains enough alkali to prevent the growth of some crops. The tree can stand prolonged drought and also water-logging. It cannot stand frost.



Jujube fruits

Climate

The ber is a hardy fruit tree and can grow successfully even under unfavourable climatic conditions, where most other fruit trees fail to grow. It can be grown up to a height of 1,000 meters above sea-level, beyond this it does not bear well. Ber relishes hot and dry climate for its successful cultivation, but the trees need adequate watering during the fruiting season. Excessive atmospheric humidity is considered a limiting factor for satisfactory fruiting. Frost during winter does not have much effect on the tree. It can very well withstand hot and dry weather during summer months of May-June, its tree enters into dormancy by shedding its leaves. New growth starts in July with the advent of rains and the growth period continues till the middle of November when it is inhibited with the onset of cold weather.

Soil

Ber provides a good scope for cultivation on soils which have so far been considered marginal or even unsuitable for growing other fruits. Its tree developes a deep tap-root system within a short period of growth and as such adopts itself to a wide variety of soils. Ber is well known for its ability to thrive under adverse condirions of salinity, drought and water-loggin. The research work conducted at the Punjab Agicultural Universityhas revealed that ber can flourish even in soils with pH as high as 9.2. Ber cultivation can succeed even under constraints of irrigation and fertilisation, however, for good tree growth and yield, deep sandy-loam soils with neutral or slightly alkaline reaction and good drainage are more desirable.

Varieties

Umran: This variety is cultivaed in a large scale in Punjab and Haryana. The fruit is large, oval in shape with a roundish apex and has an attractive golden yellow colour which turns into chocolate brown at fully maturity. The fruit is sweet, with 14-19 per cent TSS and has pleasant flavour and excellent dessert quality. It is a prolific cropping variety, yielding 150-200 kg of fruit per tree. The fruits ripen late from second fortnight of March to mid-April and have a good keeping quality. It is susceptible to powdery mildew.

Sanaur-2: This is a selection from Sanaur-a small town near Patiala, which is known for ber cultivation. The fruit is large and oblong with a roundish apex. On ripening, fruits attain a light yellow colour and TSS of 18-19 per cent. Like Umran, it is also a prolofic bearer-yielding about 150 kg fruit per tree. It is a mid-season variety, ripening during second fortnight of March under Panjab conditions and has been found fairly resistant to powdery mildew disease.

Kaithli: This variety is a selection from Kaithal in Haryana. The fruit is medium in size, oval in shape and has a tapering apex. Fruit pulp is soft and sweet with TSS of 14-16 per cent. Fruits ripen in the second fortnight of March to first week of April. The average yield is 120 kg fruit per tree. This is an excellent variety but appears to be more susceptible to powdery mildew disease.

Z.G.-2: The fruit is medium in size and roundish in shape with smooth skin. The fruit pulp is soft with an excellent sugar-acid blend. When ripe the fruits attain light yellow colour and TSS of 15-16 per cent. The average yield amounts to 150 kg fruit per tree and the ripening time extends from second fortnight of March to first week of April. This variety is recommended for growing for local markets only. It is less susceptible to powdery mildew.

Sanaur-5, Gola, Sanaur-4, Chhuhara and Laddu are other important varieties of ber, which have good taste and bears heavily.

Planting

The ber plants can be planted in February-March and again in Augast-September, but the latter season of planting gives a better success. Recently, Punjab Agricultural

University has also recommended the bare-rooted planting of ber during December-January. One metre deep pits of one metre diameter should be dug and left exposed for one month before actual planting. Pits should be refilled with a mixture of top-soil, about 20 kg well-rotten farmyard manure and 1 kg superphosphate per pit. To avoid attack of white ants 30 g of BHC 10 per cent dust is added to each pit.

The refilled pits should be about 2-3 cm higher than the ground level and irrigated thoroughly, so that the loose soil settles down firmly. A plant may be set in the centre of a pit with the help of planting board, maintaining the same level of soil at which it stood in the nursery. The budding point should remain about 15-20 cm high from the ground level. The plants should be immediately watered after plantation. They should be irrigated after every 4-6 days atleast during the first two months and subsequently after every 7-10 days for another 3-4 months or until the plants get fully established.

The grafted ber is spreading in habit and grows into a big tree. The tree requries proper spacing for its healthy growth and fruiting. For obtaining good income, ber palnts should be planted 7.5 metres apart in square system (from row to row and plant to plant) thus accommodating 180 trees per ha.

Lifting plants from the nursery: The budded ber plants should be transplanted during February-March or Augast-September. The plants are dug out from the nursery with good-sized earth-balls so that their root-system is not much distributed. The plants should be packed carefully to keep the earth-ball intact. The earth-ball should be kept moist throughout the period of transportation and upto plantationso that the roots of tree do not dry up in the intervening period.

While lifting bare-rooted plants, the leaves and shoots of the budded ber plants are removed before uprooting them from the nursery. These plants are also headed back at a height of 60-75 cm from ground level. Then, these plants are dug from the soil with the help of of Spade and Khurpa to keep maximum feeding roots with them. These plants are tied loosly in bundles and are wrapped in moist rice straw. Such plants can easily be trained according to modified central leader system. The bare-rooted plant should be lifted from nursery from mid-December to early-February.

Planting as Windbreak: Besides regular ber plantations, the tree can also be successfully planted as a windbreak around the commercial orchards to provide an effective wind screen. The tall-growing tres like Safeda, Arjun and Simbal shouls be interplanted with ber, being a low-headed tree.

Rootstock and Propagation: Seeds of Katha ber are generally used for raising rootstock, which are easily available from the wild growing trees and possess the qualitiesof a good rootstock. The ber plants should be budded on *Zizyphus mauritiana* (Elongated Dehradun) for higher fruit yield. Ber plants raised on semi-vigorous rootstock Zizyphus mauritiana

(Coimbatore) can profitably be planted at a closer spacing of 6 x 6 m. Umran trees grafted on this rootstock show a spread of 6 metre as compared to the recommended rootstock viz. Zizyphus mauritiana (*Elongated Dehradun*) on whom the tree spread to an area of 7.5 metre. Thus about 50% more plants/ha can be accommodated with over 20% increase in yield of equally good quality fruit. Seeds of Mallah ber (*Zizyphus numularia*) can also be used as rootstock. The seedlings of Mallah ber are slow growing and become buddable after longer period than the seedlings of Katha ber.

Raising of Rootstock: The germination of ber seed is quite a difficult process on account of the stony nature of the shell (endocarp) which contains the seed. A large percentage of seed stones are non-viable and require elimination at the time of sowing. Seed stones collected from dropped fruits contain 50-70 percent non-viable seeds. Seeds should be dipped into a salt solution of 17-18 percent concentration for 24 hours before sowing.

The flaoting seeds should not be sown as these are generally non-viable. The ber seeds can also be sown by cracking the hard shell (endocarp). They germinate rapidlly in about 8-10 days. However, for commercial purpose, stones should be sown as such to avoid injury to embryos. To get best root-stock material, it is important that seeds should be collected only from healthy and vigorous-growing wild ber trees. The ber seedlings raised from Katha ber stones, which are sown during March-April, after fresh extraction, in well-prepared nursery field at a distance of 15 cm in rows 30 cm apart. Germination starts in about 3-4 weeks and seedlings make a rapid growth. The seedlings should be trained to the single stem. Nearly one-fourth of the seedlings attain buddable size of a lead pencil by Augast, while the rest are ready for budding by April next.

Budding

The propagation of ber by budding is the most successful method. Both Shield or T-budding and ring-budding methods are employed but the former is preferable, because it is easier to perform. Budding operation should be done when there is proper flow of sap in the stock to be budded. Shield-budding is done during March-April or August-September, but it has been found that August-September budding gives a far better success. The buddlings make growth at a very fast speed. Plants budded in April usually become saleable in August-September, where as those budded in rainy season are ready for planting by February-March next. The ring-budding is preferable during June-July when the new growth starts. Shield-budding done during August-September has given success of 75-81 per cent, whereas budding in April has given a little success.

Selection of Stock and Scion: The stock seedlings should be healthy and vigorous and it is allowed to grow as a single stem only. The budding is done when the stock stem has attained the thickness of a lead pencil. It is essential that bud sticks are taken only from selected trees which are known for bearing a heavy fruit crop of good quality. The mother plant from which the scion bud-sticks are obtained for budding should be healthy, vigorous, free from diseases and insect-pests and should be true-to-type. Two to three months old shoots with plump buds should be selected. Bud-sticks, about 30 cm long, are cut from the selected mother plants. For sending to distant places, about 20 cm long bud-sticks should be taken. The leaves of the bud-sticks should be cut away, keeping the leaf stalks attached to the buds. These should be tied in small bundles and wrapped in moist piece of cloth. The bud-sticks should be kept moist till they are used for budding.

Flowering and Fruiting

The whole period of bud development is divided into eight stages. It takes 21 days to 22 days for passing through various stages of bud development. The flowering period lasts for about two and a half months from September to November. The peak of flower anthesis is at 6 A. M. in Sanaur-2, Sanaur-5 and Chhuhara ultivers and 2 P.M. in Thornless, Khaithli and Umran cultivars. The dehiscence of anthers starts just after anthesis and completes within 4 hours. Pollen grains are highly viable-the viability ranging between 87 to 91 percent in different cultivers. Pollen grain germinability is also quite high to 36-48 per cent. The peak receptivity in stigma is found on the day of anthesis. It does not set any fruit by self-pollination, thereby shows self-incompatibility.

Fruit-setting starts in second week of October and continues upto first fortnight of November. The ber fruit reaches to ripe stage in about 180 days after fruit-setting. The fruit growth in terms of lenght and diameter shows three distinct phases and follows a pattern of 'Double Sigmoid' curve.

Orchard Cultural Practices

Training

The ber plants start bearing within 2-3 year of their planting in the orchard. In the fourth year, the trees bear commercial crop. Hence, the ber plants should be properly trained during the first 2-3 years, to build up a strong framework. The young budlings should be given support with a bamboo stake to avoid the breakage of the bud-union and to support the main stem. The commercial varieties are spreading in nature, therefore, staking is absolutely essential during the first two years to train the tree properly.

The plant will make vigorous growth during the first year. Many secondary branches will emerge from the main stem. All the branches upto 75 cm from the ground level should be removed. Four or five laterals which are most favourably located around the main stem should be selected to make the proper framework. At the end of the year, the main stem should be headed back to some outgrowing laterals.

Pruning: The pruning of ber trees is highly desirable to maintain their vigour and productivity as well as to improve fruit size and quality. Pruning also saves the fruit from being affected by the powdery mildew disease and strong winds. The ber tree remains young upto 30 years, if proper pruning is done regularly. Ber fruit is borne in the axils of leaves on the younge growing shoots of the current year. Hence, a regular annual pruning is essential to induce a good and healthy growth which will provide a maximum fruit bearing area on the trees as well as to improve the fruit size and quality. In unpruned ber tree, the canopies of the trees get un-necessarily enlarged, the growth and branchlets become weak and both fruit size and quality gets impaired. Ultimately, such trees become economically unproductive besides occupying large orchard space.

Some thinning out of the branches of ber trees is also necessary to avoid too much crowding so as to admit adequate sunlight and facilitate proper aeration. Ber pruning experiments have shown that the light pruning, i.e. heading back of 25 per cent of the previous year's growth (branchlets, shoots, etc) is desirable to obtain heavy yield, good fruit size and better quality. The lower branches should be pruned suitably to prevent them from spreading on the ground. The diseased, broken and intercrossing branches should also be thinned out. Severe pruning after every four-five years, is recommended. The ber trees shed their leaves and enter into dormancy by the end of May. The best time for taking up pruning would, therefore, be end-May or beginning of June.

Irrigation: Irrigation is essential during the development of fruit, i.e. from October to February at intervals of 3 or 4 weeks depending upon the weather. Trees will continue to bear even if no irrigation is applied during this period but the yield is substantially reduced because of heavy fruit drops and smaller size of the remaining fruit. The quality of fruit is also very poor. It has been observed that the fruit become large and their quality is improved the fruit shedding is very much minimised if irrigation is applied during fruit development period. Irrigation should be stopped in March as fruits on the branches lying on the ground get damaged and their ripening is delayed. The harvesting of fruit is over in April and they become dormant in May-June and shed their leaves. They need little or no irrigation during this period. If irrigation is applied during the dormant period, the trees would continue to put fourth growth haphazardly which is not desirable. Under Panjab conditions there are sufficient rains during July to September when the tree produce the maximum fresh growth. During the second half of September and in October the trees come into flowering. At this time, light irrigation should be given.

Manuring and Fertilisation

Proper nutrition of ber tree is necessary to get good crop over the years. The fruit becomes large and attractive and get decent price in the market. 20 kg farmyard manure and 100 g nitrogen (400 g CAN) is recommended for one year old ber tree. Similar amount of farmyard manure and nitrogen should be increased every year up to the age of five years. The quantity of farmyard manure and nitrogen should be stabilised at 100 kg and 500 g (2 kg CAN), respectively, after the age of five years. Farmyard manure should be supplied in May-June. Half of the CAN may be applied during rainy season (July-August) and the other half at the time of fruit-set (October-November). The fertiliser should be evenly spread in the basins of trees upto the periphery. After adding the fertiliser, light hoeing with spade or khurpa should be given to the basins to mix it thoroughly with the soil.

Intercropping: The ber tree begins to bear after one year of its planting in the field. To develop the tree properly, it is advisable that no fruit should be taken at least for the first two-three years. Intercropping can be successfully practised on the vacant land in the young orchard during the first four years. Only leguminous crops of short stature like gram, moong and mash can be grown to get some income from the land in these initial years. These crops also enrich the soil by fixing nitrogen. The other exhaustive and tall-growing crops should not be grown in the ber orchard as they deplete the soil of its nutrients to a greater extent and compete for light with the trees. Manures and fertilisers, irrigation and plant protection measures should be given seperately to the fruit trees and intercrops according to their needs.

Weed Control

Pre-emergence application of Hexuron 80 WP (diuron) at 1.2 kg/acre can be made during the first fortnight of August when field is free from growing weeds and stubbles. Glycel 41 Sl (glyphosate) at 1.2 litres/acre or gramoxone 24 WSC (paraquat) at 1.2 litres/acre as post-emergence should be sprayed when the weeds are growing actively preferably before weeds flower and attain a height of 15-20 cm. Dissolve the herbicide in 200 litres of water per acre to give complete coverage of weeds/field. Spray Glycel and Gramoxone during the calm day to avoid spray drift to the foilage of the fruit trees.

Control of Fruit Drop: Spray application of 20-30 ppm Naphthalene acetic acid once in the second week of October and again in the second week of November, check 11 per cent fruit drop in Sanaur-5 snd 10 per cent in Kaithli cultivers of ber.

Harvesting and Fruit Handling

Harvesting

The ber tree grows quickly and and the first crop can be harvested within 2-3 years of planting. The fruit itself requires about 22-26 weeks to mature after fruit-setting. The peak season of harvesting in north India is in mid-March to mid-April but some early varieties may ripen by end-February. This period being a slack season for other kinds of fruits, ber sells readily at remunrative prices.

The fruit should always be picked at the right stage of maturity, i.e. when it is neither under-ripe nor over-ripe. It should be picked when it has acquired normal size and characteristic colour of the variety, e.g. golden yellow colour in Umran. Normally four to five pickings have to be made as all the fruits on the tree do not ripen at the same time. In no case, the fruit should be allowed to become over-ripe on the trees, as they deteriorate in taste and quality and thus fetch lower price in the market.

Insect-pests:Fruit-fly (Carpomyia vasuviana costa): It causes great damage to ber fruits. The larvae feed inside the fruits and render them unfit for human consumption. To control the pest, pick and destroy the infested fruits and spray 500 ml of Roger 30 EC (Dimethoate) in 300 litres of water during February-March, care being taken that sprayings are stopped atleast 15 days before fruit harvest.

Leaf-eating caterpiller (Porthmologa paraclina Meyrick) and ber beetle (Adoretus pallens Harold): The plantation should be watched carefully during rainy season regarding the attack of these insect-pests. Leaf-eating caterpillars feed on leaves and cause huge damage. To control these, spray with 750 g Sevin 50 per cent (Carbaryl) in 250 litres of water as soon as the damage is noticed.

Lac insect (Laccifer lacca): This insect also causes serious damage by sucking the sap from the twigs which usually dry up. To control this insects, remove and destroy the infested dry twigs. Spray the trees with 250 ml of Rogor 30 EC (Dimethoate) or 100 ml of Dimecron 85 WC (Phosphamidon) in 250 litres of water in April and again in September.

Diseases

Powdery mildew: The disease is caused by Microsphaera alphitoides f.sp. Zizyphi and appears from September to December. It has become a big meance to ber orchards in north India. If not checked in time, the disease can wipe out the entire crop. Young developing leaves and fruits are covered with withish powdery mass of the causal fungus. The disease cause premature defoliation and heavy fruit-drop. Affected fruits remain small and become cankered and disfigured. Sometimes the attack is so sereve that the entire crop is lost either through drop or rendered unmarketable, thus causing heavy economic losses to the growers. The disease can be controlled by 3-4 spray of 0.05 per cent Karathane 40 EC (50-80 ml in 100 litres of water) or 0.25 per cent wettable sulpher (250 g in 100 litres of water). First spray must be given before flowering (first fortnight of September), second spray after fruit-set in early October and the third in the end of October. Another spray can be given if need arises.

Leaf spots: Two leaf spots of ber are very common in ber growing regions, i.e. 'Phoma Leaf Spot' caused by Phoma macrostoma Mont. and 'Black Mould of Leaf' caused by Isariopsis indica. Both diseases are caused by different fungi, while the Phoma leaf spot appears on the upper surface, the black mould make its appearence only on the lower surface of leaves. In case of Phoma leaf spot symptoms appear when the leaves have fully expanded, in the Black mould case the sysmptoms can appear even on young leaves. Phoma leaf spot appears with grey centre, yellow margin and dark fungal growth on the mid-rib, main vein, petiols and the leaves. Black mould spot appears as small circular, small finger-like projections like softy tufts. Both the leaf spots of ber can be controlled by spraying the following fungicides as given below:

First spray: Bordeaux mixture 2: 2: 250 or with 0.3% copper oxychloride 50% (300 g in 100 litres of water) should be sprayed both on upper and lower surface of leaves with the appearance of disease in August or when the leaves have expanded.

Second spray: This spray should be given after 14 days of the first spray with 0.2 per cent Dithane M-45 WP 75% both on upper and lower surface of leaves. First and second spray should be repeated alternatively at 14 days interval till the fruits are fit for marketiing. Thereafter sprayings are stopped a week before harvesting.

JAMUN

Climate

Jamun is successfully grown under tropical and subtropical climate. It also occurs in the lower range of the Himalayas upto an elevation of 1300 metres and in the Kumaon hills upto 1600 metres above sea level. It is widely grown in the larger parts of India from the Indo-Gangetic plains in the North to Tamil Nadu in the South. It is one of the most hardy fruit crop and can be easily grown in neglected and marshy areas where other fruit plants can not be grown successfully.

Jamun fruits

Jamun is somewhat more susceptible to cold and drought than the seedling mango trees. It requires dry weather at the time of flowering and fruiting. For ripening of fruit and proper development of its size, colour and taste, early rains are considered very beneficial. The fruits show remarkable improvement in these respects after the very first shower of rain.

Soil

Jamun tree is exact in its soil requirements. The tree requires deep, loam and well-drained soil for its optimum growth and good fruiting. Its cultivation should be avoided in very heavy or light soils.

Choice of varieties:Ra Jamun: It produces big sized fruit with average lenght of 2.5-3.5 cm and of diameter 1.2-2.0 cm. Fruits are oblong in shape, deep purple or bluish black in colour at fully ripe stage. The pulp colour of ripe fruit is purple pink and the fruit is juicy and sweet. The stone is small in size. It ripens in the month of June-July. The variety is very common among the people.

Small sized Jamun: It is a late maturing variety. The average lenght of fruit is 1.5-2.0 cm and diameter is 1-1.5 cm. The fruit is slightly round in shape, deep purple or blackish in colour at full ripe stage. The colour of the pulp is purple, less in juice, weight and sweetness of pulp in comparison of that of 'Ra Jamun'. The stone is very large. Fruits ripen in the month of August.

*Propagation and Rootstock:*Though lot of jamun plantation is seen on road side or scattered plantation at farmer's field, yet no single well established orchard is reported in North India. Also no systematic work has been done on its propagation.

The most common method of jamun propagation is by seed. Seedling plant bears fruit of variable size and quality. For improved and selected true-to-true, vegetative methods of propagation like inarching and air-layering have been advocated.

Sexual Propagation: Seeds are sown fresh in flat nursery beds during July when this fruit ripens. The seeds should be sown at a distance of 15 cm in rows which are 25-30 cm apart. The seedlings can also be raised in polythene bags of 22.5-30 cm size. The bags should be filled with a mixture of soil and farmyard manure in equal proportion. To drain out excess water the polythene bags should be pricked from all sides before filling the mixture. It has been seen that more than one seedling comes out from a single seed. These seedlings are separated in different bags when they are about two weeks old. Plants grown from seed become transplantable during next spring season.

Vegetative Propagation: T-budding and patch budding: According to the recent research conducted at Punjab Agricultural University has revealed that jamun can be best propagated through T-budding as well as through patch buddding. The seedling of jamun is used as a rootstock. The per cent success is higher in T-budding (70%) than patch budding (60%). The best time for budding in both the cases is either during February-March or during August-September.

Inarching: The rootstock used for propagating jamun is the jamun seedlings. For raising the rootstock, seeds are collected from healthy, vigorously growing and high yielding jamun trees. Seedlings are raised either in bed or in pots singly. In the month of June-July one or two year old rootstocks are inarched with the matching thickness of scion.

Veneer grafting: Veneer grafting gives 31 per cent success when one year old seedlings are used as rootstocks. The shoots are taken from spring flush and the method is employed in the month of July.

Planting Operation

Jamun can be transplanted during spring (February-March) or during monsoon (August-September). However, the later season of planting is considered better because the plants easily get established during the rainy season. The plants are transplanted with earth ball and are given irrigation till they get established. The size of the pit should be 1 × 1 × 1 m and these should be filled with a mixture of surface soil, silt and well rotten farmyard manure. The jamun is planted at the distance of 10-12 metres in square system, thus accommodates 105-75 plants per hectare.

Flowering and Fruiting

The flowering in jamun starts in the first week of March and continues up to the middle of April. The trees are in full bloom in the second week of April. The inflorescence in jamun is generally borne in the axils of leaves on branchlet. The flowers are hermaphrodite, light yellow in colour. The maximum anthesis and dehiscence were recorded between 10 A.M. and 12 Noon. The pollen fertility was higher in the beginning of the season. The maximum receptivity of stigma was observed one day after anthesis.

Jamun is a cross-pollinated fruit. The pollination is done by honeybees, house flies and wind. The maximum fruit set i.e. 32.6-36.0% was obtained when pollination was done one day after anthesis. Thereafter, a sharp decline was observed in fruit set.

Three distinct phases of fruit growth in jamun are recorded. During the first phase (15-52 days after fruit set), the rate of growth was slow. In the second phase (52-58 days after fruit set), the rate of development was quite rapid and the third and last phase (58-60 days after fruit set) comprised comparatively slow growth with little addition of the fruit weight. The lenght and diameter of fruit showed a continues increase with advancement of maturity. The colour of jamun fruit changed from dark green at fruit set to light reddish colour at partial ripening and dark or bright purple at full ripe stage. The fruit took 63 days for complete ripening from fruit set. The ripe jamun had 76 per cent edible portion and 3: 1: 1 pulp to seed ratio. TSS and sugars followed an increasing trend, while tannin content followed a decreasing trend during growth and development.

Orchard Cultural Practices

Irrigation

During the initial year, the jamun plants required 8-10 irrigations in a year while bearing trees (full grown) required 4-6 irrigations during the summer months of May and June when fruits ripen. In the remaining period of the year, irrigation may be given when there are no rains or dry spell persists.

Intercropping

To supplement the income from pre-bearing period of jamun, intercropping should be practised judiciously. Intercropping also improved fertility of the soil. Fruit crops like peach, pulm, guava, kinnow, kagzi lime, phalsa and papaya can be grown as filler trees. Such filler trees can be uprooted when the jamun trees starts bearing commercial crop. The leguminous crop like gram, peas, moong and mash can be grown successfully. In addition, intercrops of vegetables near established market may be taken with cauliflower, cabbage, knol, khol, radish, brinjal, turnip, carrot etc.

Manuring and Fertilisation

During the pre-bearing period of jamun, a dose of 20 kg well rotten farmyard manure should be applied. To the bearing tree 80 kg FYM per tree should be supplied annually for proper growth and fruiting. Sometimes in highly fertile soils, the plants produce profuse vegetative growth and fruiting is delayed. Under such conditions, the manures should not be given and irrigation should also be given sparingly and withheld in September-October and again in February-March. This procedure will prove beneficial in fruit bud formation, flowering and fruit setting. Ringing and root pruning are also helpful.

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6

Temperate Fruit Crops

Temperate fruits include such well-known species as apples (Malus) and pears, grapes and figs, as well as stone fruits (Prunus), such as apricots, cherries and plums. Familiar temperate nut crops include almonds, cashews and walnuts. There are also many other neglected and underutilised fruit species that are particularly suited to dry areas, such as pomegranates, pistachio and date palm.Temperate fruits require a cold season for satisfactory growth. The cultivation and management of practices of some importance temperate fruits are described in this chapter.

Many of the world's best-known and favorite fruits (such as apple, pear, peach, plum, grape, and strawberry) are adapted to climates in the middle latitudes and are known as temperate fruits. Temperate fruits have two climatic adaptations: they require some cold periods (dormancy) to complete their life cycle, which conditions their adaptation in tropical climates, and they have various degrees of winter hardiness, which conditions their adaptability in cold climates.

Fruits that do not specifically require cold but have slight frost tolerance (citrus, fig, olive, persimmon, pomegranate) are known as subtropical fruits; they are not discussed here. In contrast, tropical fruits typically are very sensitive to cold and are often injured by low temperatures above freezing. Temperate fruits are usually classified by their growth habit as tree fruits (apple, pear, peach), vine fruits (grape, kiwifruit), or small fruits (strawberry, raspberry, currant, and blueberry). The term "small fruits" refers to the size of the plant and not necessarily the fruit. In the United Kingdom they are better known as bush fruits or soft fruits.

TREE FRUITS

The best-known temperate tree fruits are members of the rose family (Rosaceae). These include the pome and stone fruits. Pome fruits (apple, pear, quince, and medlar) are fleshy fruits in which the outer portion is formed by expanded floral parts and receptacle.

The stone fruits, all members of the genus Prunus (almond, apricot, cherry, peach, nectarine, and plum) are fleshy fruits that contain a stony pit (hence the name "stone fruits"), which encloses a solitary seed.

Apple (Malus × domestica) is the best known of the pome fruits. It has been known since antiquity and is grown in Siberia and northern China where winter temperatures can fall as low as –40°F and in high elevations in Colombia as well as Java, Indonesia, straddling the equator, where two crops can be produced in a single year provided leaves are stripped. While there are many species of Malus, the domesticated kinds seem to be derived from M. siversii indigenous to Kazakhstan and neighboring countries where forests of wild apple contain seedlings with all of the characteristics of the domesticated sorts.

Apples are popular because they can be consumed in many ways: fresh, dried, or cooked and in liquid form as juice, alcoholic cider, or brandy (Calvados). Processed apples are appreciated as a filling for many bakery items and enjoyed as a sauce or concentrated as a butter. Some apples have a long storage life under refrigeration, in some cases as long as a year, especially under controlled atmospheres (low oxygen). In the United States the apple is the symbol of wholesomeness; "an apple a day keeps the doctor away" is a popular aphorism.

Pear (Pyrus species) can be divided into two types, the European pear (P. communis), which usually are consumed when they soften after harvest, and the Asian pear (P. pyrifolia and P. ussuriensis), which are consumed when crisp. The pear is as old a fruit crop as apple but is somewhat less popular in the West. This is probably because the postharvest ripening required makes it difficult to determine optimum quality, and some fruits contain grit (stone cells), which can be objectionable. Asian pears (known as nashi in Japan and as li in China) are probably more popular than apples in China, Japan, and Korea. Pears are closely related to apples and are consumed in similar ways.

The quince (Cydonia oblonga) is the third most important pome fruit. It is not very popular because most are too sour and astringent to be consumed raw, but it is excellent cooked, especially in preserves, jams, and jellies, to which sugar is added. Some types grown in warm climates soften and can be consumed raw. It is an important crop in Argentina. Some quinces are used as dwarfing rootstocks for pear. Quinces have a wonderful perfume and should be more widely grown but have passed into the realm of a neglected fruit. The Asian quinces (species of Chaenomeles) are often grown as ornamentals, but there have been attempts to domesticate these species in the Balkans for juices and preserves.

Medlar (Mespilus germanica) is truly an almost forgotten fruit. It is mentioned and disparaged by Shakespeare, who notes that it must be almost rotten to be enjoyed. The medlar is inedible until an internal fermentation occurs, producing an aromatic taste that appeals to some. The medlar can still be found in Italian markets.

The peach, despite its scientific name (Prunus persica), which suggests a Persian origin, is native to China, where it has always been highly prized for the beauty of its flowers and fruit. The peach seems to have been introduced to Europe via Persia in the first century B.C.E. but may have been known to the Greek philosopher Theophrastus (372–287 B.C.E.), who writes of Persian fruit and Persian apple. The fruit was well known to the Romans, and pictures of peaches were found in Herculaneum, destroyed in the eruption of Vesuvius in 79 C.E.

Peach germplasm was introduced to the United States by the Spanish in the sixteenth century and became naturalised, but quality was low. Introductions from China in the middle of the nineteenth century, particularly one called Chinese Cling, are the progenitors of modern American cultivars. Peach is now the most popular temperate summer fruit. There are a number of distinct types. The freestone types with melting flesh and white or yellow flesh are usually consumed fresh. The cling-stone, rubbery-flesh types are used in processing. The nectarine, a peach with a nonfuzzy skin, resulted from a mutation. Peentao, a saucer-shaped, flat peach is another variant type. Breeding in the United States has created many cultivars of both peach and nectarine that are widely grown in Europe, and some have been reintroduced to China for greenhouse production.

Almond (Prunus amygdalus) is native to the hot arid regions of western Asia but was introduced to Greece and West Africa in prehistory. The flesh is leathery and inedible, although the very immature fruits are consumed in Arab countries. Unlike most stone fruits, which have a bitter seed due to hydrocyanic (prussic) acid, the seeds of almond are nonbitter and are the edible part of this fruit. This species is therefore discussed under nuts. The almond is the most extensively planted "fruit" in California and is widely grown in countries of the Mediterranean basin.

Cherries, one of the most popular early summer fruits, are a symbol of joy as expressed in a famous song line: "life is just a bowl of cherries." There are about thirty species of cherry. The edible types include sweet cherry (Prunus aviuim), a diploid with two sets of chromosomes ($2n = 16$), and tart (sour) cherry (P. cerasus), a tetraploid with four sets of chromosomes ($2n = 32$). Another tetraploid type called Duke cherry is derived from a hybrid between sweet and tart cherries. Cherries may be red, yellow, or bicolored and are consumed fresh, dried, or processed, including as a liquor called kirsch. The Maraschino cherry is almost an artificial fruit in which cherries are brined, bleached, and then artificially colored and flavored with bitter almond oil. They are often used in a wonderful confection: chocolate-covered cherries. Cherries are now available over a long season in North American markets due to the efforts of American and Canadian breeders.

Apricot (Prunus armeniaca), an ancient fruit native to central Asia and China, was thought by the Greeks to have originated in Armenia, hence its scientific name. The beautiful, aromatic fruit with a velvety skin is consumed fresh, dried, and processed. Apricot liquor is well appreciated. The apricot blooms very early, is subject to spring frost, and is difficult to grow. This may explain why apricot has not become as important as peach, cherry, or plum. The beautifully flowered Chinese plum (P. mume) is more properly included with the apricots than the plums.

Plums are a diverse group of fruits, as exemplified by the many names by which they are known: bullaces, cherry plums, damsons, date plums, egg plums, greengages, mirabelles, plums, prunes, and sloes. Various species originated in Europe, Asia, and America. Two European species (Prunus domestica and P. insititia) are hexaploid, with six sets of chromosomes. The domestica plums include several groups of cultivars, such as greengage and prune types, while P. insititia includes bullaces, damsons, mirabelles, and St. Julien types. Among Asiatic species are P. salicina and P. simonii, the former of which includes both red-and green-fleshed Japanese plums. Many of these were introduced by Luther Burbank, with the red-fleshed Santa Rosa being the best known. P. simonii (apricot plum) is cultivated in China. There are a number of American plum species, but none are widely cultivated.

At the start of the twenty-first century, the world plum industry is largely made up of P. domestica in Europe and P. salicina in Asia. Plums are consumed fresh or dried. Plums that dry without fermentation are called prune plums or simply prunes. They are dried down to very low moisture levels, in which state they can be stored for long periods of time. They are rehydrated when they are sold as packaged prunes, processed into jelly and jam (popular as a bakery filling), made into a diluted juice, or turned into brandy or cordials. The wrinkled dried fruit was widely consumed by senior citizens because of its laxative properties and thus became a source of comic derision. (It has been said that the turndown service at senior hostels includes a prune rather than a chocolate on the bed.) As a result, the industry has changed the name of prune to dried plum!

VINE FRUITS

Grapes (species of Vitis, Vitaceae, or grape, family), one of the most important temperate fruit species, are usually grown on trellises. Total world production of this fruit is surpassed only by all citrus and species of Musa (banana and plantain). Grapes derived from the European species, V. vinifera, have been prized as the source of wine since antiquity. Although wine can be made from any sweet fruit, the grape is the preferred species because the combination of sugars, acids, and astringent substances such as tannins gives character to the product. The name of wines, such as cabernet sauvignon and pinot noir, refer to the grape cultivar. Because these wines have become a standard product there is great reluctance to change grape cultivars used for wine, but various clones have been selected throughout the many years they have been cultivated. Some grapes (known as table grapes) can also be enjoyed fresh; many of the new cultivars bred for this purpose are seedless. Nonalcoholic grape juice is enjoyed in the United States; this industry derives from Concord, a cultivar of the American species V. labrusca, the fox grape.

American grapes are typically winter-hardy and have a slip skin and a unique flavor referred to as foxy. Concord juice in the United States is also used to make the sweet wine used traditionally in Jewish ceremonies, a product often derided by wine connoisseurs but still enjoyed by millions of ordinary folk. American grapes have long been grown in Japan, where their foxy flavor is appreciated. The large-fruited table grape Italia, widely appreciated in Europe, has a muscat flavor that is similar to the foxy flavor of labrusca grapes, many of which are sweet and pleasant but insipid. The strong-flavored muscadine (V. rotundifolia), native to the southern United States, has a small market in this area for fresh fruit, juice, and wine.

The kiwifruit (Actinidia deliciosa, Actinidiaceae) is an example of a fruit species that has been essentially domesticated in the twentieth century. It derives from a gathered Chinese fruit known as yangtao, which had long been appreciated in China but was collected rather than cultivated. Introduced to the United States and New Zealand early in the twentieth century by the plant explorer E. H. (Chinese) Wilson, it was referred to as Chinese gooseberries. Although it remained a curiosity in the United States, New Zealand growers and nurserymen succeeded in domesticating the crop by selecting suitable male and female clones (the plant is dioecious), as well as techniques for cultivation. One seedling selected by A. Hayward Wright and subsequently named Hayward became the mainstay of the world industry. The fruit was exported to the United States and promoted by Frieda Caplan, a marketer of new crops.

In 1959 the relatively unattractive brown fruit received the new name kiwifruit after the kiwi, an endemic flightless bird often used as a nickname for New Zealanders. Kiwifruit has a pleasant but weak flavor with very high vitamin C content, but the nutritious quality of the fruit has not been promoted; rather, it was the beautiful and unique appearance of the sliced flesh, which is used as a garnish on bakery products or as a component of mixed fruit, that made this fruit popular worldwide. The long storage life of the fruit made it possible for New Zealand to export the fruit year-round.

The popularity of the crop made millionaires of many New Zealand growers, but as kiwifruit began to be grown in such countries as the United States, Italy, and Chile, the boom crashed and New Zealand growers had to struggle to survive. Kiwifruit is consumed out of hand in New Zealand, usually scooped with a spoon, but this technique has not caught on, and further expansion is probably linked to development of a simple method for peeling. A yellow-fleshed kiwifruit marketed as Zespri Gold (A. chinensis) was introduced at the turn of the twenty-first century, and the New Zealand growers are attempting to control its distribution. It is too early to know if this will succeed. A small-fruited hardy American species (A. arguta), sometimes called tara fig, is now cultivated in gardens but this species has not been commercialised.

SMALL FRUITS

Strawberry, the most widely grown small fruit, has an interesting history. Although a small-fruited species of strawberry (Fragaria vesca, a diploid species, $2n = 16$) is native to Europe, the modern strawberry is derived from hybrids between two octoploid ($2n = 56$) native American species, F. virginiana, indigenous to the East Coast of North America, and F. chiloensis, native to Chile. Hybrids between these two species were produced naturally in Brest, France, early in the eighteenth century when a pistillate clone of the large-fruited F. chiloensis, introduced by Amedée François Frezier, a French army officer, was interplanted with staminate plants of F. virginiana.

The new hybrids (now known as Fragaria × ananassa, or pineapple-strawberry) initiated the modern strawberry industry. Breeding efforts through the years have resulted in tremendous advances as the plant was changed from a predominantly dioecious species with male and female plants to a hermaphroditic species, in which flowers contain both stamens and pistils. Fruit size has been greatly increased, and modern cultivars tend to be very firm-fleshed (too firm for some), with improved flavor and appearance. Although strawberries are grown in all temperate countries, the industry is now concentrated in some favored locations such as southern California in the United States, southern Spain, and various locations in Italy. Some strawberries now are grown in greenhouses.

The genus Rubus is very diverse. The cultivated Rubus species known as brambles includes red raspberry (R. idaeus), black raspberry (R. occidentalis), and blackberry (Rubus species), including various interspecific hybrids between raspberry and blackberry, such as loganberry, boysenberry, and tayberry. Brambles have delicious flavors but marketing has been a problem because of the soft texture of the fruit.

Cultivated species of Vaccinium and Ericaceae are berry crops domesticated in the twentieth century. Blueberry (various species) is native to the United States and grows in bushes of various heights. The blue fruits are easy to preserve by freezing and have become very popular in the United States because of their use as a fresh fruit and in muffins or pancakes. They are increasing in popularity in Europe and in New Zealand. The cranberry (V. macrocarpon) is an unusual berry crop because it is grown submerged in bogs. The fruits are too acid to be eaten raw and are consumed processed as jelly or as a sauce. In the United States cranberry is a favorite food for the feast of Thanksgiving.

Sweetened dilute cranberry juice, consumed alone or mixed with other fruit juices, has become popular because of its therapeutic benefits in urinary tract problems of women. Lingonberry (V. vitisidaea minus) is native to northern regions of Europe, Asia, and North America. The bright red fruit has long been gathered from wild stands in Scandinavia, and a large commerce developed from this source. Attempts to domesticate the crop are based on the management of natural stands. There are a number of other native Vacciniums, such as bilberry (V. myrtillus) and bog bilberry (V. uliginosum), that have been considered as possible domesticates.

Cultivated Ribes species include a number of popular berries such as black currant (Ribes nigrum), red and white currant (R. sativum and R. rubrum), and gooseberries (R. grossularia). They are too acid to be consumed fresh and are essentially used for jams, jellies, and juice. Black currant was the source of ribena syrup, widely fed to British children during World War II as a source of vitamins. Black currant is not widely grown in North America because cultivation was discouraged and even made illegal because the plants were alternate hosts for white pine blister rust.

APPLE

The apple is the pomaceous fruit of the apple tree, species Malus domestica in the rose family Rosaceae. It is one of the most widely cultivated tree fruits. The tree is small and deciduous, reaching 3 to 12 metres (9.8 to 39 ft) tall, with a broad, often densely twiggy crown. The leaves are alternately arranged simple ovals 5 to 12 cm long and 3–6 centimetres (1.2–2.4 in) broad on a 2 to 5 centimetres (0.79 to 2.0 in) petiole with an acute tip, serrated margin and a slightly downy underside. Blossoms are produced in spring simultaneously with the budding of the leaves. The flowers are white with a pink tinge that gradually fades, five petaled, and 2.5 to 3.5 centimetres (0.98 to 1.4 in) in diameter. The fruit matures in autumn, and is typically 5 to 9 centimetres (2.0 to 3.5 in) diameter. The center of the fruit contains five carpels arranged in a five-point star, each carpel containing one to three seeds.

The tree originated from Central Asia, where its wild ancestor is still found today. There are more than 7,500 known cultivars of apples resulting in range of desired characteristics. Cultivars vary in their yield and the ultimate size of the tree, even when grown on the same rootstock.

At least 55 million tonnes of apples were grown worldwide in 2005, with a value of about $10 billion. China produced about 35% of this total. The United States is the second leading producer, with more than 7.5% of the world production. Turkey, France, Italy and Iran are also among the leading apple exporters.

In India, Apple occupies nearly 12,141 hectares, mostly in temperate regions of Punjab, Uttar Pradesh, Himachal Pradesh and Kashmir and to a small extent in the Nilgiris.

Figure 1. A branch of Apple tree

Varieties

There are more than 7,500 known cultivars of apples. Different cultivars are available for temperate and subtropical climates. Reputedly the world's biggest collection of apple cultivars is housed at the National Fruit Collection in England. Most of these cultivars are bred for eating fresh (dessert apples), though some are cultivated specifically for cooking (cooking apples) or producing cider. Cider apples are typically too tart and astringent to eat fresh, but they give the beverage a rich flavour that dessert apples cannot.

Commercially popular apple cultivars are soft but crisp. Other desired qualities in modern commercial apple breeding are a colourful skin, absence of russeting, ease of shipping, lengthy storage ability, high yields, disease resistance, typical "Red Delicious" apple shape, long stem (to allow pesticides to penetrate the top of the fruit), and popular flavour. Modern apples are generally sweeter than older cultivars, as popular tastes in apples have varied over time. Most North Americans and Europeans favour sweet, subacid apples, but tart apples have a strong minority following. Extremely sweet apples with barely any acid flavour are popular in Asia and especially India.

Old cultivars are often oddly shaped, russeted, and have a variety of textures and colours. Some find them to have a better flavour than modern cultivators, but may have other problems which make them commercially unviable, such as low yield, liability to disease, or poor tolerance for storage or transport. A few old cultivars are still produced on a large scale, but many have been kept alive by home gardeners and farmers that sell directly to local markets. Many unusual and locally important cultivars with their own unique taste and appearance exist; apple conservation campaigns have sprung up around the world to preserve such local cultivars from extinction. In the United Kingdom old cultivars such as Cox's Orange Pippin and Egremont Russett are still commercially important even though by modern standards they are low yielding and disease prone.

Apple varieties fall into two categories : diploids and triploids. Diploids have plenty of good pollen and are self-fruitful. Triploids are self-unfruitful and become productive only when pollinated by using suitable pollenizer varieties. Even self-fruitful varieties have to be interplanted to get commercial crops through cross-pollination. Varieties selected for interplanting should sufficiently overlap in their blossoming periods. Important varieties are listed below :

- *Himachal Pradesh.* 'Red Delicious', 'Golden Delicious', 'Worester Pearmain', 'Newton Wonder' (all diploids), 'Cox's Orange Pippen' (triploid), 'King of Pippens' (No. 13), 'Starking (Royal) Delicious' and 'Richard'.
- *Kashmir Valley.* 'Red Delicious' (diploid), 'Baldwin' (triploid), 'Ambri Kashmiri', 'White Dotted Red' and 'Blood Red'.
- *Simla Hills.* 'Beauty of Bath' (triploid), 'Red Delicious', 'Jonathon', 'Rome Beauty' (all diploids), 'Early Shanburry', 'Red Astrachan', 'Red Sudeley', 'Stayman Winesap', 'Winter Banana' and 'Yellow Newton'.
- *Kumaon Hills.* 'James Grieve', 'Jonathon', 'Rome Beauty' (all diploids), 'Blenheim Orange Pippen', 'Delicious', 'Early Shanburry', 'Golden Pippen', 'King of Pippens', 'Rhymer' and 'Winter Banana'.
- *Kulu Valley.* 'Ben Davis', 'Red Delicious', 'Golden Delicious' (all diploids), 'Cox's Orange Tippen', 'Blenheim Orange', 'Baldwin' (all triploids), 'Red Astrachan', 'King of Pippens', 'Yellow Newton' and 'Granny Smith'.
- *Nilgiri.* 'Rome Beauty' (diploid) and 'Irish Peach'.

Propagation

Propagated mainly by shield-budding, bench-grafting and tongue-grafting on seedlings raised from seed. Use M. IX dwarfing stock and 7.5 to 9 metres if on seedling stock. Standardised clonal rootstocks of the Malling-Merton series are recommended where woolly aphis is serious.

Breeding

Like most perennial fruits, apples ordinarily propagate asexually by grafting. Seedling apples are an example of "Extreme heterozygotes", in that rather than inheriting DNA from their parents to create a new apple with those characteristics, they are instead different from their parents, sometimes radically. Most new apple cultivars originate as seedlings, which either arise by chance or are bred by deliberately crossing cultivars with promising characteristics. The words 'seedling', 'pippin', and 'kernel' in the name of an apple cultivar suggest that it originated as a seedling. Apples can also form bud sports (mutations on a single branch). Some bud sports turn out to be improved strains of the parent cultivar. Some differ sufficiently from the parent tree to be considered new cultivars

Breeders can produce more rigid apples through crossing. For example, the Excelsior Experiment Station of the University of Minnesota has, since the 1930s, introduced a steady progression of important hardy apples that are widely grown, both commercially and by backyard orchardists, throughout Minnesota and Wisconsin. Its most important introductions have included 'Haralson' (which is the most widely cultivated apple in Minnesota), 'Wealthy', 'Honeygold', and 'Honeycrisp'.

Apples have been acclimatised in Ecuador at very high altitudes, where they provide crops twice per year because of constant temperate conditions in a whole year.

Pollination

Apples are self-incompatible; they must cross-pollinate to develop fruit. During the flowering each season, apple growers usually provide pollinators to carry the pollen. Honeybee hives are most commonly used. Orchard mason bees are also used as supplemental pollinators in commercial orchards. Bumble bee queens are sometimes present in orchards, but not usually in enough quantity to be significant pollinators.

There are four to seven pollination groups in apples depending on climate:

- Group A – Early flowering, May 1 to 3 in England (Gravenstein, Red Astrachan)
- Group B – May 4 to 7 (Idared, McIntosh)
- Group C – Mid-season flowering, May 8 to 11 (Granny Smith, Cox's Orange Pippin)
- Group D – Mid/Late season flowering, May 12 to 15 (Golden Delicious, Calville blanc d'hiver)
- Group E – Late flowering, May 16 to 18 (Braeburn, Reinette d'Orléans)
- Group F – May 19 to 23 (Suntan)

– Group H – May 24 to 28 (Court-Pendu Gris) (also called Court-Pendu plat)

One cultivar can be pollinated by a compatible cultivar from the same group or close (A with A, or A with B, but not A with C or D).

Varieties are sometimes classed as to the day of peak bloom in the average 30 day blossom period, with pollinizers selected from varieties within a 6 day overlap period.

Maturation and Harvest

Cultivars vary in their yield and the ultimate size of the tree, even when grown on the same rootstock. Some cultivars, if left unpruned, will grow very large, which allows them to bear much more fruit, but makes harvesting very difficult. Mature trees typically bear 40–200 kilograms (88–440 lb) of apples each year, though productivity can be close to zero in poor years. Apples are harvested using three-point ladders that are designed to fit amongst the branches. Dwarf trees will bear about 10–80 kilograms (22–180 lb) of fruit per year.

Storage

Commercially, apples can be stored for some months in controlled-atmosphere chambers to delay ethylene-induced onset of ripening. Ripening begins when the fruit is removed. For home storage, most varieties of apple can be stored for approximately two weeks, when kept at the coolest part of the refrigerator (i.e. below 5°C). Some types of apple, including the Granny Smith and Fuji, have an even longer shelf life.

Pests and Diseases

The trees are susceptible to a number of fungal and bacterial diseases and insect pests. Many commercial orchards pursue an aggressive programme of chemical sprays to maintain high fruit quality, tree health, and high yields. A trend in orchard management is the use of organic methods. These use a less aggressive and direct methods of conventional farming. Instead of spraying potent chemicals, often shown to be potentially dangerous and maleficent to the tree in the long run, organic methods include encouraging or discouraging certain cycles and pests. To control a specific pest, organic growers might encourage the prosperity of its natural predator instead of outright killing it, and with it the natural biochemistry around the tree. Organic apples generally have the same or greater taste than conventionally grown apples, with reduced cosmetic appearances.

A wide range of pests and diseases can affect the plant; three of the more common diseases/pests are mildew, aphids and apple scab.

– *Mildew*: which is characterised by light grey powdery patches appearing on the leaves, shoots and flowers, normally in spring. The flowers will turn a creamy yellow colour and will not develop correctly. This can be treated in a manner not dissimilar from treating Botrytis; eliminating the conditions which caused the disease in the first place and burning the infected plants are among the recommended actions to take.

- *Aphids*: There are five species of aphids commonly found on apples: apple grain aphid, rosy apple aphid, apple aphid, spirea aphid and the woolly apple aphid. The aphid species can be identified by their colour, the time of year when they are present and by differences in the cornicles, which are small paired projections from the rear of aphids. Aphids feed on foliage using needlelike mouthparts to suck out plant juices. When present in high numbers, certain species may reduce tree growth and vigor.
- *Apple scab*: Symptoms of Scab are olive-green or brown blotches on the leaves. The blotches turn more brown as time progresses. Then brown scabs on the fruit (see apple picture on the left). The diseased leaves will fall early and the fruit will become increasingly covered in scabs - eventually the fruit skin will crack. Although there are chemicals to treat Scab, their use might not be encouraged as they are quite often systematic, which means they are absorbed by the tree, and spread throughout the fruit.

Among the most serious disease problems are fireblight, a bacterial disease; and Gymnosporangium rust, and black spot, two fungal diseases. Young apple trees are also prone to mammal pests like mice and deer, which feed on the soft bark of the trees, especially in winter.

APRICOT

The Apricot is a species of Prunus, classified with the plum in the subgenus Prunus. The native range is somewhat uncertain due to its extensive prehistoric cultivation, but most likely is northern and western China and Central Asia and possibly also Korea and Japan.

It is a small tree, 8–12 m tall, with a trunk up to 40 cm diameter and a dense, spreading canopy. The leaves are ovate, 5–9 cm long and 4–8 cm wide, with a rounded base, a pointed tip and a finely serrated margin. The flowers are 2–4.5 cm diameter, with five white to pinkish petals; they are produced singly or in pairs in early spring before the leaves. The fruit is a drupe similar to a small peach, 1.5–2.5 cm diameter (larger in some modern cultivars), from yellow to orange, often tinged red on the side most exposed to the sun; its surface is usually pubescent. The single seed is enclosed in a hard stony shell, often called a "stone", with a grainy, smooth texture except for three ridges running down one side.

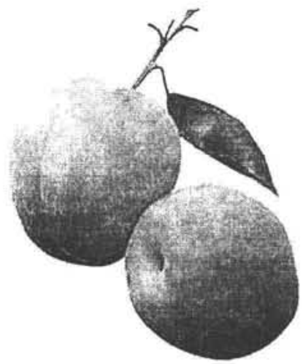

Figure 2. Apricot fruits

Cultivation

The Apricot was first cultivated in India in about 3000 BC. In Armenia it was known from ancient times, having been brought along the Silk Road; it has been cultivated there so long it is often thought to be native there. Its introduction to Greece is attributed to Alexander the Great, and the Roman General Lucullus (106-57 B.C.E.) also exported some trees, cherry, white heart cherry and apricot from Armenia to Europe. Subsequent sources were often much confused over the origin of the species. Loudon (1838) believed it had a wide native range including Armenia, Caucasus, the Himalaya, China and Japan.

Nearly all sources presume that because it is named armeniaca, the tree must be native to or have originated in Armenia as the Romans knew it. For example, De Poerderlé asserts: "Cet arbre tire son nom de l'Arménie, province d'Asie, d'où il est originaire et d'où il fut porté en Europe ...." ("this tree takes its name from Armenia, province of Asia, where it is native, and whence it was brought to Europe ....") There is no scientific evidence to support such a view. Today the cultivars have spread to all parts of the globe with climates that support it.

Apricots have been cultivated in Persia since antiquity, and dried ones were an important commodity on Persian trade routes. Apricots remain an important fruit in modern-day Iran where they are known under the common name of Zard-alu.

Egyptians usually dry apricot and sweeten it then use it to make a drink called "'amar al-din".

More recently, English settlers brought the apricot to the English colonies in the New World. Most of modern American production of apricots comes from the seedlings carried to the west coast by Spanish missionaries. Almost all U.S. production is in California, with some in Washington and Utah.

Many apricots are also cultivated in Australia, particularly South Australia where they are commonly grown in the region known as the Riverland and in a small town called Mypolonga in the Lower Murray region of the state. In states other than South Australia apricots are still grown, particularly in Tasmania and western Victoria and southwest New South Wales, but they are less common than in South Australia.

Although often thought of as a "subtropical" fruit, this is actually false - the Apricot is native to a continental climate region with cold winters, although can grow in Mediterranean climates very well. The tree is slightly more cold-hardy than the peach, tolerating winter temperatures as cold as -30 °C or lower if healthy. The limiting factor in apricot culture is spring frosts: They tend to flower very early, around the time of the vernal equinox even in northern locations like the Great Lakes region, meaning spring frost often kills the flowers. Furthermore, the trees are sensitive to temperature changes during the winter season. In their native China, winters can be very cold, but temperatures tend to be more stable than in Europe and especially North America, where large temperature swings can occur in winter. The trees do need some winter cold (even if minimal) to bear and grow properly and do well in Mediterranean climate locations since spring frosts are less severe but there is some cool winter weather to allow a proper dormancy. The dry climate of these areas is best for good fruit production. Hybridisation with the closely related Prunus sibirica (Siberian Apricot; hardy to -50°C but with less palatable fruit) offers options for breeding more cold-tolerant plants.

Apricot cultivars are most often grafted on plum or peach rootstocks. A cutting of an existing apricot plant provides the fruit characteristics such as flavour, size, etc., but the rootstock provides the growth characteristics of the plant. Apricots and plums can hybridise with each other and produce fruit that are variously called pluots, plumcots, or apriums.

Apricots have a chilling requirement of 300 to 900 chilling units. They are hardy in USDA zones 5 through 8. Some of the more popular cultivars of apricots include Blenheim, Wenatchee Moorpark, Tilton, and Perfection.

There is an old adage that an apricot tree will not grow far from the mother tree. The implication is that apricots are particular about the soil conditions in which they are grown. They prefer a well-drained soil with a pH of 6.0 to 7.0. If fertilizer is needed, as indicated by yellow-green leaves, then 1/4 pound of 10-10-10 fertilizer should be applied in the second year. Granular fertilizer should be scattered beneath the branches of the tree. An additional 1/4 pound should be applied for every year of age of the tree in early spring, before growth starts. Apricots are self-compatible and do not require pollinizer trees, with the exception of the 'Moongold' and 'Sungold' cultivars, which can pollinate each other. Apricots are susceptible to numerous bacterial diseases including bacterial canker and blast, bacterial spot and crown gall. They are susceptible to an even longer list of fungal diseases including brown rot, Alternaria spot and fruit rot, and powdery mildew. Other problems for apricots are nematodes and viral diseases, including graft-transmissible problems.

Varieties

The cultivated varieties of apricot are mainly exotic and they grow successfully at varying elevations. The following varieties are recommended : 'Shipley Early', 'Kaisha', 'New Castle', 'St. Ambroise', and 'Royal'. All these varieties are self-fruitful.

Propagation

Apricot is propagated by shield-budding on wild apricot stock, i.e. zardalu. Peach stock may also be used. Plant one-year-old grafts in autumn 6 to 7.5 metres apart.

Pruning

Apricot grafts usually have numerous lateral branches unlike the straight whips of apple, pear and cherry. If the laterals developed in the nursery are not properly spaced, cut off the main stem while planting, about 50 to 75 cm above the ground level to promote the growth of new laterals. During the first summer, remove all unwanted laterals, leaving three to five well-placed branches to form the framework. Head-back the scaffold branches breast-high next winter to get secondary scaffold branches. Leave the upper branches longer than the lower ones, as the latter grow faster and crowd out the upper branches. By the end of the second growing season, the tree produces a large number of laterals on the scaffold branches and trunk, which should all be removed, except a few short growths (7 cm to 12 cm long) on the trunk and the main branches. Retain only five to seven secondary scaffolds. In subsequent years, thin only the branches which are either crossing or crowding one another. This practice admits light into the centre and encourages the growth of spurs.

The pruning of old trees should aim at producing new spurs to replace those broken during picking. The kind and the amount of pruning depend upon the bearing habit of the variety. Light to moderate thinning of branches and the shortening of new wood back to the laterals is the usual practice. If new growth is less than 40 to 80 cm each year, resort to severe pruning.

Thinning

Thin the fruits 4 to 8 cm apart, leaving not more than two to three fruits on each spur.

Harvesting

The fruit should be picked when it is still hard, but has attained the proper colour. For drying, the fruit is harvested by hand-picking when it is fully ripe.

CHERRY

The word cherry refers to a fleshy fruit (drupe) that contains a single stony seed. The cherry belongs to the family Rosaceae, genus Prunus, along with almonds, peaches, plums, apricots and bird cherries. The subgenus, Cerasus, is distinguished by having the flowers in small corymbs of several together, and by having a smooth fruit with only a weak groove or none along one side. The subgenus is native to the temperate regions of the Northern Hemisphere, with two species in America, three in Europe, and the remainder in Asia. The word "cherry" comes from the French word "cerise", which comes in turn from the Latin words cerasum and Cerasus.

The Wild Cherry (P. avium) has given rise to the Sweet Cherry to which most cherry cultivars belong, and the Sour Cherry (P. cerasus) is used mainly for cooking. Both species originate in Europe and western Asia; they do not cross-pollinate each other. The other species, although having edible fruit, are not grown extensively for consumption, except in northern regions where the two main species will not grow. Irrigation, spraying, labor and their propensity to damage from rain and hail make cherries relatively expensive. Nonetheless, there is high demand for the fruit.

Major commercial cherry orchards in Europe extend from the Iberian peninsula east to Asia Minor, and to a smaller extent may also be grown in the Baltic States and southern Scandinavia. In the United States, most sweet cherries are grown in Washington, California and Oregon.

Important sweet cherry cultivars include "Bing," "Brooks," "Tulare," "King" and "Rainier." Both Oregon and Michigan provide light-colored "Royal Ann" ('Napoleon'; alternately "Queen Anne") cherries for the maraschino cherry process. Most sour (also called tart) cherries are grown in Michigan, followed by Utah, New York, and Washington. Additionally, native and non-native cherries grow well in Canada (Ontario and British Columbia). Sour cherries include Nanking and Evans Cherry. Traverse City, Michigan claims to be the "Cherry Capital of the World," hosting a National Cherry Festival and making the world's largest cherry pie. The specific region of Northern Michigan that is known the world over for tart cherry production is referred to as the "Traverse Bay" region. Farms in this region grown many varieties of cherries and companies like Traverse Bay Farms sell the fruit of the region.

In Australia the New South Wales town of Young is famous as the "Cherry Capital of Australia" and hosts the internationally famous National Cherry Festival. Popular varieties include the "Montmorency," "Morello," "North Star," "Early Richmond," "Titans" and "Lamberts."

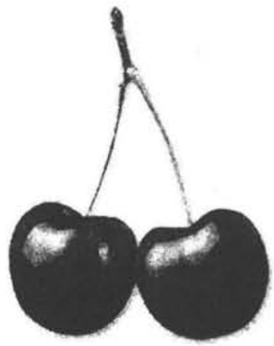

Figure 3. Sweet cherries

Cherries have a very long growing season and can grow anywhere, including the great cold of the tundra. In Australia they are usually at their peak around Christmas time, in southern Europe in June, in America in June, and in the UK in mid July, always in the summer season. In many parts of North America they are among the first tree fruits to ripen.

Annual world production (as of 2007) of domesticated cherries is about two million tonnes. Around 40% of world production originates in Europe and around 13% in the United States. The US is the world's second largest single country producer, after Turkey.

Varieties

Selected varieties of proven merit are : 'Early Rivers', 'Governor Wood', 'Bigarreau de Schreken', 'Elton','Bedford Prolific', 'White Bigarreau', 'Monstrueuse de Mezel', 'Bigarreau Napoleaon', 'Emperor Frencis' and 'Late Black Bigarreau'. It is desirable to choose varieties that will ripen in succession in order to obtain the crops over a longer period.

A large number of varieties are self-unfruitful and do not set fruits with their own pollen. As they are also cross-incompatible, only the compatible varieties, whose period of flowering overlaps to effect cross-pollination, should be interplanted to get commercial crops.

Propagation

The plants are propagated by whip or tongue grafting on seedlings of wild cherry stock, called paja. Grafts are ready for transplanting in two years. Sometimes, the rootstock plants are planted in permanent positions in the orchard and grafted in situ.

As cherry-trees are generally affected by frost, the site selected for planting should be such that the sun reaches the trees gradually. The distance between the trees varies from 9 to 12 metres, depending upon the variety. The trees should be properly staked after planting.

Pruning

Cherry-trees grow into shape without much pruning. Crowded branches should be thinned out and dead-wood removed in the dormant season. The pruned cuts should be painted with tar.

Manuring

Cherry orchards are best put under grass which is grazed by sheep. In addition to sheep manure, phosphate manures are applied to obtain a good growth of clovers. A dressing of fertilizers to supply 75 to 100 kg of N, 55 to 90 kg of P_2O_5 and 110 to 165 kg of K_2O per hectare may be recommended.

PEACH

The peach is known as a species of Prunus native to China that bears an edible juicy fruit also called a peach. It is a deciduous tree growing to 5–10 m tall, belonging to the subfamily Prunoideae of the family Rosaceae. It is classified with the almond in the subgenus Amygdalus within the genus Prunus, distinguished from the other subgenera by the corrugated seed shell.

The leaves are lanceolate, 7–15 cm long (3-6 in), 2–3 cm broad, pinnately veined. The flowers are produced in early spring before the leaves; they are solitary or paired, 2.5–3 cm diameter, pink, with five petals. The fruit is a drupe, with a single large seed encased in what appears to be wood, but isn't (called the "stone" or "pit"), yellow or whitish flesh, a delicate aroma, and a skin that is either velvety (peaches) or smooth (nectarines) in different cultivars. The flesh is very delicate and easily bruised in some cultivars, but is fairly firm in some commercial cultivars, especially when green. The seed is red-brown, oval shaped and approximately 1.3-2 cm long. Peaches, along with cherries, plums and apricots, are stone fruits (drupes). The tree is small, and up to 15 ft tall.

The scientific name persica, along with the word "peach" itself and its cognates in many European languages, derives from an early European belief that peaches were native to Persia (now Iran). The modern botanical consensus is that they originate in China, and were introduced to Persia and the Mediterranean region along the Silk Road before Christian times.

Figure 4. Peach

Cultivated peaches are divided into clingstones and freestones, depending on whether the flesh sticks to the stone or not; both can have either white or yellow flesh. Peaches with white flesh typically are very sweet with little acidity, while yellow-fleshed peaches typically have an acidic tang coupled with sweetness, though this also varies greatly. Both colours often have some red on their skin. Low-acid white-fleshed peaches are the most popular kinds in China, Japan, and neighbouring Asian countries, while Europeans and North Americans have historically favoured the acidic, yellow-fleshed kinds, though some prefer the other fruits.

In India, the area under peach (Prunus persica (L.) Stokes) is very small and is mainly located in the Himalayas at various elevations.

Varieties

Some of the promising varieties are 'Early Beatrice', 'Alexander', 'Early Rivers', 'Duke of York', 'Peregrime', 'Noblesse', 'Late Devonian', 'Elberta', 'J.H. Hale', and 'Triumph'. Except 'J.H. Hale', all other varieties are self-fruitful and set good crops without cross-pollination.

Propagation

Propagation is done by budding on seedling peach. One-year-old grafts are planted 6 to 8 metres apart in early spring. Immediately after planting, the trees are white-washed to protect the bark from the sun.

Pruning

At the time of planting, the stem is cut to about 0.6 metre from the ground and three to four branches are allowed to develop, distributed round the main stem. All other shoots that grow during the first summer are removed. During the first dormant season, two well-spaced secondary branches on each main branch are selected and the main branch is cut close to the secondary branches. During the second summer, water-sprouts, if any are removed. At the time of second pruning in winter, secondary branches are not cut, except to regulate the shape of the tree. In pruning, cut always to the outside buds to encourage a spreading shape.

In the case of bearing trees, annual pruning is necessary to maintain the centre open. Two- to three-year-old branches may be cut back to the outward-pointing side branches to encourage a spreading growth. Shorten and thin outside branches to stimulate the growth of new fruiting wood every year. A satisfactory annual growth should be 45 to 50 cm long.

Fruit-buds are borne laterally upon one-year-old wood and on short spur-like twigs. Ordinarily, they develop two fruit-buds and a leaf-bud at one node. The fruit-buds are usually located from the middle of the shoot upwards. In cutting away branches, the position of the fruit-buds should be taken into consideration.

Culture

A peach orchard should be regularly cultivated. Ploughing, which should not be deeper than 10 cm, is generally done in winter. A suitable cover or green-manure crop may be sown in the rainy season after the fruits are picked and ploughed-under during winter. A dose of fertilizers to supply 55 to 65 kg of N, 55 to 65 kg of P and 110 to 135 kg of K per hectare may be applied to the bearing trees in spring. Immediately after the natural fruit-drop in May and June, the fruits should be thinned out so as to have them 10 to 15 cm apart.

Harvesting

Peaches are picked when they are still hard, as they can ripen well during storage or in transit.

PEAR

The pear is an edible pomaceous fruit produced by a tree of genus Pyrus (pear tree). The pear is classified within Maloideae, a subfamily within Rosaceae. The apple (Malus ×domestica), which it resembles in floral structure, is also a member of this subfamily. The English word pear is probably from Common West Germanic *pera, probably a loanword of Vulgar Latin pira, the plural of pirum, akin to Greek api(r)os, which is likely of Semitic origin. The place name Perry can indicate the historical presence of pear trees. The term "pyriform" is sometimes used to describe something which is "pear-shaped".

Figure 5. Pear

Pear is grown mainly in the hills at elevations ranging from 1,500 to 2,500 metres. Its cultivation is rather restricted, mainly because the fruit does not store well. The pear may be readily raised by sowing the pips of ordinary cultivated or of wilding kinds, these forming what are known as free or pear stocks, on which the choicer varieties are grafted for increase. For new varieties the flowers can be cross-bred to preserve or combine desirable traits. The fruit of the pear is produced on spurs, which appear on shoots more than one year old.

Varieties

The following varieties are recommended : 'William Bon Christien' (Bartlett), 'Clapp'soil Favourits', 'Thimpsons', 'Doyenne du Comice', 'Easter Beurre', 'Winter Nalis', 'Conference', 'Dr, Jules Guyot', 'Marie Louise d'Uccle', Baggugosha (Citron des carmes) and Emile d'Heyst. Baggugosha can also be grown in the submontane tracts, but there its quality is poor. Nashpati is another variety that is grown successfully in the plains.

Pollination

Most of the pear varieties are self-unfruitful and the planting of pollenizer varieties is advocated. Nashpati is a self-fruitful variety.

Propagation

Pear is propagated by shield-budding which is done in June-July. The stocks are raised either from the seeds of a commercial variety or from those of wild pear, shegal (Pyrus pashia). To produce dwarf trees, quince 'C' stock is employed. Some varieties are not compatible with quince. They are propagated by double-working, using as intermediate a pear variety which can successfully be grown on the quince stock.

One-year-old grafts are planted in autumn. Those propagated on the quince stock are planted one to one-and-a-half metres apart, if they are trained as cordons. Those trained as pyramids are planted 3.5 to 4.5 m apart.

Pruning

Pears on the pear stock make vigorous growth and develop into large trees. They remain dwarf on the quince stock when they are trained into different forms. For the pyramid form, cut the graft while planting at about three-fourths of a metre above the ground. Next winter, prune the leader to about 25 cm and the laterals to about 20 cm to the outward-pointing buds. In the second summer, all the branch leaders and laterals should be pruned to five or six leaves from the clusters, allowing the central leader to grow unchecked. In the third winter, the central leader is cut back to about one-third its length, but the branch leaders and laterals are not pruned. In the third summer, the branch leaders and the laterals, except the central leader, are again cut back to five or six leaves as in the previous summer. In the fourth winter, the central leader is again cut back to one-third its length. By following this procedure, a pear-tree on the quince stock would start flowering in fourth year. The bearing pear-trees are pruned as in the case of apples.

Fruit-thinning

As a rule, less thinning is required in the case of pears than in the case of apples. One fruit per cluster in the case of prolific varieties and one to two fruits per cluster in others may be retained after thinning.

Manuring

The method of manuring and the time of its application are the same as for apples. The amount of nitrogen to be applied should, however, be a little more than in the case of apples.

Harvetsing

'Bartlett' is picked when still green and hard. The early varieties are packed without storing, whereas the late varieties require storing to develop full flavour. The fruit should be size-graded before storing.

Summer and autumn pears are gathered before they are fully ripe, while they are still green, but snap off when lifted. If left to ripen and turn yellow on the tree, the sugars will turn to starch crystals and the pear will have a gritty texture inside. In the case of the 'Passe Crassane', long the favored winter pear in France, the crop should be gathered at three different times, the first a fortnight or more before it is ripe, the second a week or ten days after that, and the third when fully ripe. The first gathering will come into eating latest, and thus the season of the fruit may be considerably prolonged.

PERSIMMON

Persimmon is grown in the Kulu Valley at elevations ranging from 900 to 1,500 kilometres. The promising varieties are 'Fuy', 'Hachiya' and 'Hyakume'. Several good varieties, such as 'Dai Dai', 'Maru' and 'Tenanshi', are also being grown successfully at the Pomological Station, Conoor in the Nilgiris in southern India. The tree is propagated by grafting (whip and tongue method) on seedlings of Diospyros lotus and D. virginiana. The grafts are planted in winter, 6.5 to 7.5 m apart.

Figure 6. Persimmon

The trees are headed back one or two metres above the ground at the planting time. Four to five shoots are allowed to grow round the stem to avoid narrow crotches and to develop a well-balanced head. There is no further pruning after this. Dead, broken and interfering branches are removed every year.

The fruit is picked when it has attained a yellowish or reddish colour, characteristic of the variety, when still hard. It is clipped from the tree, keeping intact the calyx and a short piece of the stem. It is wrapped up in tissue-paper and packed in a two-layer box for transport. With astringent varieties, the fruit has to be cured before it is fit for eating out of hand. The simplest method is to place the fruits in a closed chamber with other ripening fruits such as pears and tomatoes.

PLUM

Plum (Prunus domestica (L.) Stokes) is grown mainly in the Himalayas where the following varieties have been successfully grown : 'Grand Duke', 'Early Transparent Gage', 'Victoria', 'Santa Rosa', 'Wickson', 'Beauty' and 'Kelsey'. In the south, in the Nigiris and Kodaikanal in the Tamil Nadu stae, several choice varieties of the Japenese plum (P. salicina) are grown. The more important of these are 'Rubio', 'Alu Bokhara', 'Gaviota', 'Shiro', 'Combination' and 'Hale'. All varieties except 'Beauty', 'Santa Rosa', 'Gaviota', 'Rubio', 'Alu Bokhara' and 'Hale' which are self-fruitful, requires cross-pollination from other varieties. Plums are usually propagated by shield-budding on wild apricot or common peach stock. Planting, spacing, cultivation and fertilisation are the same as for peach.

Figure 7. Branch of a plum tree

Cultivation and Uses

Plum fruit is sweet and juicy and it can be eaten fresh or used in jam-making or other recipes. Plum juice can be fermented into plum wine; when distilled, this produces a brandy known in Eastern Europe as Slivovitz, Rakia, Tzuica or Palinka. Dried plums are known as prunes. Prunes are also sweet and juicy and contain several antioxidants.

Prune marketers in the United States have, in recent years, begun marketing their product as "dried plums". This is due to "prune" having negative connotations connected with elderly people suffering from constipation.

Various flavours of dried plum are available at Chinese grocers and specialty stores worldwide. They tend to be much drier than the standard prune. Cream, Ginsing, Spicy, and Salty are among the common variety flavours. Licorice is generally used to intensify the flavour of these plums and is used to make salty plum drinks and toppings for Shaved Ice or baobing.

Pickled plums are another type of preserve available in Asia and international specialty stores. The Japanese variety, called umeboshi, is often used for rice balls, called "Onigiri" or "Omusubi". The ume, from which umeboshi are made, is however more closely related to the apricot than to the plum.

Plums come in a wide variety of colours and sizes. Some are much firmer-fleshed than others and some have yellow, white, green or red flesh, with equally varying skin colour. Plums and prunes are known for their laxative effect. This effect has been attributed to various compounds present in the fruits, such as dietary fiber, sorbitol, and isatin. Prunes and prune juice are often used to help regulate the functioning of the digestive system.When it flowers in the early spring, a plum tree will be covered in blossom, and in a good year approximately 50% of the flowers will be pollinated and become plums. Flowering starts after 80 growing degree days.

If the weather is too dry the plums will not develop past a certain stage, but will fall from the tree while still tiny green buds, and if it is unseasonably wet or if the plums are not harvested as soon as they are ripe, the fruit may develop a fungal condition called brown rot. Brown rot is not toxic, and very small affected areas can be cut out of the fruit, but unless the rot is caught immediately the fruit will no longer be edible.

Pruning

Cut back the top to about 60 cm at planting time. Select three to five scaffold branches situated spirally round the stem, equidistant from one another, and remove the unwanted ones. At the time of first winter pruning, the main branches are headed back. All growth, except the main and secondary branches, is removed during the year. At the second winter pruning, crossing and other undesirable branches are removed. In the case of varieties having a tendency for upward growth, heading should be done to outward-pointing buds to make them more spreading. Subsequent pruning is carried out every year on similar lines. The pruning should be light as far as possible. The bearing trees are pruned to secure a balance between vegetative growth and fruiting.

Harvesting

For transporting, the fruits are picked a few days in advance of full maturity. The change of colour for each variety determines its stage of maturity. The fruits are required to be harvested in three or four pickings.

STRAWBERRY

The cultivated varieties of strawberry (Fragaria spp. grown in India are all imported. The following are recommended: 'Laxton's Latest', 'Royal Sovereign', 'Early Cambridge', 'Huxley Giant', 'Penomenol' and 'Robinson'.

Propagation

Maiden palnts (runners) that have not borne any crop are used for planting. The planting-distance is half a metre between plants and three-fourths to one metre between rows. Runners with a good root-system are used to set a new palntation. Transplanting is done in March-April in the hills and in January-February in the plains.

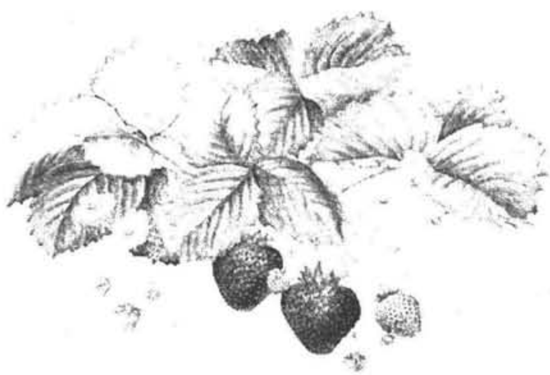

Figure 8. Strawberry

Culture

Prepare the land by ploughing deep, followed by harrowing. Add bulky organic manures. Keep down weeds by light hoeing and runners, as and when they form. Manuring is done in winter. When plants blossom in spring, bed the plantation with straw to keep fruits off the soil. After fruiting, remove the straw and weeds, and cut off all runners. Continue hoeing. Rotate strawberry with vegetables every three years.

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7

Commercial Grape Production

A grape is the non-climacteric fruit that grows on the perennial and deciduous woody vines of the genus *Vitis*. Grapes can be eaten raw or used for making jam, juice, jelly, vinegar, wine, grape seed extracts, raisins, and grape seed oil. Grapes are also used in some kinds of candy. Ancient Egyptian hieroglyphics show the cultivation of grapes. Scholars believe that ancient Greeks, Phoenicians and Romans also grew grapes both for eating and wine production. Later, the growing of grapes spread to Europe, North Africa, and eventually to the United States.

Grapes grow in clusters of 6 to 300, and can be crimson, black, dark blue, yellow, green and pink. "White" grapes are actually green in color, and are evolutionarily derived from the red grape. Mutations in two regulatory genes of white grapes turn off production of anthocyanins which are responsible for the color of red grapes.

Anthocyanins and other pigment chemicals of the larger family of polyphenols in red grapes are responsible for the varying shades of purple in red wines. Most grapes come from cultivars of *Vitis vinifera*, the European grapevine native to the Mediterranean and Central Asia.

Minor amounts of fruit and wine come from American and Asian species such as:

- *Vitis labrusca*, the North American table and grape juice grapevines, sometimes used for wine. Native to the Eastern United States and Canada.
- *Vitis riparia*, a wild vine of North America, sometimes used for winemaking and for jam. Native to the entire Eastern U.S. and north to Quebec.
- *Vitis rotundifolia*, the muscadines, used for jams and wine. Native to the Southeastern United States from Delaware to the Gulf of Mexico.
- *Vitis amurensis*, the most important Asian species.

DISTRIBUTION AND PRODUCTION

According to the Food and Agriculture Organisation, 75,866 square kilometres of the world are dedicated to grapes. Approximately 71% of world grape production is used for wine, 27% as fresh fruit, and 2% as dried fruit. A portion of grape production goes to producing grape juice to be reconstituted for fruits canned "with no added sugar" and "100% natural". The area dedicated to vineyards is increasing by about 2% per year.

The following table of top wine-producers shows the corresponding areas dedicated to grapes for wine making:

Country	*Area Dedicated*
Spain	11,750 km^2
France	8,640 km^2
Italy	8,270 km^2
Turkey	8,120 km^2
United States	4,150 km^2
Iran	2,860 km^2
Romania	2,480 km^2
Portugal	2,160 km^2
Argentina	2,080 km^2
Australia	1,642 km^2
Lebanon	1,122 km^2

THE GRAPEVINE

The growth habit of the grape is in many ways similar to that of other fruit crops. Yet it is sufficiently different to warrant special study to understand the application of many cultural practices. Grape flowers and fruit clusters are borne only on new shoots arising from dormant buds. These buds are formed in the axils of leaves the previous season and are called compound buds. This compound bud or eye contains a group of three separate buds.

When growth starts in the spring, the primary or central bud breaks dormancy and produces the fruiting shoot (Figure 1). On young vines, this shoot may remain entirely vegetative and produce no fruits. Grape shoots do not form terminal buds, and the tip typically dies back in the winter to the lignified or ripened portion of the cane.,

Spring frosts may occasionally kill the tender primary shoot in its early stages of growth. In this case, the secondary or tertiary buds in the eye develop shoots that may or may not bear fruit. This shoot normally is less vigorous and less productive than the primary shoot. However, this characteristic of the grape permits development of a partial crop even though the primary shoots are lost.

Figure 1. The fruiting shoot grows from the primary bud

Severe spring frosts may kill both primary and secondary buds. In such cases, fruit production is lost for that season, and the remaining shoot growth may be extremely vigorous.

Cluster initiation for next year's crop begins during mid-summer in the developing buds, which are in the leaf axils of the current season's shoots. By the end of the growing season, the buds are fully developed and contain leaf and cluster primordia.

The following spring as these buds begin growth, final development of the flowers occurs. By this time, shoots are 6-inches long, and clusters are clearly visible. Flowering or bloom occurs after the shoots reach 18 to 24 inches, or about four weeks after bud break.

Morphologically, the grape fruit cluster is a modified tendril. Whether a tendril or a flower cluster, development is determined by the vine's genetic code. The number of flower clusters that may develop from a single dormant bud is determined to a great extent by vine vigor and growing conditions, especially exposure to sunlight during the previous season.

Each grape species has a definite number of flower clusters per shoot. Location of these clusters on the shoot also is specific. The location and number of fruit clusters on the shoot are factors to consider in determining the vine training and pruning system. The American grape (Vitis labruscana) characteristically forms two to four flower clusters per shoot located at nodes 2, 3, 4, and 5 from the base of the shoot. Many species of grape, including most cultivars of V. vinifera, form only two flower clusters per shoot.

French hybrids as a group tend to flower prolifically, have four or more clusters per shoot, and produce flowering shoots from buds at the base of shoots and latent buds in the cordon as well as count buds in the canes.

Grapes flower later than most tree fruit and are mostly pollinated by wind. Fruit set is influenced by the weather, being greatest under sunny, warm, dry conditions.

Frequently during the growing season, a short, weak shoot is produced in the axil of the leaf adjacent to the bud and is known as a summer lateral. These lateral shoots can be important sources of photosynthetically active new leaves. However, they often do not mature well enough to survive the winter and are usually removed in dormant pruning.

After the leaves drop in the fall, the term cane is applied to the mature, dormant shoot. It is from these canes that next year's fruiting wood is selected at pruning time and from which propagation wood is taken.

The grapevine root system has important functions of moisture and nutrient element absorption as well as anchorage of the vine and production of plant hormones. In addition, the root system serves as the primary storage organ for the carbohydrate and nitrogen reserves required for early spring growth of the vine.

The root system is concentrated in the well-aerated upper 18 to 24 inches of soil but can penetrate deep into soil if not impeded by a hard pan or a high water table. By proper selection of rootstocks, grapevines can be grown in a wide range of soil types.

Grapevines require some kind of structural support for commercial and home production. The trellis or arbor provides support so the vine can be managed efficiently. This support exposes more foliage to sunlight, which increases bearing surface and improves fruit color and quality. Wire trellises, arbors, or other structures desired for a specific purpose or design may be used. Grapevines must be pruned annually to maintain productivity and fruit quality.

SITE SELECTION

Climate

General climatic conditions in many sections of the India are favorable for growing grapes. Most Indian and French hybrid grapes can be grown where the frost-free period is from 150 to 180 days. If the growing season is too short for a particular cultivar, fruit may not mature completely and may be poor in quality and low in sugar content at harvest. In addition, the vines may not mature properly in the fall, leading to possible winter injury. If the cultivar is not hardy enough to survive the winter, vine performance would be unsatisfactory.

Vineyard disease problems may be related in part to climate, especially humidity and temperature. Diseases such as black rot and downy mildew are more frequent under warmer temperatures and high humidity than in cooler, drier areas. Consequently, disease-control programmes may need altering from one climatic region to another, as from northern to southern parts of the region.

Winter Temperatures and Spring Frosts

The Concord cultivar is generally one of the most cold-hardy grapes commercially grown in the Midwestern United States. Other cultivars often are damaged more than Concord in any particular season. Some of the other cultivars commonly produced commercially are significantly less winter hardy than Concord.

Vines begin to acclimate or harden off to cold temperatures as they go dormant in the fall. Early in the winter months, vines may not have achieved adequate hardiness to withstand temperatures below 0°F. However, by the first week of January, vines have usually achieved maximum winter hardiness and may be able to withstand temperatures as low as -10°F to -30°F, depending on the cultivar. Consequently, the extent of cold damage that may occur is dependent on the time of the year and the level of cold. In addition, the pre-freeze conditions can also affect the amount of damage that occurs. This is especially true if there are warm periods (January thaws) followed by rapid drops in temperature. In many years, it is not the mid-winter cold that is responsible for cold injury but the fluctuating temperatures that occur in late winter.

By late winter, the rest requirement of the vine also has usually been achieved. After the winter rest period is completed, the vine is ready to grow, and only cold temperature keeps it dormant. Any significant warming can cause the vine to deacclimate (lose cold hardiness). If subsequent cold temperatures occur, vines frequently difficult to determine exactly when or how a vine was damaged unless it is periodically examined throughout the winter.

Once growth starts in the spring and the buds have extended to approximately 2 inches in length, they are susceptible to damage from temperatures below 28°F. Temperature variations caused by mesoclimates within a vineyard usually exist; temperatures usually are lowest near the ground, and they increase with elevation. Therefore, when possible, growers should establish vines on a trellis and grow them at a height of 5-1/2 to 6 feet.

Once primary buds are dead or damaged, various effects will result, depending on the variety. Although secondary buds generally will produce fruit, the crop will be significantly reduced.

Topography

Selection of a site with desirable climatological characteristics helps to reduce cultural problems and assure success of the vineyard. The best vineyard sites are those with full sunlight, freedom from frost injury, and good soil drainage.

The most frost-free sites are those higher than the surrounding areas. Cold air drains from higher sites into lower areas. Avoid low areas where cold air may settle, because injury is likely to be greater and yields are likely to be lower where low-temperature injury occurs. Sites south and east of the Great Lakes often provide favorable temperature conditions in both spring and fall. Even in these locations, vineyards on higher elevations are less subject to frost damage than those in low areas.

Generally, sites with steep slopes (15% or more) should be avoided in commercial plantings because of soil erosion and difficulty in operating vineyard equipment. Cool temperatures on northern slopes often delay vine growth enough in the spring to aid in avoiding frost damage. However, these slopes may be subject to harsher winter conditions. The opposite effect may occur on a southern slope, resulting in earlier spring growth and increased risk of frost injury. A western slope may have the disadvantage of exposure to prevailing winds that, in some areas or seasons, could be strong enough to damage vines and cause special trellising problems. On the other hand, movement of prevailing winds through a vineyard helps dry dew and rain from the foliage and helps reduce disease problems.

Monitoring or mapping of site conditions before planting is very desirable. Any prior knowledge of an area's elevation effects and other conditions may help producers locate their vineyard above certain critical levels and avoid damaging seasonal frosts. Advice from those who have grown fruit trees or vines in a given area can help potential producers find the elevation or location of the thermobelt and thus avoid undesirable areas.

Soils and Water Drainage

Grapes can be grown on a variety of soil types. However, the highest vine vigor and yield and the most efficient production are achieved on soils with good internal drainage. Water drainage means surface removal of water as well as percolation or internal movement of water. With good management, vineyards have produced satisfactorily on soils ranging from gravelly loams to heavy clay and silt clay loams.

Producers should avoid soils that are consistently wet during the growing season. These soils may have an impervious subsoil or other drainage problems. In poorly drained soil, roots may penetrate only 2 feet or less, whereas on a deep, well-drained soil, they will penetrate 6 feet or more. Soils with only fair drainage require more intensive soil management (e.g., tiling), and yields may not be satisfactory).

Just as cold air should not be allowed to stagnate on a vineyard site, neither should water be allowed to accumulate. The vineyard must be arranged so that no ponding or puddling of water will occur for extended periods following a rain. This is especially crucial during the growing season.

Subsoil characteristics are important when choosing a vineyard site because they often indicate the nature of internal drainage. For example, a bright, uniformly yellowish-brown subsoil indicates good internal drainage. Subsoils showing slight mottling of yellow, gray, and orange indicate only moderate drainage. Poorly drained subsoils are characterised by greater mottling or, in some cases, a uniform dark-gray color.

Internal water drainage is extremely important, especially for the more cold-tender French hybrid or vinifera grapes. A soil profile can allow water to move freely through it. However, many soils have fragipans, impermeable layers or texture changes that prevent free downward movement of water following rain or irrigation. Lateral movement of water at a given depth below the surface can result in overly wet conditions, harming the vines. Therefore, even a sloped vineyard can have problems with internal drainage. Operating equipment in wet vineyards in early spring or late fall can also cause compaction and create serious problems.

Producers should note that general soils and topographic maps that give the major soil types and conditions for an area are not sufficient to determine the best location for the vineyard.Specific sites for small acreage may be found that are considerably more favorable than the general map would indicate.

If the general topography (elevation, slope, etc.) is favorable but the internal drainage is imperfect, tile drains should be considered. Tile drainage generally improves most sites for the production of grapes and other fruit crops. Producers should carefully examine these conditions before the vineyard is planted.

Although grapevines grow and produce best on fertile, well-drained soils, naturally high fertility is not essential. Through proper fertilizer applications and soil management practices, even low-fertility soils can be improved to grow high yields of quality fruit. Thus, drainage considerations usually are more important than soil fertility when selecting a vineyard site. Improving soil fertility generally is more economical than compensating for poor water and air drainage on the site.

Because erosion is a major concern, most vineyard rows should be planted perpendicular to the predominant slope. Row directions running up and down slopes should be avoided. Contour plantings should also be avoided as they may introduce cultural or management problems and may result in weaker trellising.

CULTIVAR SELECTION

Selection of the proper cultivars to plant is a major step toward successful viticulture. Before planting, commercial growers should give serious thought to the market outlet and the requirements of the processor or consumer who will purchase the crop. Cultivars that are in greatest demand or sell for the highest price also are often the most difficult to produce.

Choosing a grape cultivar is based primarily on two major factors—market outlook and viticultural characteristics. Some important considerations are listed here, and these factors should be studied prior to planting. These considerations are listed in the order of importance:

- *Vine Hardiness:* Tolerance to low winter temperatures and/or spring frosts is often the limiting factor in cultivar selection.
- *Fruit Characteristics:* For a new grape cultivar to have real commercial value, it must first produce fruit that results in wine, juice, or eating quality that is superior or equal to the quality of available cultivars.
- *Season of Ripening:* Selected cultivars should be able to ripen their fruit and wood (hardening off) prior to the first killing frost in a given site. Late cultivars, for example, require a long growing season.
- *Tolerance of Diseases and Insects:* Resistance to the most common and destructive diseases and insect pests generally is not available in the present commercial cultivars. New cultivars that exhibit at least limited tolerance to some diseases or insects are highly desirable. Susceptible cultivars require more expensive cultural practices and in many cases should be avoided.
- *Vine Characteristics:* In addition to fruit quality, vine characteristics and productivity also must be superior to those of the cultivar being replaced. It is difficult to obtain a new cultivar with both fruit and vine characteristics superior to one already established, but this is the objective of the grape breeders. If the new cultivar has not been thoroughly evaluated by experiment stations or established with growers in similar climates and soil conditions, a trial planting should precede any extensive commercial planting.

American Cultivars

The American type (*e.g., Vitis labrusca, Vitis aestivalis, Vitis riparia*) has the widest distribution throughout the northern half of the United States. Major producing areas include the Great Lakes region, the Pacific Northwest, the Midwest, and eastern states from Delaware to New England.

Examples of important cultivars include Concord, Catawba, Delaware, Niagara, and Norton. Most American-type grapes are *slip-skinned*—that is, the flesh separates readily from the skin. Generally, they are processed into juices, jams, jellies, wine, or sherry. Well-managed vineyards have high yields of six to 12 tons per acre.

Table Grape Cultivars

Vinifera table grape cultivars, such as Thompson Seedless or Flame Seedless, do not have sufficient cold hardiness to be grown in the Midwest. Although Concord and many other seeded grapes such as Buffalo, Alden, Steuben, Seneca, Golden Muscat, Edelweiss, Swenson Red, Yates, and others are grown and consumed fresh, berries without seeds are most in demand for table use, and these will be listed separately due to their uniqueness.

Since fruit appearance and berry size greatly influence marketability, special cultural practices, such as application of gibberellic acid sprays, girdling, and thinning, must be used to produce table grapes commercially. Each cultivar demands a special mix of these practices for optimum marketability.

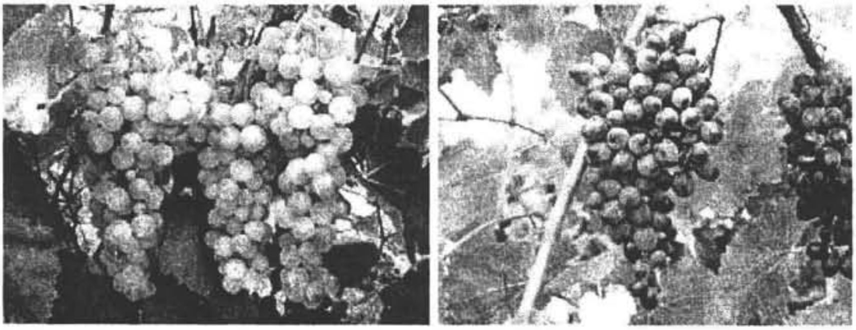


Figure 2. Márquis (L) and Jupiter (R) are new promising high-quality seedless table grape cultivars.

Hybrid Cultivars

The French-American hybrids have been widely planted in the Midwest since the mid-

1940s. This group includes new cultivars or interspecific hybrids produced by crossing European or Vinifera grapes with one of the American species. Many were introduced from French breeding programmes, and the cultivar name often includes the name of the breeder, for example, Vidal.

European Cultivars

European-type (*Vitis vinifera*) cultivars are most widely produced in warmer regions of the world such as California, Mediterranean countries (*e.g.*, France, Italy, Spain, North Africa), and Australia. Examples of widely grown vinifera cultivars are Thompson Seedless, Riesling, Chardonnay, Cabernet Sauvignon, Cabernet franc, and Merlot. Although cultivars vary slightly, fruit buds of most vinifera are injured at temperatures of -10°F, and vines are often killed if the temperature reaches -15°F or lower.

Special Cultural Practices Necessary for Vinifera Cultivars

Rootstocks: Vinifera cultivars are all susceptible to grape phylloxera (root form), which is endemic on wild grapes in the Midwest. Phylloxera feeds on the roots, weakening the vines, reducing yield and berry quality, and rendering the vine more susceptible to winter injury. Rootstocks resistant to phylloxera must be used and the selection based on the cultivar's vigor and soil conditions.

Protection of Graft Union: Hilling or mounding soil over the graft union and several inches up the trunk each fall can help protect the graft union even if cold injury or death occurs in the top of the vine. A new trunk can be initiated from this protected area, and production is lost for only one year.

Crop Management: Many vinifera cultivars have the potential to crop heavily and if crop load is not controlled, the vine carbohydrate reserves are not restored. Vines with inadequate reserves of carbohydrates stored in the canes, cordons, trunk, and roots are more susceptible to injury from cold and will be injured at milder temperatures than vines with adequate carbohydrate reserves. Vines carrying an excessive crop also are delayed in hardening off in the fall.

Leaf Quality: Most vinifera are susceptible to disease such as mildews that reduce leaf photosynthesis and impair carbohydrate production. Thus, a more thorough spray programme should be used to prevent leaf diseases.

Multiple Trunks: Since winter injury is probable, it is advisable to have multiple trunks (two to four) of different ages for vinifera. Often one trunk will be injured and develop crown gall, while another may escape.

Figure 3. Having multiple trunks is beneficial should winter injury occur. One trunk has been injured and has developed crown gall at the base, while the other trunk is still alive

GRAPEVINE PROPAGATION

In most instances, grape growers should purchase planting stock from nurseries or commercial propagators. Occasionally, however, it is necessary or desirable for growers to produce their own vines. For instance, it might be desirable to increase a new cultivar before a supply of plants is commercially available or to produce replacements for missing vines in an established vineyard. Growers should be aware that many new cultivars are patented, and propagation may be restricted.

Cultivars of grapes, like many other fruits, can be reproduced or propagated asexually. Grapes do not grow true from seed; that is, the seedlings will not be genetically identical to the cultivar that produced the seeds. Most grapevines are reproduced by hardwood cuttings or by layering of canes. These methods of asexual propagation ensure that the plants are genetically identical to their parents. In some instances, scions of healthy cultivars are grafted upon specific rootstocks. Cuttings or scions should always be taken from vines known to be true to name.

Field (Nursery) Propagation

The most common way to propagate grapes is by hardwood cuttings. Almost all commercially grown cultivars are easy to propagate from cuttings. Cuttings should be made from well-matured dormant canes of the preceding year's growth. The preferred cane size is 1/4 inch to 3/8 inch in diameter with 4- to 6-inch internodes.

Cuttings usually are made in late fall or early winter. Each cutting should contain three to four buds, although two-bud cuttings are satisfactory in mist or greenhouse propagation. Make the basal cut just below the lower bud, and the upper cut 1 to 2 inches above the top bud. Make cuts so that the upper and lower ends of the cutting can be easily identified.The cuttings may be sorted into uniform lengths and bundled for convenience in handling. Place the cuttings in cold storage (32°F to 35vF). Cuttings can also be stored by burying them in a well-drained trench and covering them with up to 3 inches of soil until spring. Buried cuttings should be mulched with 8 to 12 inches of straw for protection against severe cold.

As soon as the soil can be worked in spring, remove cuttings from storage or the trench and plant them in nursery rows. The rows should be located on deep, well-drained, fertile soil that is in a good state of tilth. Space rows 3 to 4 feet apart and make a furrow 6 to 7 inches deep. Set cuttings vertically in the furrow about 5 inches apart and firm soil with the top bud just above the soil surface. It is critical that the cuttings are set in the same direction that they were growing so that the basal end of the cutting is down and the distal end is up. The polarity must be maintained for the cuttings to root. Cuttings also can be planted through black plastic mulch to help control weeds and to retain heat and moisture.

As the season advances, shoots will develop from the above-ground bud, and roots will develop from the nodal regions below ground. Vines should be maintained in the nursery row in a high state of vigor during the growing season. Control of diseases, insects, and weeds in the nursery row is critical. Regular watering and application of fertilizer will ensure adequate growth. New vines will be ready for planting in the vineyard early the next spring. To compensate for cuttings that do not survive, start about twice as many cuttings as vines required.

Greenhouse Propagation

To produce new vines for spring planting during the same year, hardwood cuttings can be rooted during late winter under a mist system in the greenhouse (Figure 4). This method saves one year in the propagation of new vines over conventional outdoor rooting methods.

In early February, cuttings are removed from storage and inserted into a suitable rooting medium in the greenhouse (Figure 17). Vermiculite or peat/perlite is excellent for rooting because of their freedom from weed seeds and diseases. Sand or mixtures of sand and peat are also satisfactory.

Figure 4. Grapevine propagation in a greenhouse mist bench

Before insertion into rooting media, the lower ends of the cuttings can be dipped in a commercial rooting hormone such as indolebutyric acid. However, rooting hormones are generally not needed. A flat or greenhouse bench should be filled with media to a depth of 6 to 8 inches. Cuttings are planted so that the lower cut and node are pushed down to near the bottom of the flat or bed with the upper bud extended just above the media surface. Space cuttings 1 to 2 inches apart in rows 2 to 3 inches apart.

As soon as the cuttings are in place, mist them intermittently to maintain a high and constant relative humidity during the rooting period. A mist system that operates automatically for approximately 6 seconds every 6 to 10 minutes during the day is satisfactory. The duration and frequency of the mist may need to be adjusted as the cuttings begin to grow shoots and to account for sunny or cloudy conditions. The mist can be turned off at night.

Bottom heat provided by heating cable under the flats or in the bottom of a bench hastens rooting. Rooting is most satisfactory if day temperatures in the greenhouse are maintained between 65°F and 70°F and night temperatures around 60°F.

Usually, the cuttings develop roots and leaves within four to six weeks. At this time, the rooted cuttings can be transplanted into one- to two-gallon pots for easy transplanting to the field later. A suitable mixture for filling the pots is 1/3 peat, 1/3 sand, and 1/3 soil. Another alternative is a premixed commercial potting soil. Steam sterilisation of the soil mixture before filling the pots prevents weed growth and diseases.

After the rooted cuttings have been potted, place them back under the mist for a few days to allow the roots to become established in the new medium. Once established, the plants should be moved to a conventional area in the greenhouse. Moderate temperatures of 70°F to 75°F encourage growth of new vines.

Figure 5. Potted grapevine progagated from hardwood cutting in the greenhouse

The vines must be watered regularly and receive weekly applications of a dilute fertilizer solution to maintain growth. The fertilizer solution should contain nitrogen, phosphorus, and potassium. Minor elements are also desirable, depending on the potting mix used. Slow-release fertilizer mixes are also available and can be incorporated into the soil before transplanting.

Plants are ready for setting in the vineyard when new shoots are about 12 inches long. If plant growth becomes excessive in the greenhouse, lower temperatures must be used to slow growth and harden the vines before they are taken to the field. During the hardening-off period, maintain night temperatures at 40°F to 45°F and day temperatures at 65°F to 70°F. Regardless of the state of growth, new vines should not be transplanted until all hazard of frost is past. Greenhouse-grown plants are extremely sensitive to frost. Regularly inspect cuttings in the greenhouse for insects and diseases. Whiteflies and powdery mildew can be troublesome pests. To eliminate these pests, use an appropriate pesticide according to label directions.

Layering

All grape cultivars can be propagated by layering. This method is used primarily for replacing missing vines in established vineyards. However, it is too cumbersome for production of large numbers of plants. Layering is done in late winter or early spring. Vigorous one-year-old canes are used. The canes remain attached to the mother plant. This supports the establishment of a well-rooted plant during the first season. Lay the canes in a shallow trench dug in the desired location of the new vine. Place a two- to three-node section of the cane at the bottom of the trench. At least two distal buds should extend above the soil surface. Cover the part of the cane in the trench with 3 or 4 inches of soil and tamp firmly.

Roots normally develop from the covered nodes in a few weeks. Leaves and new shoots will develop from exposed terminal buds. During the growing season, any shoots developing between the layered area of the cane and the mother vine should be removed. New plants produced in a vacancy in the vineyard are left in place, and the connecting cane is cut off the following spring after the new vine is well established. If the layered vine is to be moved, it should be dug and transplanted after one year's growth.

Grafting

Grafting allows growers to propagate grape cultivars on a special rootstock, such as one resistant to certain root parasites. The European (vinifera) grape, for example, is highly susceptible to a destructive insect pest known as grape phylloxera or root louse. Consequently, cultivars of this species cannot be grown on their own root systems in phylloxera-infested soils. Therefore, it is necessary to graft European cultivars on phylloxera-resistant rootstocks to grow them successfully on many U.S. soils and those in other parts of the world. Experience indicates that rootstocks with high phylloxera resistance are also resistant to certain parasitic nematodes.

The use of resistant rootstocks for European cultivars is more important than for American and French hybrid grapes, with some exceptions. Therefore, most U.S. vineyards have been established with own-rooted vines, especially Concord. The root systems of these cultivars apparently carry considerable tolerance to phylloxera and other soil-borne parasites. However, differences in tolerance have been found in some American grape cultivars. Delaware, for example, has performed better on tolerant rootstocks than on its own roots.

Where vigor of own-rooted vines is characteristically low, favorable results can be expected from using resistant rootstocks. Poor vine vigor and productivity often occur on sites where old vines were removed and the vineyard replanted. In replant situations such as this, resistant rootstocks may prove a distinct advantage with American cultivars or with French hybrids.

Among the rootstocks carrying high resistance to phylloxera, nematodes, and possibly other soil-borne parasites are Couderc 3309, 5BB, and SO_4. These rootstocks are conventionally propagated by cuttings or layering. Once rooted, the stocks can be used for grafting to any desired cultivar. Bench grafting is commonly used in propagating grape cultivars (especially vinifera) on special rootstocks. This operation is conducted indoors and involves grafting of single bud scions onto rootstock cuttings (Figure 6).

Grafting is done in early spring before growth starts. Once callusing is complete, the grafted cuttings are planted into the nursery.

Figure 6. Bench grafting: Grafting machine with grafted and waxed cuttings.

Although top-working is not a common mode of propagation, it is possible to change over a grapevine or vineyard to another cultivar by using chip, cleft, or whip grafting techniques. Dormant scions must be used in all instances. Such grafting is most successful in midsummer. However, American cultivars are among the hardest to top-work.

VINEYARD ESTABLISHMENT

Site Preparation

Preparation of the proposed vineyard site is important and should begin the year before planting. A soil test should be conducted the season before planting to provide information on soil pH status, liming, and fertilizer requirements.

If soil pH is below 5.5, apply agricultural ground limestone to raise the pH to a more desirable level (5.5 to 6.8). The application should be made well before planting time and the limestone incorporated into the soil. For highly acidic subsoils, deep-plowing with limestone is recommended. Soil testing also will provide information on soil fertility and fertilizer needs for the first-year vineyard. Animal manures, when available, may be applied in the fall before spring planting of the vines. A suitable application is 10 to 12 tons of horse or cow manure per acre or 50 to 75 pounds per 100 square feet.

Site preparation in the year prior to planting should include land leveling, drainage tile installation (when needed), and fertility adjustments based on a soil test. At this time, growers also must pay special attention to controlling persistent weed pests such as thistle, Johnsongrass, quackgrass, dock, or woody species such as brambles.

Several safe and effective herbicides are available to control such troublesome weeds in the preparation period, but they cannot be used after the vines are planted. If possible, avoid sites that are severely infested with such weeds until the weeds have been eradicated. If the available site has internal drainage problems or areas where water will pond, install drainage tile and waterways before planting.

If the area to be planted is in sod and free of weeds, at least two options are open to the grower, depending on the topography of the site. If the proposed vineyard is on a hillside or sloping ground and erosion is a consideration, an approved systemic herbicide can be applied in the fall while the vegetation is actively growing. Herbicide is applied to the row area where the vines are to be established. The row middles will remain in sod. In fall or early spring, these row areas are tilled so the sod mat or ground cover is destroyed and a friable planting soil is established.

If the proposed vineyard site is located on relatively level or gently sloping ground so that erosion is not a serious consideration, or if it is necessary to apply lime, the site should be plowed in the fall to incorporate the lime and seeded to a suitable winter cover crop. One week before plowing, apply a systemic herbicide to kill spreading roots and rhizomes of perennial weeds.

Most grasses establish better if sown between mid-August and mid-September, rather than during the spring. An application of 35 pounds of actual nitrogen per acre at the time grass is sown will stimulate growth. Ordinary perennial ryegrass at 80 to 120 pounds per acre, Kentucky bluegrass at 20 pounds per acre, or a mixture of ryegrass and fescue, such as Companion grass at 20 pounds per acre, have proved to be adequate ground covers for vineyard row middles. If ample time is available, the best results are achieved by applying lime and fertilizer, plowing, and growing a cultivated crop on the site the season before planting the vines. However, you must be certain that the herbicide used will not carry over and affect the grapes the following year. When the crop is removed, drill the grass cover crop in the row middles.

Final site preparation should be made as early in the spring as the soil can be worked, preferably in late March or early April. After plowing or tilling, apply and disk (or till) the required fertilizer into the soil before setting the vines. Even though early spring preparation is advisable, it should not be done until the soil is dry enough to work properly. If soil is worked too wet, the advantages of early preparation will be lost because soil structure may be damaged. The effects of a *puddled* soil, particularly one with high clay content, may result in poor vine growth for a number of years.

Vineyard Design

The vineyard should be designed to achieve the following goals:

- Prevent soil erosion—the most important goal.
- Use land area efficiently.
- Optimise vine performance.
- Facilitate management and equipment operation.
- Vineyard rows need to be straight for trellis strength. On sloping land, rows should be across or perpendicular to the slope. It may be necessary to divide the vineyard into blocks to accommodate depressions or other characteristics. If erosion control can be accommodated, it is preferable to orient rows north-south. This orientation provides the most even distribution of light in the canopy and has been associated with improved yields and berry quality.

Row spacing depends in part on the proposed training and trellising system and the equipment to be used in the vineyard, such as a mechanical harvester. Nine- to 10-foot spacings between rows are common and generally ample, but 11 or even 12 feet between rows may be needed to accommodate divided training systems (*e.g.*, Geneva Double Curtain), large equipment, or steep slopes. An 8-foot spacing between rows is satisfactory for small plantings, but this is considered too restrictive for most commercial operations. In general, as distance between rows increases, yield per acre decreases.Spacing vines in the row at 8-foot intervals has proved satisfactory for average conditions. However, closer spacings have produced higher yields under certain conditions. Cultivars that produce less vigorous growth, such as Delaware, some French hybrids (Seyval and Chambourcin), and some vinifera, may be set closer together than Concord or others of similar vigor. Highest yields generally have been obtained from vineyards containing 600 or more vines per acre.

To create conventional, straight rows, establish a baseline along the edge of the field. Drive a stake at each end of the proposed line. Generally, these stakes are located by measuring a desired distance in from the edge of the field to allow turning space for equipment. By sighting from one stake to the other, additional stakes are placed on the baseline to mark it. A careful tractor operator can plow a furrow along the baseline, which also serves as the first row of grapes. There are several ways to establish rows parallel to the baseline or first row. A simple way is to establish a perpendicular line at each end of the row. First, set a stake on the baseline 30 feet from the end. Then, place a stake 40 feet from the end of the baseline on the assumed perpendicular line.

Measure the angular distance between the 30- and 40-foot stakes. If the distance is 50 feet, the assumed line is correct and can be extended by sighting. If it is not, move the 40-foot marker—not the 30-foot marker—until there is 50 feet between the two stakes. Stakes can be driven on this second base at the proper intervals to indicate the row ends.

The procedure used to mark the baseline is repeated until the required number of rows has been marked. A pole the length of the desired interval between vines can be used to space vines in the row as they are planted. However, a planting chain with lead markers at designated intervals is much more accurate.

It is important to leave enough space at the end of rows for machinery to turn. A 25- to 30-foot headland at each end of the vineyard should be adequate. It also is important to leave sufficient space on the sides of the vineyard to allow easy movement of equipment. If rows are long, 20- to 25-foot-wide crossing alleys at about 500-foot intervals will ease vineyard management.

Polyethylene Mulch Application

Black polyethylene mulch has been used successfully in establishing new vineyards. However, the introduction and the availability of approved pre-emergence herbicides and the increased cost of plastic have reduced its use. Its popularity may return if herbicides are withdrawn or become unavailable to growers. The planting procedure begins with thorough tillage of the row areas. One week before tillage, or earlier, apply a systemic herbicide to kill spreading roots and rhizomes of perennial weeds. A rotary-type tiller is recommended for soil preparation. Fertilizer and/or lime can be incorporated into the soil during tillage, as recommended by soil test results.

When the row is properly prepared and the fertilizer thoroughly tilled in, roll black plastic over the row, pull it tight, and hold the edges down with a small ridge of soil. Laying the plastic mulch is easy with modern equipment and requires little or no hand labor. In small plantings, lay the plastic by hand in a similar manner. Ordinary black plastic, 3- to 4-feet wide and 1.5 millimeters thick, is satisfactory. After the mulch is in place, mark off the plant spacings and set vines through the plastic. Plastic should be laid down well ahead of the planting. It is advisable to lay plastic when soil moisture conditions are near ideal because the soil dries slowly beneath the plastic. As soon as mulch is laid on some of the rows, planting can proceed as rapidly as possible, even on days when mulch laying or tilling is not advisable.

Vine Preparation and Planting

Handle young vines carefully to prevent drying out or other damage after they have been dug or received from the nursery. If dormant vines are not planted immediately, place them in cold storage until planting time. If proper facilities are not available, carefully heel-in vines in a sheltered location. To heel-in plants, dig a shallow trench and place vines in the trench so the tops are exposed. Cover the roots with soil and firm the soil. If the soil is not moist enough, water newly set vines to prevent the roots from drying out.

Vines should be transplanted to their permanent location as soon as possible. Soaking dormant vine roots in water two to three hours before planting also will increase their chance of survival. Early spring is the most suitable time for planting grapevines. Fall planting generally is not recommended because fall-set plants are likely to be lost to heaving during the first winter. If plants must be set in the fall, plow a 4- to 6-inch mound of soil around the base of the young vines, or mulch them with straw to protect against heaving and severe cold.

Do not prune roots except to remove broken or dead portions. Plant as much of the root as possible, ensuring good distribution in the trench or hole. Most of the reserves of the vine are stored in the roots and to ensure maximum growth, plant as much of the root system as possible. Normally vines purchased from a commercial nursery have been pruned, but if not, they should be pruned to a single cane.

It is critical to keep vine roots moist during planting and transporting to the field. Grafted grapevines should be set in the hole with the graft union several inches above the soil line and soil firmed around the roots. After soil settling, the graft union should be 2 to 3 inches above the soil line. Setting too deep will result in scion rooting and loss of phylloxera resistance of the rootstock. Non-grafted vines should be set with the junction of the older wood and new canes at the soil line.

To plant, plow a straight furrow 10 to 12 inches deep for the row. This depth will accommodate a large root system without packing a mass of roots into a small hole. Spread roots well, cover with a few inches of topsoil, and tamp firmly. A plow or disk may be used to finish filling the furrow. A short, 9- to 12-inch diameter, tractor-powered posthole auger also can be used for planting. In small plantings, the entire operation can be done by hand. In large operations, a commercial vine-planting machine often is used.

When planting is completed, the node from which the lowest cane will arise should be at or just above the soil level. Prune the single cane remaining after planting so that only two or three live buds remain. Some growers prefer to leave five or six buds. As these shoots develop, all but two of the most vigorous are removed when about one-inch long. This pruning provides two shoots to develop into vigorous new canes.

If polyethylene mulch is used, a common planting procedure is to force the long, narrow blade of a tilling spade through the plastic into the soil to a depth of 10 to 12 inches. The opening is widened by a back-and-forth motion, leaving an open hole. Insert the dormant vine and tamp soil firmly around the new plant. When vines are grown in pots or similar containers, an ordinary hand-type posthole digger is useful. After planting, pull the plastic closed around vines and place a small amount of soil on the surface.

Trellis Construction

Constructing the trellis can be the greatest cash expense in vineyard establishment, and it must be strong enough to carry heavy fruit loads and withstand strong winds. The trellis must be durable, and its real cost is determined by years of service, rather than initial cost. The physiological function of the trellis is to expose foliage and fruit to sunlight, and generally, the higher the trellis, the more foliage will be exposed and the more productive the vineyard. The best time to construct a trellis is during the first growing season or the following spring before growth begins. Waiting beyond this time will result in delayed harvest of profitable crops.

End posts should be large (4-1/2- to 6-inches diameter) and longer than line posts (9 to 10 feet instead of 8 feet) because they must serve as anchor points as well as wire supports. Copper-salts-treated pine, locust, and other suitable posts are commonly used. Posts should be pressure-treated as they will last 10 to 15 years longer than posts dipped in the same preservative. Set end posts about 3 feet in the ground and at a slight angle with the top leaning away from the direction of the row. The top should extend at least 6 feet above ground level after setting to support the top trellis wire at the desired height.

End posts can be braced in several ways. A common method is to set a screw anchor a few feet outside the end post. The angle of the wire attaching the anchor to the post should be about 34 degrees.

Another bracing method uses a brace wire from the top of the end post to a dead-man anchor in place of the screw anchor. The dead man is buried 36 to 48 inches from the post. A double-wire brace extends around the post near the top and to the anchor. The brace is tightened against the anchor by twisting the wires together. Other types of braces with the guy wire are available.

Line posts generally are cut 8- to 9-feet long with a minimum of 3-inches diameter at the top. They are set 24 to 30 inches deep and spaced 20 to 24 feet apart in the row. The exact spacing depends on vine spacing. It is suggested that posts be driven with a post pounder because it takes less installation time, and a driven post is more stable than a post set in an augured hole.

High-tensile-strength steel wire is becoming popular in newly set vineyards. Its strength and durability are in several ways superior to conventional wire. Because this wire has much greater tensile strength (200,000 psi), it must be handled differently than regular iron or galvanised wire.

Galvanised 9-gauge wire was the standard for many years. While high-tensile steel wire is initially more expensive than galvanised wire, it is more durable and may be the most economical over a long period. Rusted wire can seriously chafe vines. High-tensile-strength steel wire should have Class III galvanizing, and a wire gauge of 11 to 12.5 is acceptable, with 12.5 gauge most commonly used. The number of wires and their location depend on the training system.

The length of wire needed for an acre of grapes depends on row spacing, the gauge of wire used, and the training system. Wire is generally sold by weight, and the length in feet for 100 pounds of the following gauge wire is: 11 gauge = 2,617 feet; 12 gauge = 3,300 feet; 12.5 gauge = 3,846 feet. The weight needed for additional wires required by the training systems can be multiplied using the weight for a single wire.

Wires may be secured to end posts in various ways. A common method for galvanised or iron wire is to wind the wire around the post once or twice and then twist the end several times around the wire as it is stretched to the next post. Special devices also are available to attach the wires to the posts. These devices simplify adjustment of the wires by using a crank or a cinch that eliminates removal of wires from end posts when tightening or loosening. If high-tensile-strength steel wire is used, a special wire-crimping tool is required. There are also several types of wire anchors and connectors specifically designed for high-tensile wire.

Wires are fastened to line posts with ordinary staples or inserted in holes drilled in wooden line posts. The staples must be driven deep enough to hold the wires close to the post, but with enough play that the wire will slip through when tightening is needed. Staples are less likely to pull out if wires are hung on the windward side or the uphill side of posts. With steel posts, regular fence wire fasteners are used.

PRUNING AND TRAINING

Pruning and training are perhaps the most important cultural management practices for grapes. A thorough understanding of the concepts of pruning severity and crop load is critical to sustained production of high-quality fruit.

Pruning and Training Young Vines

Pruning and training of young grapevines are done to establish a vine form that meets the requirements of the training system. The grower should decide which training system to use prior to planting the vineyard. The information presented here will assume that the vines will be trained to a high cordon (HC) system, the most common training system for American and French hybrid wine grapes. Growers planning to use other training systems will need to make modifications to these directions.

Good vine growth during the first two years is critical to the future performance of the vineyard. Vines that do not establish well due to poor cultural management are usually set back several years. One main goal is to establish a large healthy root system by promoting maximum amounts of healthy, well-exposed foliage. To accomplish this goal during the first two years, care must be taken to train vines properly, control weeds, provide necessary nutrients, and control diseases and insects.

Once vines are planted, the grower has several options for pruning and training the vines. Support should be provided for young vines to keep them off the ground. This will greatly reduce disease problems and provide full sun exposure for maximum growth. The trellis can be established soon after planting to provide this support. If the trellis cannot be established during the planting year, then a single stake should be driven next to each plant, and the shoots tied to the stake. Though it is not necessary to establish the trellis during the planting year, doing so greatly facilitates vine training.

First-Year Management

Proper training begins during the year of planting, and the goal is to develop strong, straight shoots that are long enough to be retained as trunks for the second growing season. Shoot vigor is directly related to management of weeds and fertility. If weeds are controlled and if the vines receive adequate nitrogen fertilizer, then they should produce several shoots capable of reaching the top wire of the trellis system. In this case, the vines can be left unpruned, or pruned to six to eight buds after planting. Vines left unpruned will develop more functional leaf area and larger root systems than vines pruned to a small number of growing shoots. If, however, the grower is not prepared to adequately control weeds and provide needed nutrients, then unpruned vines are likely to produce several short shoots, none of which will be long enough to retain as trunks at the start of the second year. In this case, vines should be pruned to a few buds and all growth removed, except the two strongest shoots. This should assure that at least one shoot will be long enough to retain as a trunk. Generally, mistakes are made by rushing vineyard establishment when growers are not fully committed to good vineyard management. In this case, it is recommended that vineyard establishment be delayed until a commitment can be made.

Grow Tubes

In recent years, grow tubes, or vine shelters, have become popular for vineyard establishment. These plastic tubes create a greenhouse-like environment around the plant that promotes rapid shoot growth early in the season. This early rapid growth usually results in a single dominant shoot that has long internodes and is very straight.

The primary advantage of using grow tubes appears to be protection from broad-spectrum contact herbicides, such as glyphosate and paraquat, and animal depredation and a reduction in the time needed for early-season vine training. However, the time saving is generally offset by the labor required to install and remove the tubes. Protection of vines from post-emergent herbicides allows the grower to apply broad-spectrum herbicides easily and safely with conventional spraying equipment. Good weed control is critical for achieving acceptable vine growth, so this offers an advantage.

Grow tubes also keep the vines off the ground with minimal tying required during the first few weeks of growth. However, once the shoots grow out of the top of the tube, they must be tied to a string or a stake to prevent damage from wind blowing them across the top of the tube. Grow tubes must be removed in mid-August to early September to promote hardening of the new growth and aid in winter survival.

Second-Year Management

During the second year, the primary goal is much the same as the first year—maximizing vegetative growth. Weed management and nutrition are again critical for acceptable vine growth. At the start of the second year, canes of the previous year's growth will be retained to be the trunk(s). It is important to retain only healthy canes that are free of mechanical damage or winter injury, if the vine is to have good strong trunks that will be productive and healthy for several years. Additionally, the straightness of the trunks is determined at this time. Not only are straight trunks more esthetically pleasing, they are also easier to manage, especially if mechanised pruning and harvesting are planned.

One method to ensure straight trunks is to cut the cane off about 4 inches shorter than the top wire, tie a short piece of twine to the end of the cane and secure it tightly to the tensioned top wire. A second method is to tie a piece of twine from a spur at the base of the vine to the top wire. The cane is then gently wound around the piece of twine and tied to the top wire. Bamboo or wood stakes can also be used to train straight trunks, but they increase cost.

If a double trunk system is desired, then two canes are retained as trunks. If possible, the two canes should originate from below ground. Proper planting depth of own-rooted vines will encourage development of shoots from below the ground surface. On grafted vines (all European vinifera cultivars are grafted onto Phylloxera-resistant rootstocks and some hybrids are grafted to increase vigor), the shoots must originate from above the graft union, and the graft union must remain above the soil line to prevent scion rooting. If double trunks are desired, but there is only one cane of sufficient length and quality to retain as a trunk, then a shoot can be retained from the base of the vine during the second growing season. If none of the first-year canes is of sufficient length to reach the top wire, then the vine should be cut back to six to eight buds and handled as a first-year vine.

In addition to establishing the trunks, the cordons will be developed during the second season. Shoots are retained at the appropriate position and trained along the top wire. On moderately vigorous vines, thin to the best two to four shoots at the top of the trunks. On more vigorous vines, several shoots can be retained above the middle wire to increase the total leaf area. All shoots below the middle wire should be removed unless one is to be retained as a second trunk.

Some growers like to pinch the tips when these shoots reach the appropriate cordon length (4 ft. for 8-ft.-spaced vines). This promotes lateral branching and early development of spurs on the future cordon. However, some growers prefer to let the shoots grow full length and cut them back to the appropriate length at the beginning of the third season.

Third-Year Management

At the beginning of the third season, the best canes are retained to be the cordons. Other canes are cut back to renewal spurs or completely removed. If pencil-size lateral shoots are present on the cane and have persisted—are healthy and not winter damaged—they can be cut back to one- to two-node spurs.

The new cordons should be loosely wrapped about one full turn over the top wire. Securely attach the end of the cordon to the top wire with wire twist ties and loosely attach the base of the cordon to the top wire with plastic chain-lock or similar ties that are strong but loose. The cordon should be wrapped loosely around the top wire so there is room for it to expand over time.

Many growers reverse the direction that they wrap the cordon on each side of the vine to reduce the chances that the vine will unwind. That is, the cordon on one side of the vine is wrapped over then under the wire, and the cordon on the other side is wrapped under then over the wire.

Pruning Mature Vines

The primary purpose in pruning mature grapevines (four years and older) is to balance the amount of crop produced to the vine's capacity to ripen the crop. Understanding the relationship between pruning, yield, and vine vigor is a necessity for the grape grower.

Pruning modifies the size and form of the vine, making it possible to produce more high-quality fruit. At the same time, pruning helps the vine maintain adequate vegetative vigor for high yields in future crops. If training efforts during the first two years have been successful, the third-year vine is fully formed and trained for the desired training system. Consequently, the pruning procedure for a three-year-old vine is essentially the same as for a mature vine.

The wood remaining after pruning in the third season is used to produce the crop. The amount or extent of pruning is done in proportion to the amount of wood produced in the second growing season, or vine vigor. The same principle applies in the fourth and all consecutive seasons. By today's standards, a good mature Concord vineyard is capable of producing six or more tons of grapes per acre. If the vines are planted 8 feet apart in the row with 10 feet between rows, there will be 545 vines per acre. This means the average yield must be at least 22 pounds per vine. An average cluster of grapes usually weighs 3 to 4 ounces. Therefore, 80 to 100 clusters per vine are needed to produce 22 pounds of fruit. Because each fruit-bearing shoot produces one to three clusters, 40 to 50 shoots per vine can produce the crop.

A single shoot arises from a bud, but not all shoots flower and set fruit. Consequently, more than 50 buds per vine may be necessary to produce the 6-ton crop. French hybrids and vinifera cultivars differ from Concord; however, the principles are the same. The mature grapevine will have several hundred buds before pruning, and more than half are capable of producing fruiting shoots. If all buds remain, the vine will overcrop, resulting in delayed fruit maturity, small berries, and small clusters. More important, the vine will not produce enough good fruiting wood for the next year's crop. On the other hand, if the vine is over-pruned, the current season's crop will be reduced, and new growth may be overly vigorous. Excessively vigorous growth produces poor fruiting wood for the following season.

Time of Pruning

Grapevines can be pruned throughout the dormant season. However, fall-pruned vines are more prone to winter injury than those left unpruned. Growers should wait until late winter or early spring to prune so that uninjured canes can be selected for fruiting. Some cultivars are much more prone to winter injury than others, so if time is limited, growers can prune their hardiest cultivars first and the least hardy cultivars last.

Delaying pruning until later in the dormant season also tends to hold back growth that may be affected by untimely frosts. However, pruning should be completed before bud swell since cane removal may cause bud breakage, especially on vines trained with catch wires such as the vertical shoot-positioned system (VSP).

Types of Pruning

There are two basic types of pruning—cane pruning and spur pruning. These differ only in the length of the one-year-old fruiting wood that is retained. Cane pruning requires that long, 10- to 20-node fruiting canes be retained for fruiting. Spur pruning utilizes short, 2- to 6-node canes (called spurs) for fruiting.

Most cultivars will perform well using either cane or spur pruning. Some training systems employ both types of pruning. Some cultivars have been reported to perform better when cane pruned because the buds that are four to 12 nodes from the base of the cane are more fruitful than at the basal two or three nodes. Proper shoot positioning should improve fruitfulness of the basal nodes and make spur pruning feasible.

Some cultivars have a tendency to push many secondary and tertiary buds from canes and latent buds from cordons. Short spur (two node) pruning seems to exacerbate this problem whereas long spur (six node) or cane pruning seems to reduce this tendency. Whichever type of pruning is performed, the training system must effectively display the fruiting wood.

Balanced Pruning

Although 60 or more buds can easily be left on a grapevine, a crop of 6 tons per acre cannot be expected unless the vine has sufficient vigor to support such a fruit load. To determine the potential fruit capacity of a vine at pruning time, growers can use the concept of *balanced pruning*. The principle is valid for all grapes in general, but varies in magnitude from one cultivar to another.

Balanced Pruning Procedures

- Estimate the amount (weight) of one-year-old wood; select the fruiting canes to be retained; and remove all other one-year wood (leaving a margin of error).
- Weigh the one-year-old prunings from the vine to determine *vine size*. Weight of the one-year-old prunings is highly correlated to the total leaf area the vine possessed the previous season and, thus, its potential to mature a crop. After pruning and weighing a few vines, growers will make more accurate weight estimates. Only periodic weighing is necessary afterward. Note that wood older than one year, if removed, should not be counted as part of the pruning weight.
- Apply the vine size value to the pruning formula to determine the total number of buds to leave.
- For best results with Concord, use the (30 + 10) formula. This means that 30 buds are left for the first pound of prunings plus 10 buds for each additional pound of wood removed. If the prunings weigh 1 pound, leave 30 buds; if 2 pounds, leave 30 + 10 = 40 buds; if 2.5 pounds, leave 30 + 10 + 5 = 45 buds; and so on.
- Pruning formulas vary depending on the type of grape or cultivar.

- For example, if a Concord grapevine has a vine size of 3 pounds, then prune so that 30 + 10 + 10 = 50 buds remain on the vine.
- Using a cane-pruned training system (such as the Umbrella Kniffen), the grower would leave five or six canes, each with 10 to 12 good buds, plus some renewal spurs.
- Using a spur-pruned training system (such as the bi-lateral cordon), the grower would leave 10 or 12 fruiting spurs, each with 5 or 6 buds plus some renewal spurs.
- Leaving 10% to 20% more buds than called for by the balanced pruning formula will adjust for lack of fruitfulness. If winter injury is significant, then adjustment can be made for percentage live (or dead) buds.

Evaluating and Adjusting for Winter Injury

Cold injury to grape buds is relatively easy to detect. Using a sharp razor blade, make a series of cross-sectional cuts across the buds, getting deeper with each cut until the primary bud is exposed. Cutting too shallow reveals only the brown bud scales, and cutting too deeply misses the center of the bud and reveals the basal tissue, which may appear alive even if the bud is not. Live buds appear bright green while dead buds appear brown or black.

It is important to thoroughly sample the vineyard and properly handle the canes prior to evaluation of cold damage. Collect canes with 100 or so buds from each cultivar. A sample of ten 10-bud canes is usually sufficient. Samples should be collected after the end of the cold period has occurred, brought indoors, and allowed to warm for 24 to 48 hours to make the damaged buds easier to differentiate from live buds.

Samples should be representative of the type of wood that will be left at pruning in terms of the node position on the canes. For instance, f you normally spur prune to five or six node spurs, then you will want to pay particular attention to damage to the basal five or six buds. Depending on the circumstances, there can be considerable difference in cold damage to buds from the base to the tip of a cane. Keep track of the position of the buds as you cut and record the damage so you will know what part of the cane has the most damage.

Adjusting Pruning Level to Maintain Vine Balance

For cultivars in which secondary buds are not very fruitful, the general rule of thumb is as follows:

- If less than 15% of the primary buds have been killed, then prune as normal.
- If 15% to 50% have been killed, then adjust the pruning formula proportionally to the bud kill to account for the dead buds.

For instance, if you have 30% bud kill on Concord, you will want to leave 30% more buds than is called for by the 30 + 10 formula. For a vine that produced 2 lbs. of prunings, you would leave 40 + (30% x 40) = 40 + 12 or 52 buds. The extra buds retained should make up for the percent that has been killed and should produce fruit that will help keep the vine in balance.

It is important to determine if there is a relationship between bud kill and node position. If most of the damage is confined to basal buds (because they were shaded and did not acclimate well), then you would want to leave longer spurs rather than more short spurs to account for the total number of buds.

If more than 50% of the primary buds have been killed, then do not prune, or only prune to eliminate the canes close to the ground or out of the vine space. Wait until growth begins in the spring to prune these cultivars so that a more accurate assessment can be made.

For French hybrid cultivars that have fruitful secondary buds, the increase in number of buds to retain may not be proportional to bud damage. There is no exact formula to determine the number of extra buds to retain, but realize that some adjustment is necessary. It is always best to leave more buds than needed, rather than fewer. Final adjustments can be made by removing shoots after bud break.

Pruning to Avoid Frost Damage

Frost is another possible time of cold injury to buds following budbreak. Pruned vines tend to bud out earlier than unpruned vines. However, delaying pruning until after budbreak is not practical in most cases because cane removal may cause a significant amount of bud breakage. On cold tender cultivars and cultivars that bud out early (such as Marechal Foch), the best approach may be to do a first rough pruning, leaving considerably more buds than required (long spurs), then follow up to adjust bud number after budbreak. This approach, often called *double pruning*, can sometimes delay budbreak of the desired basal buds by up to two weeks. It is most practical on spur pruning systems such as high cordon or VSP.

Other Pruning Considerations

Pruning and cluster thinning: In general, pruning formulas work well for American and vinifera varieties. However, some French hybrids tend to overcrop (very fruitful buds) and using the pruning formula alone to control yield is not adequate. In this case, balanced pruning should be followed by cluster thinning. Examples of varieties that require cluster thinning include Chambourcin, Chancellor, Seyval, and Vidal.

Pruning and shoot thinning: Under conventional trellising systems, if more than 60 buds should be left on a pruned vine, considerable shading may occur. A general rule of thumb is that six shoots per foot of row are about the maximum that can be left and still achieve good sunlight distribution on the leaves. This varies somewhat with cultivars, but it is a good rule to follow. This means that vines spaced at 8 feet apart in the row will have the best sunlight distribution with about 50 shoots. Leaving an additional 10 buds can make up for blind nodes. Pre-bloom shoot thinning can be used to make the final adjustment in shoot number.

Disposal of Prunings

After the vine or vineyard section has been pruned, the prunings are placed between the rows. Prunings should be removed carefully from the trellis to avoid breaking those canes retained for production. The prunings may be removed from the vineyard or chopped between the rows with a heavy-duty rotary mower or flail mower. Most commercial vineyards chop the prunings, which reduces labor for this operation while adding a small amount of organic matter to the soil.

Training Systems

Training is the arrangement of the vine on the trellis. There are many different types of training systems for wine grapes, but all have the same goals:

- To position the annual shoot growth so that the fruit and leaves receive optimum exposure to light.
- To position the fruit for ease of pest control and ease of harvest.
- To facilitate pruning and other vineyard management operations.

Optimum sunlight exposure of leaves and fruit ensures good fruit quality and bud fruitfulness. Without adequate exposure, fruit quality suffers and vine productivity is reduced.

The most efficient training systems provide well-spaced, evenly distributed fruiting wood along the trellis to promote maximum interception of sunlight and provide optimum sun exposure for clusters and shoots. In addition, a well-designed training system will produce a high canopy surface area and low canopy density. This encourages high production of sugars with minimal effects of shading.

Researcher and grower experiences have shown that shoot density of about six shoots per foot of canopy is optimal. This should provide a canopy that has one to two layers of leaves and minimal shading. As shoot density gets higher, leaf layers increase and shading occurs.

Shading has detrimental effects on fruit quality, such as lower soluble solids; higher total acidity; higher pH; reduced color, anthocyanin, and phenolic content; and increased potassium content. Wine quality can be adversely affected by each of these changes. Understanding that sunlight exposure is necessary for good fruit quality is the basis of training and trellising system selection.

Choosing a Training System

Growers are advised and cautioned that there is no universal training system. One-size-fits-all does not apply in choosing a training system. With this in mind, a grower should realise that choosing a training system depends on several factors, including the anticipated vigor of the vineyard, cultivar to be planted, capital and annual labor cost, equipment used, and the potential to mechanise the vineyard. Trellis construction is one of the most expensive components of vineyard establishment. It makes sense to carefully consider the reasons for choosing a particular training system.

Anticipated Site Vigor

Anticipated or potential site vigor is probably one of the most important factors in selecting a training system, but it is difficult to assess. The selection of a training system and vine spacing should be based on the anticipated vigor of the vineyard.

Vine vigor is affected by rain, soil type, depth, fertility, water-holding capacity, and cultivar. Thus, information on these factors should be gathered to assess the anticipated vigor of the site as accurately as possible. New growers should check neighboring vineyards to have a general idea about vigor potential in their area.

Eventually, growers should be able to rank their new vineyard sites as low, moderate, or high vigor. In general, in a low-vigor site, choosing a non-divided canopy training system (e.g., VSP) is the most adequate, whereas in a high-vigor site, choosing among divided canopy training systems (e.g., GDC) is recommended. The choice of the training system must take into consideration cultivar and rootstock vigor, growth habit, cold hardiness, and disease susceptibility. The choice of the training system is often dependent on the growth habit of the cultivar being grown.

Most American and French hybrid cultivars tend to have a downward, or procumbent, growth habit. Therefore, a high training system, which allows ample distance for shoots to grow downward, is recommended. On the other hand, European, or vinifera cultivars, have a strong upright growth habit, especially early in the growing season. This growth habit is best managed with a low training system, which allows upward vertical shoot growth.

Common Training Systems

To date, there are more than a dozen training systems used throughout the world. Training systems used for wine production range from single to divided curtain systems with the High Cordon system being the most common. Although the High Cordon system is commonly used, it is not always the most adequate. A general description of each system and its pros and cons is presented here.

High Bi-Lateral Cordon (HC)

The HC or *single curtain* is the most commonly used training system. Two cordons extend along the top wire (5.5 to 6 feet above ground) of the trellis in each direction and meet cordons half way from adjacent vines. The cordons remain as semi-permanent extensions of the trunk, though they may need replacement every five or so years. A second training wire may be used at 36" to 42" above ground to provide extra support for young and mature vines and minimise breakage from strong winds. This system can be cane- or spur-pruned; however, the latter is more common. Fruiting spurs two- to six-nodes long are spaced along this cordon. Shorter renewal spurs are left to provide fruiting wood for the next season. The primary advantages of HC are low establishment and production costs and ease of mechanisation, including mechanical harvesting and pre-pruning. The high location of the fruit and renewal zones improves sunlight penetration, which thus has the potential to increase yield. Wildlife depredation (deer) and frost injury may also be minimised.

Umbrella Kniffin

Umbrella Kniffin (UK) used to be the most popular and common system in the Midwest and the East. This system utilizes long canes (10 to 20 buds each) that originate from renewal spurs at or near the top of the trunk. Four to six canes are retained, bent over the trellis wires, and tied securely. Mechanical damage to the tender buds during the tying process can be a problem, so pruning and tying must be finished before bud swell begins. Other drawbacks of this system include extra time and effort for tying, and difficulty in leaving extra buds to protect against damage from spring frosts (double pruning). Additionally, cane pruning cannot be mechanised. In recent years, UK has been used less in newly established vineyards.

Vertical-Shoot Position

This Vertical-Shoot Position (VSP) system is also called low- or mid-cordon system and is the most commonly used trellis worldwide on vinifera cultivars. Trunks are trained to a low (12") or mid wire (up to 42") with cordons or canes extending along this wire. Shoots are positioned vertically upward between two to three pairs of catch wires.

The first pair of catch wires is positioned about 10" above the cordon wire; the second and third at 12" and 24" above the first catch wires. Shoot positioning is done by either moving catch wires or by manually tucking shoots between fixed catch wires.

The advantage of this system is that the distance between rows can be reduced, allowing more efficient vineyard design and improved productivity. It is also easy to manage and mechanize. This system keeps the fruiting wood close to the ground to allow easy renewal of trunks in case of winter injury.

The disadvantages of VSP are lower light exposure than HC since the fruiting zone is at the base of the canopy; thus, lower yields than HC are expected. Furthermore, the proximity of the fruit zone to the ground makes it more susceptible to wildlife depredation and frost injury.

VSP is normally used under low- to moderate-vigor conditions. This system is most suited to cultivars with upright growth habit, including most vinifera cultivars and some hybrids (*e.g.*, Chancellor, Seyval, and Vignoles).

The Fan System

The Fan System (FS) is often used with cold tender cultivars to assure some live buds each year. This is a *spare-parts* approach in which several trunks of different ages are retained and spread out across a multiple wire trellis. Older trunks are often more susceptible to winter injury than young trunks but are also more fruitful, so trunks of different ages are saved to provide for continuous renewal of fruiting wood.

Fruiting wood is selected from canes on the different trunks. In case of winter injury to one trunk, additional buds are retained on the remaining trunks to balance the bud number. Fruiting wood may be pruned as long canes or short, depending on the degree of winter injury and available buds.

Geneva Double Curtain

As the name indicates, Geneva Double Curtain (GDC) was developed at the New York Agriculture Experiment Station in Geneva, New York, by the late Dr. Shaulis. This system is similar to HC but instead of having a single curtain of shoots, there are two horizontally divided curtains. These curtains are supported by fruiting wires that are separated by cross arms that are usually 4-feet wide.

Since the two curtains extend 2 feet on each side beyond the vine row, row spacing should be wider than other systems. Row spacing of 11 to 12 ft is generally recommended. Vines can be trained either with two cordons (bilateral) on one side of the canopy, or four cordons (quadrilateral), with two on each side of the canopy. At the same vine spacing, the bilateral cordons are twice as long as the quadrilateral cordons.

Field observations indicate that GDC with quadrilateral cordons produces more uniform bud break and shoot growth; cordons have less blind nodes and are quicker to replace in case of disease or winter injury than GDC with bilateral cordons.

The GDC system supports more growth and yields (30% or more, higher than HC) since shoot number and leaf surface areas are doubled. Thus, GDC is more suitable under high-vigor conditions where soils are deep and fertile. This system is also suitable to vigorous cultivars such as Concord, Frontenac, Norton, and Traminette and some table grapes.

GDC produces higher fruit quality, higher yields, and less disease incidence than other systems. Although GDC has a high establishment cost due to more trellising materials, the long-term benefits from higher revenues exceed the initial costs. A potential drawback of GDC under a hot climate is excessive fruit exposure to sunlight and heat, which may result in sunburn and may negatively affect flavor components, especially of white varieties.

Scott Henry

The Scott Henry (SH) system is similar to VSP, but curtains are vertically divided upward and downward. Vertical curtains are formed by alternating the fruiting zone height. Shoots from the upper canes (or cordons) are positioned vertically upward, while shoots from the lower canes (or cordons) are positioned downward, leaving an open space or window 8" to 10" wide between the two curtains.

SH is best adapted for moderate to high-vigor conditions. The SH trellis system uses 8 wires—two cordon wires, two pairs of catch wires for the upper curtain, and one pair for the lower curtain. Therefore, SH is more labor intensive than the previous trellising systems.

Advantages include higher yields and quality than VSP. Thus, the high establishment and production costs may prove to be worthwhile in the long-term. Another significant advantage of SH is reduction in bunch rot, which causes yearly crop losses for several cultivars grown under wet and humid conditions. Cultivars prone to bunch rot, such as Pinots and Vignoles, can benefit from this system.

Smart-Dyson

This Smart-Dyson (SD) system is similar to SH where curtains are vertically divided. Thus, SD has similar advantages to SH. The only difference with SH is that shoots in SD originate from the same cordon or fruiting zone. Also, SD requires one type of pruning called *spur pruning*, which is easier and less labor intensive than SH. This system is adaptable to machine harvesting, pre-pruning, and leaf removal. Smart-Dyson

Ballerina is a modification of the SD system, with very similar training except that the Ballerina is used more often in cases of retrofitting existing vineyards from VSP in case of excessive vigor.

As with SH, there is limited experience and research with SD, and further evaluation of this system is needed.

Lyre or U-System

The Lyre or U-System (U) is similar to VSP but with two curtains divided horizontally. Thus, this system is adapted to upright growing cultivars and is suitable to moderate and high-vigor conditions. As with other divided canopy systems, yields are increased due to increased shoot number and leaf area per acre.

However, the U system is the most expensive to build among all training systems. Furthermore, this system is difficult to mechanize. Because of the extensive cordon development required, this system is difficult to maintain in areas where cold injury is common.

Other Innovative Pruning and Training Systems

Another trend that has developed in recent years is the use of mechanical pruning, or minimal pruning, techniques. Much work has been done in New York and Arkansas to mechanise all aspects of grape production. Training systems employed are usually High Bilateral Cordon or Geneva Double Curtain. Pruning severity can range from closely approximating hand pruning to only minimal skirting of canes in the lower section of the trellis. These systems are probably best suited for juice grapes, but wine grapes are increasingly being grown using these systems.

CROP CONTROL AND CANOPY MANAGEMENT

Concept of Crop Control

Crop control is a vineyard practice that includes the physical adjustment of the vine as needed to balance the amount of fruit with the growth of foliage. This practice adjusts the crop level so there will be sufficient growth of shoots with leaves on each vine, and each shoot will be capable of maturing the fruit retained.

Growers often experience the adverse effects of allowing vines to overproduce and lose vigor. This leads to improper maturation of the crop and causes the vine to enter the winter in a weakened condition. Growers then realise that an effective crop control programme for each cultivar must be developed to keep the vineyard productive and healthy over an extended period. As more cold-tender cultivars are planted and the need for high quality increases, growers more than ever must use other methods in addition to balanced pruning to control the crop in a given year.

Crop Control on Young Vines

It has been shown that cropping of young vines can reduce the size of the root system and overall vine vigor. Unless vines are vigorous, fruit should not be retained during the first and second growing season. Remove flowers and fruit early in the season, when shoots are about 12-inches long. If the vines exhibit high vigor, a small amount of fruit can be left during the second season, but it should be only one or two clusters per plant.

Leaving a small amount of fruit helps the grower check for off-type vines early in the life of the vineyard so they can be removed and replaced. Additionally, the presence of fruit on vigorous vines helps slow vine growth in the fall and promotes shoot maturation.

Since the first three seasons are used to establish the vine form, there is usually a considerable amount of fruitful wood retained during the second and third seasons. This can lead to a crop potential that will exceed the capacity of the vine to support the fruit load in the third year.

About one half of a full crop of fruit can be retained during the third season if vine vigor is sufficient. Heavy fruiting of young vines will result in small vine size and reduced yields, and vines may need several years to recover and regain vigor. It is best to be patient and crop vines only after they are well established.

Canopy Management of Mature Vines

With the tremendous vineyard expansion during this decade, production is estimated to increase exponentially in the coming years. Winery owners and managers will be more selective and demand high-quality grapes.

The recognition of the important role of viticulture in the production of premium wines has led to considerable interest in viticulture practices that can improve wine quality. Among these practices, canopy management has made one of the biggest impacts in world viticulture in the last 20 years.

Therefore, to ensure the production of high-quality grapes, growers should embrace canopy management practices. These practices are usually conducted in fine-wine regions to produce premium fruit and wine. However, they are becoming a routine practice for vineyards seeking maximum wine quality.

Canopy management is the practice which results in the modification of position or amount of leaves, shoot, and fruit in space to achieve a desired arrangement. Vine canopy is the shoot system, which includes the stem, the leaves, and fruit clusters. In the viticulture world, canopy is described by its length, height, width, leaf area, number of leaf layers, and shoot density. Shoot density refers to the number of shoots per foot of row or foot of canopy.

Canopy management (CM) has several viticulture advantages, such as maximizing sunlight interception, which means minimizing shading, and very importantly, maintaining a balance between shoot growth and fruit production. The benefits of CM include:

- Increased air movement, which leads to faster drying time from rain and dew, and thus less disease pressure.
- Improved spray penetration and disease control.
- Improved fruit composition and varietal character.
- Increased bud fruitfulness.
- Improved winter hardiness.

There are five major steps or practices that growers should follow and apply to their vineyards. Some grape cultivars require all five steps; others require fewer; and certain cultivars require a repeat of some of the five steps.

The growing season also has a major impact on CM. Dry summers require fewer CM practices than wet summers. Growers have to follow the basics and fine-tune the steps according to cultivar, site, season, and their own experience. The five CM steps are listed here in chronological order of vine development throughout the growing season:

Step 1. Shoot Thinning (Suckering)

Suckering Trunks and Cordons: This consists of removal of suckers (unwanted shoots that grow on the trunk or cordon). One or two suckers are left at the base of the trunk only if a new trunk needs to be trained in second- and third-year vines, or if trunk replacement is deemed necessary due to injury—cold, disease, or mechanical injury. On the cordons, unfruitful shoots are removed first unless they are needed for spur renewal.

Once all shoot thinning is done, shoots should be spaced evenly along the cordon length and have a density of four to six shoots per foot of cordon or canopy. With 8-foot vine spacing, this corresponds to 32 to 48 shoots per vine on a single curtain/high cordon (HC) system, and 64 to 96 shoots per vine on a Geneva Double Curtain (GDC) training system. Note that with a divided canopy (*e.g.*, GDC and Scott Henry), there are two feet of canopy for each foot of row.

This is best done early in the season when shoots are about 1 to 3 inches (trunk suckering) to 6 to 12 inches (cordon suckering) long. At this stage, shoots are easily rubbed off; fruit clusters are visible to distinguish between fruitful and unfruitful shoots; and less labor is involved. Suckering may require more than one pass. Growers with frost-prone vineyard sites should plan to thin shoots after the spring frost threat has passed.

Step 2. Shoot Positioning

The best scenario is when shoots grow vertically (parallel to the trunk), either up or down, depending on the training system. In the real world, however, shoots tend to grow sideways and attach to the cordon wire with their tendrils. This is why shoot positioning is conducted to disallow lateral and horizontal shoot growth. Shoot positioning also allows the spread of shoots to promote an open canopy, improve spray penetration, and adhere to the shape of the given trellis system.

Combing: This is the generic term for positioning shoots downward. Combing is conducted on high training systems such as High Cordon (HC) and Geneva Double Curtain (GDC). Shoots are combed in a vertical downward position.

Tucking: This is the generic term for positioning shoots upward and is used on low training systems such as Vertical Shoot Position (VSP). Shoots are held upright by using two or three pairs of moveable catch wires, 10 to 12 inches apart. Sometimes extra tying with tape is needed in order to keep the shoots upright.

Combing/Tucking: Both practices are required in vertically divided canopies such as Scott Henry and Smart Dyson training systems. The upward growth of both systems is tucked between catch wires, and the downward growth is combed.

Timing is critical for reducing the amount of shoot breakage and ease of positioning. Growers should realise that the most important aspect is to reduce shading as soon as possible after bloom as fruit bud development begins about that time and sunlight exposure is critical for bud fruitfulness.

Step 3. Cluster Thinning

Growers are sometimes tempted to take the risk and avoid cluster-thinning altogether for quick vineyard production. Others do cluster thin and have in mind the long-term benefit of this practice for the well-being and life span of the vineyard.

Cluster thinning is a MUST for some cultivars that have very fruitful primary buds and tend to produce three or more clusters per shoot. Examples include Seyval, Chancellor, Vidal, and Chambourcin.

Among these cultivars, some also have fruitful secondary and base buds, which in turn produce several clusters per shoot. Seyval and Chancellor are good examples. These two varieties still produce a normal crop after losing their primary buds to cold injury.

There are two periods—before bloom (pre-bloom) and after fruit set (post fruit set).

Pre-Bloom Thinning: This consists of the removal of flower clusters. This practice can be done at the same time as shoot thinning.

The advantage of this timing is that clusters are easy to see; thus, thinning can be done quickly. By removing flower clusters this early, several things happen—berry set is improved (more berries per cluster as a result of less competition with fewer clusters), and berries are bigger at harvest. Other advantages include increased yield, increased sugars and flavors of the fruit, improved vine size and hardiness.

Disadvantages of early thinning include tighter clusters (as a result of increased fruit set and larger berries); thus, bunch rot can be a problem. Seyval produces large and tight clusters and is susceptible to bunch rot. Therefore, thinning before bloom is not recommended for Seyval. However, this practice is beneficial to cultivars that have loose clusters and are not susceptible to bunch rot, such as Chambourcin and Chancellor.

Post Fruit Set Thinning: In this case, berry set is less than that of pre-bloom thinning. There are fewer berries per cluster; thus clusters are looser, and bunch rot incidence is reduced. This practice is more common and recommended for cultivars susceptible to bunch rot, such as Seyval. With this method, yield, sugars, vine size, and hardiness are improved.

This method, however, is more time-consuming, hence more expensive—it is more difficult to see the fruit due to a more developed canopy. At this stage of shoot development, the vine canopy is about 75% formed.

The following rule of thumb for cluster thinning can be used as a general guideline:

- Remove all clusters from shoots less than 12 inches long.
- Leave one cluster per shoot for shoots 12 inches to 24 inches long.
- Leave two clusters per shoot for shoots more than 24 inches long.

Step 4. Leaf Removal (Pulling)

Leaves, and sometimes lateral shoots, are removed in the fruiting zone in order to accomplish two goals. First is to improve air movement and spray penetration, thus reducing bunch-rot infection. This is especially critical for cultivars susceptible to botrytis bunch rot such as Pinot noir, Pinot gris, Pinot blanc, Riesling, Vignoles, and Seyval.

Second is to improve sunlight exposure of fruit and basal buds. This results in better color for red wine varieties, and lower potassium and pH in the juice.

Leaf pulling is done on the shade side of the canopy, which is either the east side of a north-south row or the north side of an east-west row. One to three leaves are removed at the base of each shoot and around clusters. Leaf pulling is either minimally done or completely avoided (depending on the canopy thickness) on the sun side of a canopy in order to avoid sun burning of fruit. A disadvantage of leaf pulling is increased bird damage as result of exposed berries.

Leaf pulling is first performed after fruit set. One more cleanup pass may be necessary before veraison by removing old and yellow leaves. Leaf pulling should be avoided at or after veraison as this may lead to fruit sunburn.

Step 5. Shoot Hedging and Skirting

Shoot hedging consists of cutting shoots that grow beyond the allocated space in a given trellis system in order to control shoot length. It is called hedging for upward shoot training, such as on a VSP system, and skirting for downward shoot training, such as on a high cordon (HC) system. Shoot hedging may be required for VSP systems and upper canopies of Scott Henry (SH) and Smart Dyson (SD) systems. High cordon (HC) and GDC systems do not usually require skirting unless shoot tips interfere with traffic in row middles. In general, a minimum of 12 to 15 leaves per shoot should be left after hedging in order to mature the fruit and wood.

DISEASE MANAGEMENT

As with other fruit crops, the generally drier conditions in the western half of the United States are more conducive to organic grape production than in the humid East, particularly with respect to cultivation of *Vitis vinifera*. The many large-scale organic wine and table grape vineyards in California are testimony to the relative ease of organic grape culture in that part of the country. As recently as 1997, California had 96 percent of the country's organic grape acreage.

However, with careful attention to pest control and cultivar selection appropriate for each climate, grapes can be grown organically almost anywhere in the United States. Native American grape cultivars, or crosses between American grape cultivars and *Vitis vinifera*, known as French hybrids, may be easier to grow organically in the East, because of their generally greater resistance to pests.

In contrast to the West, organic viticulture in the eastern U.S. is still limited to a few innovative growers, and many questions remain about organic management practices, especially those regarding disease control in a humid climate. An eastern grower producing for the fresh market should have a disease-control plan. From 1990 to 1995, Cornell University researchers explored organic vineyard management in the Northeast in collaboration with grape growers.

In the East, several diseases can be devastating, but black rot (*Guignardia bidwellii*) is perhaps the most important of these to control. It only takes a few black, rotted grapes to render a cluster unsaleable on the fresh market. On the other hand, grapes produced primarily for juice, wine, or other processed products will have a slightly higher tolerance for cluster damage.

Northern growers should choose cultivars with proven cold hardiness for their particular climatic zone. The European wine grape (*Vitis vinifera*) is not well-adapted outside of USDA climate zone 8; zone 7 can be marginal. In zones 5 to 7, American types (mostly *V. labrusca*) or some of the American-European hybrids (French hybrids) are the best choices. There are some American types that are cold hardy in zones 3 and 4.

Extreme disease pressure makes organic culture of bunch grapes very difficult in the deep South. However, many cultivars of the indigenous muscadine grape, *V. rotundifolia*, are readily grown without pesticides of any sort. Muscadines have a special appeal in southern markets and are consumed fresh as well as processed into jams, preserves, juices, and wine.

Diseases Affecting Grapes

The simplest and most practical approach to disease problems on grapes is to plant disease-resistant varieties and to use certified disease-free stock. Unfortunately, the market often prefers those varieties not native to a particular region, and that are especially susceptible to diseases indigenous to the region. This is the case with the *V. vinifera* cultivars, the high-quality European wine grapes. In general, they are highly susceptible to all American grape diseases and pests, including downy mildew, black rot, Phomopsis leaf spot, powdery mildew, and phylloxera. If a grower in a humid climate decides to plant *V. vinifera* cultivars, the grower will likely be culturing a susceptible plant under environmental conditions that invite disease.

Therefore, profitable production of a marketable product without the use of fungicides will be very difficult. However, as already indicated, states with dry, Mediterranean climates are quite amenable to the culture of the European wine grape, and organically acceptable fungicides will be adequate for controlling most disease problems. Organic growers are allowed to use some mineral fungicides, since they are mined materials; however, sulfur and sulfur-containing fungicides can be disruptive to beneficial insects and other arthropods, such as spiders and mites that are present in the vineyard.

Another problem associated with the use of sulfur is tissue injury, or phytotoxicity. This damage can occur when sulfur is used while temperatures are above 85°F. Some cultivars, especially those of *V. labrusca* origin such as the Concord, are highly susceptible to sulfur injury even at lower temperatures.

Bordeaux mix is less likely to be phytotoxic than sulfur due to the "safening" influence of the lime. However, damage can still occur on sensitive cultivars, especially in high temperatures. Organically acceptable alternatives to mineral-based fungicides exist. A new generation of microbial fungicides, such as AQ-10™ and various commercial formulations of *Bacillus subtilis*, provide organic growers with new tools to manage plant diseases. New fungicides of this type, and new uses for previously registered microbials, appear regularly on the market. Compost teas have been successfully used in other plant production operations as a combined foliar feed and disease suppressive technique. There is potential for using aerobic compost tea in vineyards to manage diseases, but the parent material of the compost used to make the tea is an important consideration, as is the interval between last application of the tea and harvest.

Powdery Mildew

Vitis species differ greatly in susceptibility to powdery mildew. *V. vinifera* cultivars are highly susceptible, whereas American species are much less so. The French hybrids developed by crossing *V. vinifera* with American species have varying levels of resistance. Cabernet Franc, Cabernet Sauvignon, Chancellor, Chardonnay, Chelois, Gewurztraminer, Merlot, Pinot Blanc, Pinot Noir, Riesling, Rosette, Rougeon, Sauvignon blanc, Seyval, Vidal 256, and Vignoles are considered highly susceptible.

Powdery mildew can reduce vine growth, yield, fruit quality, and winter hardiness. The fungus that causes powdery mildew, *Uncinula nector*, overwinters inside dormant buds on the grapevine or on the surface of the vine. Its control in commercial vineyards generally is based on the use of fungicides. Sulfur is effective against powdery mildew, but, as mentioned above, care must be taken to avoid damage to sulfur-sensitive cultivars. Cultural practices may reduce the severity of powdery mildew. Planting in sites with good air circulation and sun exposure, and orienting rows to take advantage of these factors, are helpful.

The use of training systems that promote good air circulation should be incorporated. Some vineyards manage the leaf canopy by leaf thinning so that both leaves and grape clusters are exposed to good air circulation, allowing them to dry off quickly after heavy fogs or rainstorms, and thus helping reduce the possibility of infection. Although moisture is not necessary for powdery mildew infections to occur, rains and heavy fogs can help spread the spores.

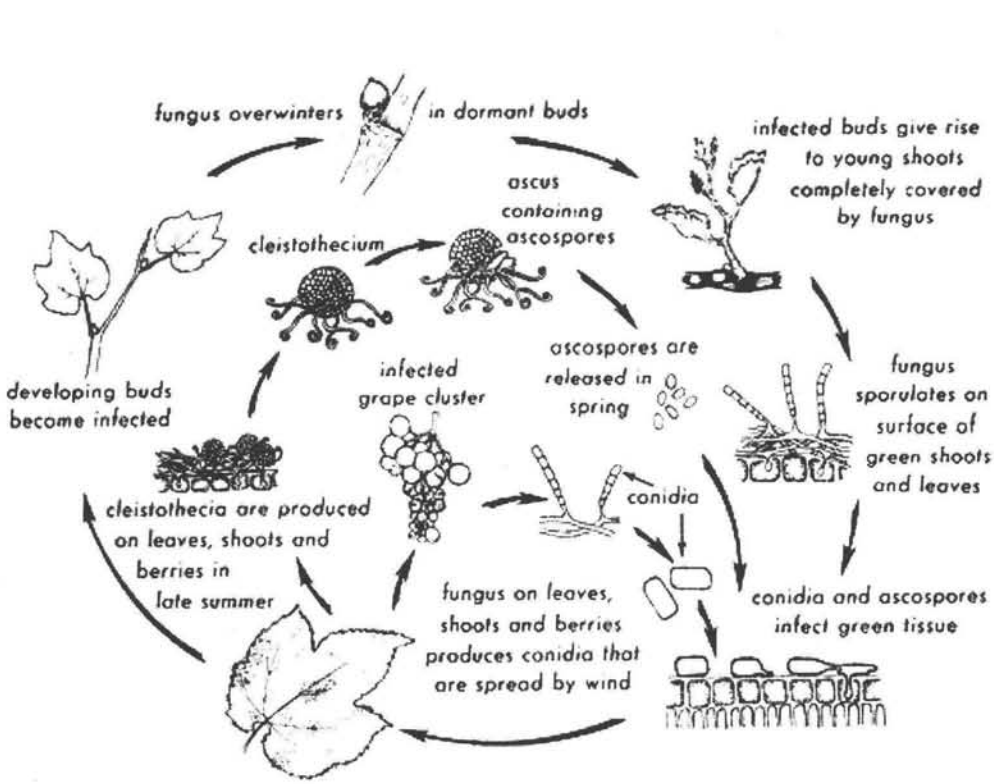


Figure 7. Powdery Mildew—Life cycle

Applied materials for managing powdery mildew include sulfur products, bicarbonates, oils, and biologicals, described in more detail below. Some formulations of sodium and potassium bicarbonate also have proven successful in controlling powdery mildew on grapes. Research in Germany demonstrated that sodium and potassium bicarbonate were highly effective against powdery mildew and can be used in organic viticulture to minimise sulfur or completely substitute the use of sulfur.

Calcium has been shown to inhibit fungal spore germination. Low calcium or excess nitrogen levels in the grape leaf tissue can set up conditions for powdery mildew. A 1:1 ratio of calcium to nitrogen in a tissue test is ideal. There is some evidence that foliar sprays of milk, diluted 1:10 with water, can reduce powdery mildew levels on grapes, although it is not clear if the fungal inhibition is a function of calcium/milk toxicity to fungal spores, competition from other organisms feeding on milk nutrients, increased calcium uptake by leaf cells resulting in stronger cell walls, or some combination of these factors. Whey is also used by some practitioners due to its availability and is diluted at a ratio of 1:3 (whey:water). The milk/whey formulations are most effective when used on varietals that have some resistance to powdery mildew.

Various formulations of oils, some of them botanically based, can be used to manage powdery mildew. Research in Germany demonstrated that rapeseed oil reduced the incidence of *Uncinula necator* by 66 to 99 percent and reduced the severity of the disease by 96 to 99.9 percent on ripening berries. However, some side effects on predatory mites were observed. A new product from Agraquest is also now available; Sonata is a formulation of *Bacillus pumilus* and is registered for use against powdery mildew on grapes. In the late 1980s and '90s, field and greenhouse studies on compost teas in Germany found that undiluted compost watery extracts were effective against the causative agent of powdery mildew, *Uncinula necator*.

The effects do not appear to be systemic, but are antagonistic in nature, correlating with high levels of active microbes on the leaf surface. More recent research from Germany supports these findings, but found that at high rates of infection pressure, compost extracts were not able to provide a sufficient level of protection against powdery mildew. More research is needed to better understand how the components of the extracts interact with powdery mildew spores and the time duration between application and harvest needed to ensure no contamination of the grapes by pathogens that may be in the compost teas.

Black Rot

Black rot is the most important disease facing eastern growers, yet it is virtually unknown in the West. Black rot is caused by the fungus *Guignardia bidwellii*. This fungus overwinters in mummified berries on the soil or in old clusters still on the vines. Fungal spores (ascospores) are spread by air currents and blowing rain, both in the early spring and throughout the growing season. All cultivated varieties of grapes are susceptible to infection by the black rot fungus. Proper sanitation is important in controlling black rot. Removing overwintering mummified berries from the vines and disking mummies into the soil are beneficial practices that reduce the amount of primary inoculum present in the spring. Black rot control for bunch grapes is very difficult in the East due to high humidity and foliage density.

For organic growers, liquid copper formulations, or copper-sulfur compounds such as Bordeaux mix, can be used for prevention of black rot, as well as suppression of powdery mildew, downy mildew, and phomopsis leaf spot. Some of the new microbial fungicides may provide control, though they may not yet be registered for use on grapes against black rot. Because copper and sulfur compounds cannot remedy an established infection, they must be used as protectants. That is, these compounds need to be present on the plant surfaces before an infection period is anticipated. In the case of black rot, growers with a history of the disease should begin spraying when the first vegetative shoots are 3 to 6 inches long. This is roughly when the pathogen begins releasing spores that may infect leaf or flower tissues. Protection should be maintained until the berries begin their final ripening stage. Depending on the cultivar, inoculum level, and weather conditions, it is possible that this could entail sprays every 7 to 14 days from bud break until mid-July or early August. For example, in the wet growing season of 1991, organically grown Seyval wine grapes required 17 fungicide applications for disease control.

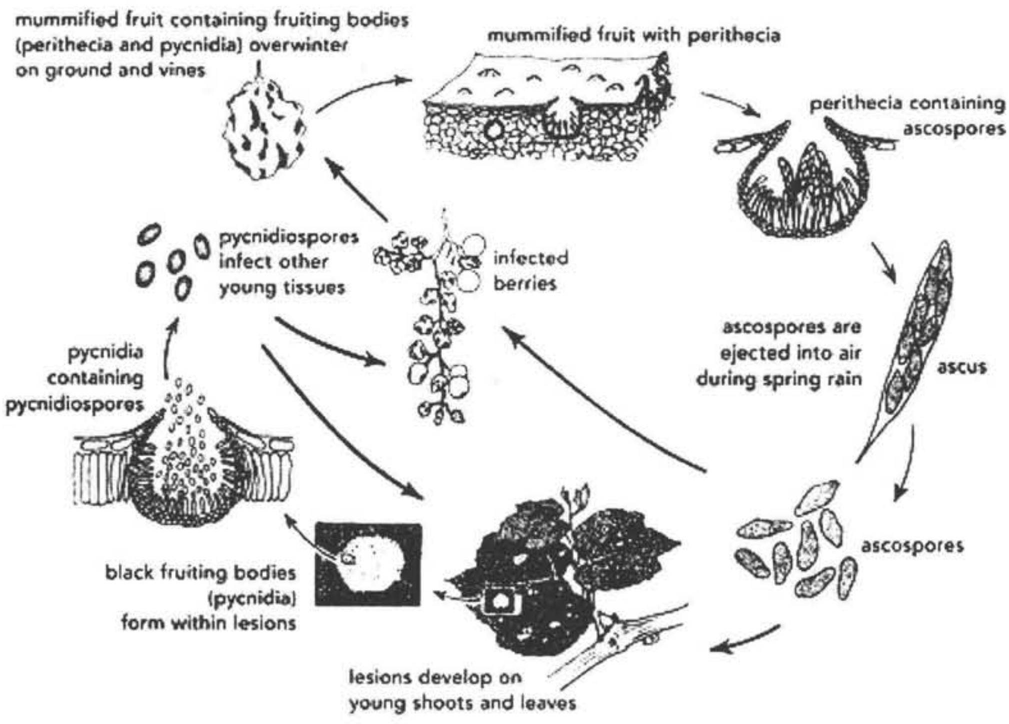


Figure 8. Black Rot—Disease Life cylce

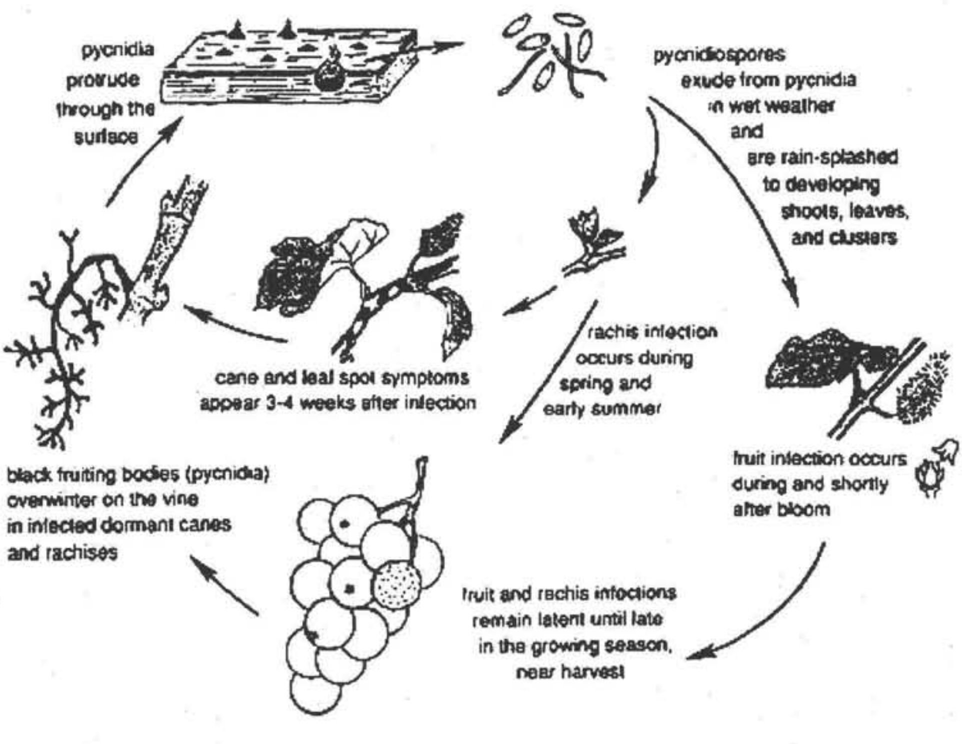
Serenade, a formulation of *Bacillus subtilis* QST 713 strain, has been effective in reducing incidence of black rot in grapes by 50-70% over control treatments of water. In other trials done by AgraQuest, Serenade plus yucca, which is a natural detergent and acts as a sticker/spreader, also provided good control of black rot.

However, because spores require free water and a certain temperature range for germination and infection, a rigorous spray schedule will probably not be necessary every year. Also, proper sanitation and good early-season control will help to reduce the inoculum levels of the pathogen.

With relatively resistant cultivars and good early season coverage, some eastern viticulturists have been able to control black rot with as few as two to four sprays of Bordeaux mix. There are few bunch grape cultivars with high levels of resistance, but some relatively resistant cultivars include Chambourcin, Cynthiana, Edelweiss, Elvira, Esprit, Foch, Ives, Cascade, Missouri Reisling, and Alwood. The non-bunching muscadine grape is very resistant to most races of *G. bidwellii*, but there are races of this fungus that are pathogenic to muscadines in some areas of the South.

Phomopsis

Phomopsis cane and leaf spot is caused by the fungus *Phomopsis viticola*. This fungus overwinters in the bark of the canes and can be especially severe in the early spring, when it rains for several consecutive days. Inoculum levels build over time, with disease problems increasing in severity with each su.:cessive cool, wet spring. Few cultivars are resistant to Phomopsis, though there are varying degrees of susceptibility.



Diseace Cycle of Phomopsis

Control of Phomopsis for the organic grower consists of a combination of appropriate sanitation measures and the use of liquid copper fungicides. Mycostop™, a commercial formulation of *Streptomyces griseoviridis*, is registered for use against Phomopsis. Growers should avoid introducing the problem into the vineyard by using only pathogen-free propagation material when planting or re-planting. Once the disease has appeared, growers should remove as much infected wood as possible from the vines during pruning. Severely infected wood in the basal areas of the cane appears bleached. Badly infected canes or spurs will have brown/black patches irregularly mixed with bleached areas. Debris should be shredded, disked, or plowed into the soil. In addition, measures such as avoiding shaded planting sites, providing good soil drainage and air circulation, and planting rows to take full advantage of sunlight and wind movement also can help control Phomopsis.

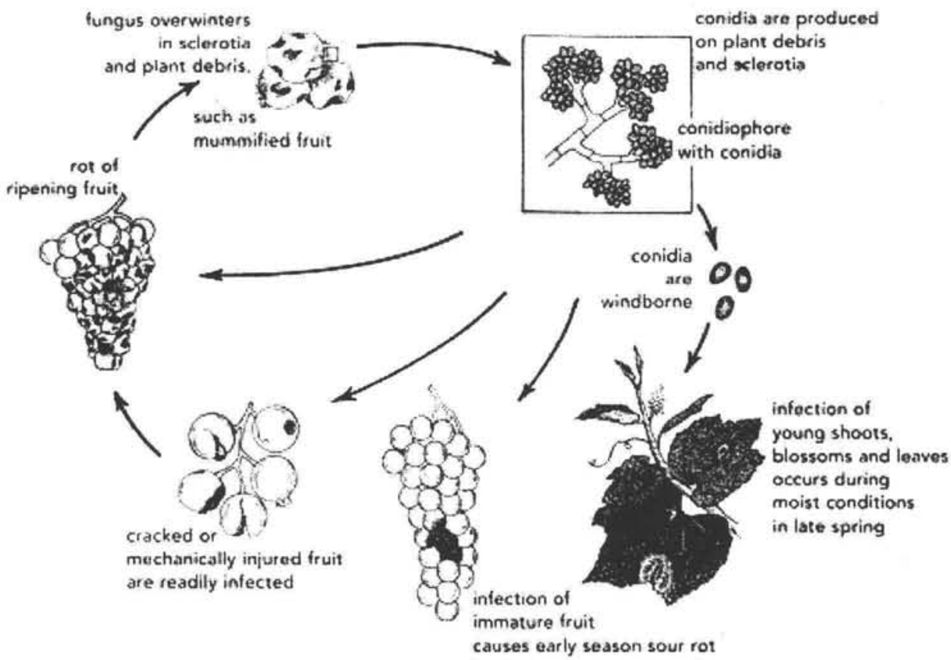
Downy Mildew

Another disease to which *V. vinifera* varieties are highly susceptible is downy mildew, caused by the fungus *Plasmopara viticola*. Downy mildew is a major disease of grapes throughout the eastern United States. It usually overwinters as spores in fallen leaves, but it may survive in buds as mycelium in regions with mild winters. Downy mildew is favored by all factors that increase the moisture content of soil, air, and host plants. Therefore, rain is the principal factor promoting epidemics. The most serious epidemics of downy mildew occur when a wet winter is followed by a wet spring and a warm summer with intermittent rainstorms every 8 to 15 days.

Preventative management practices for downy mildew consist of draining soils, reducing the sources of overwintering innoculum, pruning out the ends of infected shoots, and speeding the drying time of leaves and fruit. However, because none of these measures is sufficient for cultivars highly susceptible to downy mildew, fungicidal control may be necessary. As mentioned above, organic growers can use liquid copper, or Bordeaux mix, for control of this disease. Another option for downy mildew management is Trilogy, a commercial formulation derived from neem seeds, which is a broad spectrum fungicide and miticide.

Botrytis

Botrytis bunch rot (causal organism: *Botrytis cinerea*), also known as gray mold, can be a problem throughout the U.S., but is especially troublesome in wet or humid regions. Botrytis is more of a problem on varieties with tight clusters where moisture tends to collect. California research indicates that the incidence of botrytis bunch rot can be greatly reduced by removing leaves around a ripening cluster, thereby improving sunlight and air penetration into the cluster. Although this practice is labor intensive, and therefore relatively costly, it has positive side effects of increased fruit quality, including higher malic and total acids, decreased potassium, increased brix, and better grape color and wine quality. Reducing fertilisation, thereby reducing lush vine growth, will also help control botrytis.



Botrytis bunch rot —Disease Cylce

Bordeaux mixture and sulfur-containing fungicides are generally regarded as ineffective control measures against botrytis. New biofungicides are available for management of botrytis.

Pierce's Disease

Also known as PD, Pierce's Disease is a xylem-clogging bacterial (*Xylella fastidiosa*) infection generally fatal to European (vinifera) grape vines. The chief vector is the glassy-winged sharpshooter (GWSS). Both the GWSS and PD are endemic to the southern U.S., which would explain the native American grape's resistance to this pest, having co-evolved with the disease and the GWSS over tens of thousands of years. Some American grape rootstocks are able to transfer resistance to vinifera varieties grafted onto it. A

Texas researcher found that vinifera grapes planted on Mustang grape, *V. mustangensis* (synonym. *V. candicans*) rootstocks survived for eleven years in an area where PD had killed all other susceptible grape varieties.

The PD-GWSS complex is responsible for the difficulty of growing vinifera grapes in infested areas and has had heavy impacts on vinifera grape production in New Mexico, Arizona, and California. Chardonnay and Pinot Noir are particularly susceptible. Researchers in California and Georgia have examined applications of terpene, a naturally occurring botanical substance, via drip irrigation. Terpenes found in plants are often associated with plant defense mechanisms. Unfortunately, the trials in California did not show any significant effect in treating PD.

PD and the GWSS are severe obstacles to growing European-type grapes in the southern U.S. The PD-GWSS complex has recently become a threat to California grape growers. Although PD has been present in California since the 1880s, the strong-flying and voracious feeding glassywinged sharpshooter was found in Ventura, California, only in 1990 and has become the primary, though certainly not the only, vector of the pathogen. The presence of the GWSS in California has resulted in the rapid spread and transmission of the disease to grapevines and probably many other plant species. The blue-green sharpshooter (*Graphocephala atropunctata*) is the most important vector in coastal areas. The green sharpshooter (*Draeculacephala minerva*) and the red headed sharpshooter (*Carneocephala fulgida*) are also present in coastal areas but are more important as vectors of this disease in the Central Valley. Other sucking insects, such as grape leafhopper (*Erythroneura elegantula*) are not vectors. Management of this disease mostly revolves around management of the leafhopper vectors.

Root Rots

Good soil management, particularly practices that promote good soil drainage and avoid the creation of hard pans, will keep root rot problems caused by Phytophthora to a minimum. Standing water, or prolonged exposure of the trunk, crown or roots to water, will provide an environment on these plant parts that is infection-friendly. Armillaria root rot is a disease that results from planting vines on ground on which host plants previously grew, either natural oaks or orchards of walnuts or plums. The armillaria exists in old roots of these crops that are still in the soil. When planting a new vineyard in such an area, it is important that the new vines are not overwatered, and that they be planted into healthy, well-drained soil that has good biological activity, which will allow beneficial organisms to compete with the armillaria fungus.

INSECT AND MITE MANAGEMENT

Wherever grapes are grown, there will be insect pests. Existing with each pest, however, is a whole complex of natural controls, including parasites, predators, and diseases. One of the grower's jobs is to develop a viticulture ecosystem that takes advantage of and encourages these natural controls, while also feeding the soil and supporting plant health. Providing habitat for beneficial organisms is a sustainable approach to managing insect pests, but it must be tempered with awareness of how the presence and management of habitat influences field operations, as well as other factors, such as incidence of harmful insects and diseases.

In the West, mites, leafhoppers, and leafrollers are likely to be the most troublesome arthropod pests, and all of these are indirect pests; i.e., they do not directly attack the fruit. In general, indirect pests can be tolerated in higher numbers than direct pests, allowing more time for naturally occurring or purchased biocontrol agents to exert an acceptable level of control. Although the glassy-winged sharpshooter is considered an indirect pest, it has recently emerged as a major problem in California vineyards because it vectors Pierce's disease.

The major insect pest for eastern organic grape growers is the grape berry moth (*Endopiza viteana*). The berry moth is a direct pest of the fruit and flowers and, if left unchecked, can render whole clusters unmarketable. A pheromone-based mating-disruption system for the berry moth provides organic growers with an effective non-pesticide option for berry moth control.

Grape Berry Moth

The grape berry moth (GBM), *Endopiza viteana*, is native to eastern North America, where it originally occurred on wild grapes. It does extensive damage directly to grape berries, flowers, and buds east of the Rocky Mountains, particularly in the Northeast. It feeds only on grapes. The number of generations per year varies from 1.5 to 2 in New York, to 2 to 3 in Michigan, and 4 to 5 in Virginia. High populations and damage have been observed after consecutive mild winters. Substantial winter mortality occurs after several days of very cold temperatures (-6 to +5°F).

The only biological control agent that has been found to be of appreciable value is the egg parasite *Trichogramma minutum*, which can be purchased from many insectaries. However, the grape berry moth does not appear to be an optimal host for the egg parasite, and resulting adults have poor vigor and exhibit developmental abnormalities. It's possible that a different *T. minutum* ecotype, one that is naturally found parasitising eggs of the GBM, would be more effective.

Destruction of fallen grape leaves, which are overwintering sites for the cocoon-protected pupa, can help reduce spring populations. Covering leaves with at least an inch of firmed soil is another control option. One popular method is to throw the soil from the row centers into a low ridge under the grape trellis with a grape hoe, disk, or plow. This should be done 30 to 45 days before harvest. The row centers should be almost level and seeded to a winter cover crop.

In the spring, at least 15 days before grape bloom, the ridge soil containing the cocoons in its surface is pulled from under the trellis into the row centers with a mechanical grape hoe. Any islands of soil left around the posts and grapevines may have to be raked by hand into the row centers. The row centers are then disked and cultipacked to bury the cocoons. Rain or irrigation after this operation will help to seal in the cocoons. This practice has reduced berry moth populations to a point where shortened spray schedules can be used in commercial vineyards. There is a higher risk of developing GBM populations in vineyards bordering woodlands.

Pheromones can be used to monitor emerging populations. Pheromone traps can help time management activities, or pheromone dispensers can be used in a mating disruption system that disperses pheromones throughout the orchard, making it difficult for males to locate females.

Monitoring of Pheromone Systems

Timely use of *Bacillus thuringiensis* (Bt) can suppress populations of the grape berry moth. Use of pheromone traps can aid the grower in timing Bt applications. The Bt should be applied as the first instar larvae are hatching out of eggs.

Leafhoppers

Grape leafhoppers, *Erythroneura* species, also can be a serious problem throughout the United States, but these pests more consistently trouble West Coast vineyards.

Research in California indicates that biological control of grape leafhoppers by a tiny parasitoid wasp can be achieved if habitat for non-pest leafhopper species—especially blackberry bushes and French prune trees—is maintained near the vineyard. The bushes and trees attract related *Erythroneura* species of leafhoppers, providing an important food source for the parasitic wasp. However, maintaining diverse habitat in this manner may conflict with management for the glassy-winged sharpshooter.

Clean cultivation in and around the vineyard can help reduce leafhopper populations, because the adults overwinter in shelters provided by weeds in these areas. If leafhoppers are a problem, and the grower wants to use alley cover crops, then selecting those cover crops least attractive to leafhoppers is an option. Organic growers can use insecticidal soaps and the botanical insecticide sabadilla to control leafhoppers. Soap sprays are only effective if they cover the leafhopper; i.e., if there is no residual effect from soap left on a plant surface. PyGanic, a formulation of pyrethrins, is an effective control of leafhoppers and also listed by OMRI.

The glassy-winged sharpshooter, *Homalodisca coagulata*, emerged in the 1990s as a major pest of grapes in California. The GWSS feeds on stems and leaves of a wide range of plants and efficiently vectors Pierce's Disease (PD), a xylem-clogging bacterial infection generally fatal to grape vines. Although PD has been present in California since the 1880s, the strong-flying and voracious feeding GWSS has become the primary vector of the pathogen. PD and the GWSS are important obstacles to growing European-type grapes in the southern U.S. Riparian areas in the West have a wide variety of plants that are hosts to the GWSS and can be leafhopper corridors. Monitoring should be directed to areas of the vineyard closest to riparian zones.

Research in California has shown that, if properly managed, winter annual legume-grass cover crops—such as a vetch and oats mix—can reduce reliance on insecticides and miticides to control leafhoppers and spider mites in vineyards. This is in addition to the soil-improving and weed-suppressive benefits of cover crops. This research examined two cover crop systems: (1) cover crop biomass was cut and placed on row berms as a dry mulch to suppress weeds and reduce herbicides, and (2) cover crop biomass was cut and left in row middles. If sulfur dust was used sparingly in late spring and early summer, the presence of these cover crops increased early season activity of predatory mites, resulting in reduced spider mite infestations. Similarly, where leafhopper numbers were not very low and cover crops were properly maintained through early July, the presence of cover crops resulted in reduced infestations of leafhoppers. These reductions were attributed to enhanced activity of certain groups of spiders that consistently attained higher densities in the presence of cover crops, compared to the clean-cultivated systems. Leafhoppers also used the cover crops as non-host crops, which may have resulted in less time spent on vines.

Mites

Various mite species cause problems on grapes throughout the United States. Proper irrigation, dust reduction along roadways, and other practices that conserve and augment natural enemies (including predatory mites (*Metaseiulus*, *Typhlodromus*), sixspotted thrips (*Scolothrips sexmaculatus*), and other generalist predators) can help reduce spider mite problems.

In the West, the three major spider mite pests on wine grapes are Willamette mite, *Eotetranychus willamettei*, twospotted mite, *Tetranychus urticae*, and Pacific mite, *Tetranychus pacificus*. The most important mite prevention practice is dust control. Heat spikes in the weather, combined with dust-stressed plants, often result in a mite outbreak. Dust can be managed several ways: improving road surface from dirt to rock or gravel; using water, straw, or dust-suppressant compounds to prevent dust; reducing driving speed; and disking only every other alleyway—vehicle traffic is then routed on non disked rows to provide a dust-free pathway for machinery performing agricultural operations.

Growers in New Zealand use vegetable oil or fish oil as dormant sprays in combination with release of predatory mites. Soap sprays also can be effective against mites, but thorough spray coverage is essential, since the mites reside and feed primarily on the underside of the leaf surface. Soap spray should only be used early in the season because of the possibility of altering the taste of the grape or the wine. Neem-based products such as Trilogy™ are registered for use on spider mites, but like soap sprays, can negatively affect wine quality if used too close to harvest. Although sulfur dusts or pyrethrum can be used against mites, they are not commonly used since they can be disruptive to beneficial mites and other natural enemies of the pest mites, as well as natural enemies of leafhoppers.

The beneficial predatory mite *Metaseiulus occidentalis* is effective in controlling spider mites in California. Another predatory mite, *Typhlodromus pyri*, is effective against spider mites in locations as widespread as New Zealand and Oregon. These beneficial mites can be purchased from several insectaries in California and elsewhere. Maintaining a ground cover on the vineyard floor is advantageous to predatory mites and various beneficial insects such as green lacewings, sixspotted thrips, and minute pirate bugs.

Grape phylloxera

The grape phylloxera (*Daktulosphaira vitifoliae*) is a very small, aphid-like insect that is very difficult to see with the unaided eye. It has two forms—an aerial, leaf-galling form and a subterranean root-feeding form. Historically, the root form has been the more economically damaging of the two.

Phylloxera is most injurious to *V. vinifera* roots, but foliar feeding on all grape species can be severe enough to cause defoliation, although this is rare. Roots of *V. rupestris* and other American species are tolerant or relatively resistant, compared to *V. vinifera*, which is why *V. vinifera* is commonly grafted onto *V. rupestris* roots. Grafting onto American species practically eliminates phylloxera injury. Although there are no known controls for already infested roots, recent studies have shown that soil management practices can significantly influence the amount of root damage resulting from phylloxera-induced fungal infections. Phylloxera infestations in organically managed vineyards resulted in less root damage, compared to that caused by similar phylloxera populations in conventional vineyards. Root damage is caused primarily by secondary infections of plant pathogens at phylloxera feeding sites.

Caterpillars

Several lepidopterous species attack grapes, including the grape berry moth, orange tortrix, the omnivorous leafroller, cutworms, the grape leaf skeletoniser, beet armyworm, and the saltmarsh caterpillar. Providing habitat for beneficial organisms is an important management strategy to maintain "ecological pressure" against all life stages of these pests—eggs, larva, pupa and adult. Providing habitat for bats can help reduce these pests through direct predation—bats feed at dusk and at night, when many of the moth pests are flying—as well as through avoidance.

Mealybugs

Mealybugs are not a major pest in the Northeast or the South, but three species—the grape mealybug, *Pseudococcus maritimus*; the obscure mealybug, *Pseudococcus viburni*; and the longtailed mealybug, *Pseudococcus longispinus*—can become pests in California vineyards. Natural controls generally keep these pests in check, although ants must be controlled if they are milking the mealybugs and warding off natural enemies. Trilogy™, a formulation derived from neem. Female mealybugs can not fly, so must rely on other means of transport to spread, such as equipment, birds, infected vines and human traffic.

A new pest in vineyards is the vine mealybug (VMB), *Plannococcus ficus*. The VMB has several attributes that make it a more damaging pest than most other mealybug species. It is native to the Mediterranean, so there are no parasites or predators that have evolved locally to control it. Hosts in its native range include grape, fig, date palm, apple, avocado, citrus, and a few ornamentals. It has five to six generations per year, so it is able to multiply quickly. It has a cryptic lifestyle, hiding in the roots or under the bark, especially as the weather cools. The VMB exudes more honeydew than other mealybugs, and this characteristic, along with infestations below the soil line, will help vineyard workers identify the pest. Management of this pest requires managing the ants that spread it. Controlling the ants increases the chances of parasitism by the imported VMB parasite, *Anagyrus pseudococci*.

PLANT PARASITIC NEMATODES

Nematodes are tiny worm-like creatures that live in the soil. Some nematodes are beneficial and feed on bacteria and fungi, while other species, such as root-feeding nematodes, are plant parasites and destructive to crops.

There are many nematode species that attack grape roots. As a consequence, no single rootstock provides complete resistance. Grape cultivars recognised for broad resistance to nematode species include Ramsey, Freedom, and several rootstocks in the Teleki series. Important points for nematode management:

- Soil type influences the type and severity of nematode infestations (i.e., sandy soils increase the potential of nematode problems).

- Ecological soil management—with its emphasis on building organic matter through additions of composts, cover crops, and green manures—helps manage nematodes in two ways:
  - Soil with increased soil organic matter, and especially soil humus, functions like a sponge and retains soil moisture for longer periods during the growing season, thus reducing vine stress.
  - Soil amended with organic matter possesses greater populations and diversity of soil organisms, which results in competition and predation of plant parasitic nematode

Cover cropping can cause increases, decreases, or no change in nematode populations in the vineyard, depending on the nematode complex that is present and the type of cover crop planted. For example, Cahaba White vetch as a cover crop is a good host for *Meloidogyne hapla* (northern root knot nematode), a poor host for *M. incognita* (root knot nematode), and antagonistic to *Xiphinema americanum* (dagger nematode).

VERTEBRATE PESTS

Vertebrate pests fall into two categories: mammals and birds. Mammals, such as ground squirrels, voles, gophers, rabbits, and deer, generally damage the roots, the vine, or the foliage. High populations of these animals can be very damaging, particularly for young vineyards. Sustainable management entails:

- Identifying the animal causing the problem
- Identifying habitat modifications that may reduce population pressures
- Identifying practical short term management options (use of baits, fumigants, or traps)
- Identifying habitat modifications that will increase predator populations.

Birds are serious pests of grapes. Control is generally more difficult because birds are so mobile and the fact that many species are protected. Again, habitat modification is helpful to reduce attractiveness of nearby areas as nesting and resting sites. Flags, noisemakers of various kinds, mylar strips, etc., generally are effective for only a short time, and then birds become habituated to these devices and ignore them.

WEED MANAGEMENT

Weed management will vary widely in vineyards across the country, due to differences in climate, soil, and irrigation. It is helpful to discuss weed control strategies in the context of goals for the vineyard floor. Goals for the vine row or berm will likely be different from those for the alleyway.

In-Row Weed Management

The most difficult task in farming grapes organically may be managing weeds under the vine rows. A common in-row strategy is to eliminate all forms of vegetation to avoid competition and interference with the vines, at least during the first three to five years of establishment. Thereafter, living mulches are sometimes grown in the vine row during certain parts of the growing cycle.

Especially in young vineyards, a weed-free zone around each vine or down the entire row is commonly recommended to eliminate vegetative competition. Specialised tillage implements designed for vineyards and orchards are widely used to stir the soil and disrupt weeds in organic vineyards. These include a tractor-mounted French plow or grape hoe, as well as articulating swing-arm implements that retract when a sensor touches the vine. Thermal weed control equipment is becoming more popular in organic vineyarding and includes flame, infra-red, and steam options. Drip irrigation should be hung on trellis wires when thermal weeding is planned and to avoid interference with mechanical implements.

"Mow and blow" cover crops can provide an in-row mulch from cover crop biomass raised in the alleyways. This can prevent germination of weed seed, but it is not very effective in killing weeds that are already there, so it's important when using this technique to start with a clean in-row area. Mulching will also minimise temperature and moisture fluctuations in the upper soil layer, which may benefit the grape vine. A study in California found that dried cover crop residue varied among vineyards, so weed suppression using the mow-and-mulch technique can vary. Perennial weeds, such as field bindweed, were not well-controlled. Use of alternative herbicides—with ingredients such as acetic acid, lemon oil, and clove oil—provide a burn-down option for management of weeds and living mulches, but their use may be restricted to roadsides, ditches, and noncropping areas.

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8

Cultivation of Lychee

Lychee (*Litchi chinensis* Sonn.), which originated in southern China and possibly northern Viet Nam belongs to the *Sapindaceae* family. The *Sapindaceae* is a relatively large family containing at least 125 genera and 1,000 species, which are widely distributed in the tropics and warm sub-tropics. The most widely cultivated fruit trees in this family other than lychee are rambutan (*Nephelium lappaceum* L.) and longan (*Dimocarpus longan* Lour.). The main centre of origin of lychee is believed to be between latitudes 23° and 27° north in the subtropical parts of southern China, northern Viet Nam, and Malaysia. It seems to have been in cultivation since about 1500 BC by people of Malayan descent and has since been subjected to intense selection.

China has a long history of lychee cultivation for more than 2000 years and from China it reached Burma (Myanmar) by the end of 17th century and was introduced in India and Thailand about 100 years later. Lychee reached Madagascar and Mauritius around 1870 and was introduced in Hawaii in 1873 by a Chinese trader. It arrived in Florida, from India, between 1870 and 1880 and was introduced in California in 1897. Lychee was probably brought to Australia by Chinese migrants in 1954 and arrived in Israel sometimes between 1930 and 1940. China, Taiwan Province of China, Thailand, India, South Africa, Madagascar, Mauritius and Australia are now major lychee producing countries in the world.

LYCHEE CULTIVATION IN THE ASIA-PACIFIC REGION

Lychee is widely spread across south China, between latitudes 31° and 18°N and longitudes 101° and 120°E, whereas the commercial production zone lies between latitudes 19° and 24°N. In south China lychee has become a major industry since the 1980s. It provides huge scope for employment of the local populace and about 320,000 people are involved in this industry. In 1999, lychee output was about 950,000 tonnes from 530,000 hectares for China as a whole. Guangdong Province is the most important area for lychee production in China.

Figure 1. Lychee fruits

Other provinces where lychee grows well include Guangxi, Fujian, Hainan and Yunnan. In India lychee is grown mainly in the states of Bihar, West Bengal and Uttar Pradesh. It is also grown in limited scale in Tripura, Orissa, Punjab, Himachal Pradesh, Assam and the Nilgiri hills in the south. Current production of lychee is about 429,000 tonnes from an area of about 56,200 hectares. Lychee is mainly grown in the northern part of Thailand where the climate is classified as sub-tropical.

The major concentrations are in Chiang Mai, Chiang Rai, Phayao and Nan provinces in the north and Samut Songkhram in Central Thailand. The production of fresh lychee fruit in Thailand during 1999 was 85,083 tonnes from 22,200 hectares. Northern Viet Nam includes part of the geographical area where lychee originated. This species has been grown commercially for many centuries near Hanoi, but production has only expanded rapidly in the past five years. The total area under cultivation is about 25,000 hectares, with 10,000 hectares under bearing trees and the total production in 1998 was 27,000 tonnes.

Lychee is mostly grown in central and southern Taiwan Province of China. The total area under cultivation in 1999 was 11,961 hectares, with 11,580 hectares of bearing trees and 108,668 tonnes of total production. In Bangladesh, lychee is grown in Dinajpur, Rangpur and Ragshahi districts. The total area under cultivation in 1998 was 4,750 hectares with 12,755 tonnes of total production. Although lychee was introduced into Australia about 60 years ago, major commercial plantings commenced only from the

1970s. Currently, there are about 350 growers with an annual production of about 3000 tonnes. About 50 percent of commercial plantings are found in northern Queensland, 40 percent in southern Queensland, and the balance in northern New South Wales.

CULTIVARS

The Chinese consider that the lychee has more cultivars than any other fruit crop. Although over 200 cultivars are grown, only about eight are commercially important in China. In Guangdong Province, the cultivars Baila, Baitangying, Heiye, Feizixiao, Gwiwei, Nuomici and Huaizhi are being cultivated commercially and each of these cultivars covers more than 20,000 hectares. However, Guiwei and Nuomici are most widely cultivated. In Fujian Province, Lanzhu is the main cultivar covering about 25,000 hectares.

The most important cultivar of Taiwan Province of China is Hap Ip, which accounts for about 90 percent, and is followed by Yu Her Pau and No Mi Tsu. The dominant lychee cultivars of India are Shahi, Bombai, China, Deshi, Calcutta, Rose Scented and Mazaffarpur.

There are over 40 cultivars of lychee in Australia. Cultivars currently being planted in northern Queensland on the Atherton Tablelands and coast include Kwai May Pink, Fay Zee Siu and Souey Tung. Kwai May Pink is also popular in central and southern Queensland and in northern New South Wales, along with Salathiel and Wai Chee. In Thailand the main cultivars are Haak Yip, Tai So and Wai Chee. The lychee cultivars of Thailand are, however, divided into two groups, namely the lowland lychee or the tropical lychee and the sub-tropical lychee. The tropical lychee is well adapted and commercially grown in the Central Region with warm winter months.

Almost 20 cultivars are known in this group. The sub-tropical group of lychee grows in the northern part of the country where the winter months are rather cool. About 10 cultivars are known in this group. A number of local cultivars are found in the northern mountainous provinces of Viet Nam, but most of these are low yielding and sour. There are a number of local cultivars in Ha Tay province.

The main cultivars are Thiew Thanh Ha, hybrid lychee and Phu Ho. Thiew Thanh Ha is the most popular and more than 90 percent of the production is from this cultivar. Seven cultivars were also imported from Australia and planted in the Luc Ngan District and Ha Giang Province of which Wai Chee and Salathiel appear the most promising.

CLIMATIC REQUIREMENTS

The lychee is adapted to the warm sub-tropics, cropping best in regions with brief, dry, frost free winters and long, hot summers with high rainfall and humidity. Poor production is experienced in most countries. This is often because winters are not cool or dry enough to induce a growth check prior to flowering. Irregular flowering in lychee is related to variations in the timing of flushing. If early flush development, when buds swell, coincides with days of 20°C or cooler, then flower panicles will be initiated. On the other hand, if the warm or the cool weather arrives when the buds are longer than a few millimeters, then the flush will be vegetative. In some parts of southern Queensland, Australia, winter frosts may damage the panicle and developing flowers and limit fruit production in that season.

In China, conditions during flowering are often cool and overcast. This can prevent pollination and fruit set. More frequently, conditions during spring and early summer in Australia are hot and dry. Similar conditions are found in the lychee areas of northern India. Flowers may dehydrate and fail to develop, while fruit may drop or split. This is because lychee has a low ability to transport water from roots to leaves. Wet soil alone cannot prevent the development of tree water stress. In Thailand, however, the cultivars are divided into two groups according to temperature requirements for flowering: (i) the cultivars that require no or only a short cool period for flowering (for the central part of Thailand); and (ii) the cultivars that require a longer cool period for flowering. In India, the major producing state is Bihar where a longer cool period before flowering is available in most years. In West Bengal, occasional hot and dry conditions prior to flowering restrict production.

PLANTING DENSITY

Traditionally, lychee trees were planted with wide spacing of 9 or 10 m x 12 m or even 12 m x 12 m, with about 70-80 trees per hectare. Such plantings can have very high yields on a tree basis after 10 or 15 years, but are wasteful of land in the early years. Also, with large trees there are problems with harvesting, spraying and protection from birds and bats. The old plantations in India, Australia, Thailand, and China were planted at a density of 80 to 150 trees per hectare. New orchards in Australia are planted at a closer spacing of 6 m x 8 m or 4 m x 6 m or 7 m x 3 m, equivalent to 200 to 600 trees per hectare . In China, starting from the 1980s lychee trees were planted in closer spacing, popularly 5 m x 4 m or 6 m x 5 m, i.e., 330-500 trees per hectare. There are also some extra dense orchards containing 1500 trees per hectare (3 m x 2.5 m). In India different planting systems as well as density are now being investigated under the All India Coordinated Research Project in different locations. Initial results have shown that hedgerow planting is more remunerative during early fruiting years.

NUTRITION MANAGEMENT

One of the major factors limiting fruit production in lychee is lack of a suitable nutrition programme. Yields may be low because of excessive vegetative growth in winter following late or heavy N fertilisation. Deficiencies of N and K, and to a lesser extent of B, Zn and Cu, may limit yield by restricting the set and subsequent development of fruit. Although leaf nutrient standards are available for China, Australia, Thailand and India lychee growers usually apply fertilisers based on canopy sizes, fruit loads or tree age. In China the recommended annual dosage is 0.6 kg urea, 1.2 kg super-phosphate and 0.6 kg of potassium chloride on a five-year-old tree basis, with the N:P:K ratio of 1:0.96:1.3. Fertilisers are generally used separately in three stages, i.e. inflorescence emergence, rapid fruit growth and the time to stimulate autumn flushing. However, in most orchards fertilisers are applied frequently and in small doses each time.

A fertiliser schedule based on tree age and canopy size is available for Australia. However, these rates are considered as a guide and should be supported by leaf and soil analysis. The suggested rates for a 10-11-years bearing tree with 4.0-4.5 m canopy diameter and 12-16 m canopy cover are 500 g N, 170 g P_2O_5 and 700 g K_2O. The recommended application schedule being half the annual amount of nitrogen after panicle emergence and other half after fruit set. The other nutrients (P and K), are supplied in two equal applications, after panicle emergence and after harvest. In India, a fertiliser schedule based on tree age is available which, however, varies in different growing regions. Bearing trees of 7 to 10 years in age usually receive 400-600 g N, 200-300 g P_2O_5, 400-600 g K_2O and 40-50 kg organic manure annually. The full dose of organic manure and three fourths of the total inorganic fertilisers are applied in June-July after harvesting. The remaining one-fourth inorganic fertilisers are applied in early April when fruits grow to pea size.

Tentative leaf nutrient standards based on survey of high-yielding trees in southern Queensland, Australia are available for lychee. Leaf nutrient levels for Guangdong and Guangxi Province of China and for India are also available. Tentative standard leaf nutrient levels for Australian lychee orchards after panicle emergence during May-August are: 1.50-1.80 percent for N, 0.14-0.22 percent for P, 0.70-1.10 percent for K, 0.66-1.00 percent for Ca, 0.30-0.50 percent for Mg, 50-100 mg/g for Fe, 100-250 mg/g for Mn, 15-30 mg/g for Zn, 10-25 mg/g for Cu, 25-60 mg/g for B, <500 mg/g for Na and <25 percent g for Cl. The suitable leaf nutrient levels for Guangdong Province of China are suggested as 0.93-2.10 percent for N, 0.08-0.21 percent for p and 0.12-0.33 percent for K. In Guangxi, suggested levels are 1.766-1.78 percent for N, 0.25-0.28 percent for P and 0.75-0.92 percent for K. The suitable levels for microelements are 1.5-5.0 mg/kg for available Zn, 1.5-5.0 mg/kg for exchangeable Mn, 1.0-5.0 mg/kg for available Cu, 0.40-1.00 mg/kg for water soluble B and 0.15-0.32 mg/kg for available Mo.

MANIPULATING FLUSHING CYCLES AND FLOWERING

Lychee trees initiate flowers when early flush development coincides with low temperatures. Consequently, flowering only occurs if new flushes develop during cool weather. Olesen and his co-workers from Australia suggested four possible ways to alter flushing and induce flowering in lychee. Trees can be hedged to induce one or two vegetative flushes over summer and autumn, and a second or third in winter or droughted in autumn to prevent more than one or two leaf flushes after the preceding harvest. They can also be pruned going into winter to induce flowering directly below the pruning cut.

There is also the possibility of using ethephon to selectively remove the young red flushes in winter. Full recommendations for the strategy will be available for Australian growers this year. However, a good flowering is no guarantee of fruit set or a good crop. Investigations by Yuan and Huang in China found that an extra peak of root growth in May was the characteristic of young 'Nuomici' lychee, which caused serious fruit drop. Zhou *et al.* found absence of this root growth peak in young 'Huaizu' and also bearing trees of 'Nuomici' showed less fruit drop.

Positive response of spiral girdling was observed in China in speeding up the maturation of autumn flushes and in inhibiting winter flushing in favour of flower initiation, in increasing percentage of pistillate flowers, in overcoming excessive fruit drop and in improving fruit size and quality. It is recommended that for flowering, girdling should be made at a stage between the turning green of leaves and flower initiation during the winter, and for fruit setting, immediately after bloom.

To promote flowering, 'Feizixiao' lychee trees are usually spiral girdled in mid-November, but 'Nuomici' and 'Guiwei' are spiral girdled in late-November/early December on trunks or scaffold branches 10 cm in diameter. However, to improve fruit set in 'Nuomici' and 'Guiwei' girdling is usually made in early May on branches 5 cm in diameter.

The girdling width is 2 to 4 mm, with 1-2 spirals and the distance between two neighbouring spirals is about 6-10 cm. Experimental evidence is available from Thailand for flower induction of lychee in cv. Hong Huay by use of ethephon and in cv. Bombai by ethephon, potassium nitrate and TIBA spraying in the months of October-December, however, large scale field testing is needed before any commercial recommendations can be made.

PROBLEM OF FRUIT CRACKING

Fruit cracking is a major problem of lychee in many lychee growing areas in India and China. Among the cultivars grown in India, Early Large Red, Deshi, Muzaffarpur and Elaichi are more prone to crack while the high priced Nuomici and Gwiwei cultivars in China are susceptible to cracking. Plant growth regulators and integrated management showed some positive results in lowering the cracking rate.

MAJOR PESTS AND DISEASES AFFECTING PRODUCTION

Over 58 species of pests have been reported damaging lychee trees in China. Of these the major pests are lychee stink bug (*Tessaratoma papillosa*), lychee barking miner (*Conopomorha sinensis*), lychee longhorn beetle (*Aristobia testudo*), lychee midge (*Dasineura* sp.) and Erinose mite (*Eriophyes litchi*). Erinose mite is the most serious pest of lychee in India, Thailand and Viet Nam. The macadamia nut borer (*Cryptophlebia ombrodelta*) is the most serious pest of lychee in Australia. However, the most devastating damage is caused by flying foxes amounting up to 50 percent of the crop loss in Australia.

Fortunately, the lychee growers in other countries of the Asia-Pacific are not facing the problems of flying foxes. Protocols exist for control of most of the other pests in different countries. There are about 25 species of natural enemies of lychee pests. Of these egg parasitoid, *Anastatus* spp. for controlling stink bug, nematode *Steinernema carpocapsae* for controlling longhorn beetle and predaceous mite *Agistemus exsertus* for controlling erinose mite have been used successfully. There are no serious diseases of lychee. The 'sudden death' phenomenon is, however, observed in Australia, China and Viet Nam. Initial findings suggest that sudden wilt is a soil-borne disease, associated with *Fusarium solani*, *Phytophthora* sp. and *Phythium* sp. Poor drainage, deep planting and inadequate nutrition favour the disease.

A number of diseases affect lychee after harvest, which are generally not apparent during harvest and packing. They develop as the fruit reach the end of their post-harvest life. Several fungi have been associated with disease symptoms affecting the sides of fruit or around the stem end. Among the post-harvest diseases, anthracnose (*Colletotrichum gloeosporioides*) is mainly responsible for such loss in China, Australia, Taiwan Province of China, Thailand and India.

HARVESTING OF FRUITS AND YIELD

Only few fruits can be compared with the taste of a fully mature lychee fresh from the tree. If growers take care to harvest their fruit only when it is fully mature and then grade, treat and pack it properly, consumers can enjoy that same delicious flavour, and the market for the fruit will develop quickly. Maturity standards based on TSS/acid ratio, fruit weight, peel colour etc., have been standardised for most of the commercial cultivars of India, Australia, China, Taiwan Province of China and Thailand. Lychees are harvested manually in bunches along with a portion of the branch and few leaves.

The panicles are cut from the tree with secateurs or harvester meant for the purpose. In most countries, ladders, cherry pickers and picking bags are used. Average lychee yields range from 1 to 15 tonnes per hectare in different countries of the world. In Taiwan Province of China, the productivity is about 9.4 tonnes/ha compared with 7.63 tonnes/ha in India, 3.83 tonnes/ha in Thailand, 2 tonnes/ha in Viet Nam, 1.8 tonnes/ha in China and 1.66 tonnes/ha in Australia.

POST-HARVEST MANAGEMENT

Once lychees are picked, they start to dry out and brown. The mechanisms of pericarp browning, colour retention, and pulp quality maintenance have been the worldwide focus of lychee post-harvest biology research. Progress has been made in lychee pericarp browning and colour maintenance. Fruits should be kept in high humidity and cooled to 5°C as quickly as possible. Hydro-coolers or cool rooms are frequently used for this purpose.

Sulphur fumigation has so far been the main post-harvest handling technology in prevention of lychee browning and maintenance of fruit quality. However, it has recently been questioned by both scientists and customers due to the chemical S residues and off-putting taste. At the moment the cool-chain system can provide satisfying resolution to lychee transportation, storage and marketing problems in developed countries. However, the cool-chain system is still at the very early stage of establishment in developing countries such as China, India, Thailand, Viet Nam, Bangladesh and some other Asian countries.

INTERNATIONAL TRADE

Among the major international markets .Hong Kong and Singapore receive approximately 12 to 15 thousand tonnes of lychee from China and Taiwan Province of China during June-July. Taiwan Province of China exported about 5,900 tonnes of lychee in 1999, and the main destinations were Philippines (1,735 tonnes), USA (1,191 tonnes), Japan (933 tonnes), Canada (930 tonnes), Thailand (489 tonnes) and Singapore (408 tonnes). The European markets absorb about 20,000 tonnes of fresh lychee of which nearly 50 percent was imported by France alone and the rest mainly by Germany and the United Kingdom. The market is especially lively between Christmas and New Year's Day. The main suppliers are Madagascar (80 percent), and South Africa (12.6 percent) during this period. The same markets also receive a small quantity from Australia during Christmas and from Thailand between July and August (400 tonnes), India (about 25 tonnes), China and Taiwan Province of China.

The lychee market in the United Arab Emirates, Saudi Arabia, Yemen, Lebanon, Dubai and Canada are expanding and can absorb a few hundred tonnes more fresh lychee. Except for Australia, the other lychee producing countries in this Region are exporting very little of their total production. The reasons are mainly that all the producing countries have a good domestic market and lack proper cool-chain and other exporting facilities. Small quantities of lychees are, however, frozen and canned and exported to Japan, USA, Canada, Malaysia, Republic of Korea and Australia. About one third of the total production of China was dried in 1999 as lychee nut, which were marketed domestically and also exported to Southeast Asia.

LYCHEE PRODUCTION IN INDIA

The lychee (*Litchi chinensis Sonn*) an important sub-tropical evergreen fruit crop belonging to family *Sapindaceae,* is believed to have originated in China, where it has been grown in Southern Guangdong state for thousand of years. It is highly specific to climatic requirements and probably due to this reason its cultivation is restricted to few countries in the world.

In India, lychee was introduced in the 18th century through Burma, and from there, it spread to many countries. India and China account for 91 percent of the world lychee production but it is mainly marketed locally. In India, 428,900 metric tonnes of lychee is produced annually from 56,200 hectares. Lychee being exacting in climatic requirement is confined to a few states with 74 percent of production recorded in Bihar.

In this state, lychee is the livelihood for millions of people as it provides both on-farm and off-farm employment. Small and marginal farmers get additional income from lychee plants in their homesteads. Thus, lychee cultivation is the livelihood security for a large population, especially in the state of Bihar.

The lychee tree is handsome, dense, round-topped and slow growing with evergreen leaves having 6-9 elliptic oblong and lanceolate abruptly pointed leaves. Colour of leaves varies from light green to dark green. Greenish white or yellowish flowers are borne in clusters. Fruits are round or heart shaped having thin, leathery skin. The colour of fruits varies with cultivar, and is red or rose or pinkish.

The edible portion or fruit is the aril, which is immediately beneath the skin. Flavour of the aril varies with cultivar, which is distinctive. Seeds are bold but in some cultivars seeds are partially developed, due to failure of pollination, referred to as 'chicken-tongue' seed. The trees with small seeded fruits are prized because of the greater portion of pulp.

Considering the importance of this fruit crop in the region, efforts are made to provide technological support through research and promoting production, post-harvest management and marketing, including export, through development programmes. Lychee has also been identified as an important crop for export. Currently, Indian export of lychee remains quite small due to expanded domestic market.

The product for export and distant domestic markets is typically packed in 2 kg cartons after pre-cooling and sulphuring. Domestic marketing generally receives lychee in 10 kg wooden cages or 15 to 18 kg baskets. The growing of lychee in different states under various climatic conditions has advantages in terms of earliness and extended harvest. With a narrow genetic base, under given climatic conditions, fruits are available only for 3-4 weeks. However, due to the spread of cultivation over a wide range of climate there is possibility for extending the cropping period from the first week of May to the first week of July. Evidently, with an expanding market, there is ample potential for increasing area and production with improved production technology and efficient post-harvest management and storage.

PRESENT SITUATION OF LYCHEE CULTIVATION

Area and Production

In India, lychee ranks 7th in area and 9th in production among fruit crops, but in value terms, it ranks sixth. At national level banana and mango are the most important fruit but in Bihar state, lychee is considered to be the most important fruit as it contributes significantly to its total fruit production. There has been substantial increase in area and production of lychee in the last 50 years. Area has increased from 9,400 hectares in 1949-50 to 56,000 hectares in 1998-99. The contribution of lychee to total area under fruit has increased from 0.75 percent to 1.5 percent. Increase in area between 1991-92 and 1998-99 has been 14.28 percent, while production increase during the same period is to the tune of 75 percent. Productivity also recorded an increase of 52.91 percent during the same period. Evidently, production and productivity of lychee is constantly increasing in the country. Lychee being exacting in climatic and soil requirements has limited distribution. It is grown in the states of Bihar, Tripura, West Bengal, Uttar Pradesh, Punjab and Haryana. Of the total production of lychee in India, 74 percent is contributed by Bihar. The second largest lychee producing state is West Bengal followed by Tripura and Assam. Productivity is highest in Bihar followed by West Bengal.

An interesting feature of distribution of lychee in India is that maturity commences first in Tripura, followed by West Bengal then Bihar. The first and second week of May is the time for harvest in the eastern region, while lychee of Bihar matures in the 3rd-4th week of May and continues up to the first week of June. Lychee in Uttar Pradesh and Punjab is ready for harvest during the 2nd- 3rd week of June. In Himachal Pradesh, lychee of the same cultivar is harvested in the last week of June. Interestingly, in most of the states the best lychee orchards are seen along the rivers, big or small.

Varieties

Lychee varieties grown in India are highly variable under different climate and soil conditions. There are 33 varieties and classified them into 15 groups varieties of lychee grown in India have also been subsequently described. When distinguishing the cultivar, the shape of skin segments and protuberances are the reliable and stable genetic characteristics. Fruit size, shape and taste are also variables but are influenced by other than genetic factors. Indian cultivars vary greatly in vegetative flushing pattern, flush colour and flowering ability. Based on these characteristics, cultivars were classified in five groups. Group A, which has 7 cultivars is the early group, B and C groups are mid-season, and group D is the late group. Only one cultivar, which is very late, is under group E and its cultivation is confined to Muzaffarpur. The cultivars also show variation in yield, cracking, and physico-chemical quality. Shahi among the early group and China among the mid-season groups appeared to be promising in Jharkhand state.

Figure 2: Indian Lychee plant with fruits

Leaf colour along with shape and size of the leaves is of importance in varietal identification. The leaf of Rose Scented is boat-shaped while China has a distinctive twist along the length curved upward from the midrib and down along its length. Small leaflets of Bedana are oval shaped. The fruit shape of the lychee is very distinguishing. The round shape of Bedana is distinguished from the oblong shape of China or Shahi.

The fruit is smooth and pulp is even or uneven. The apex of the fruit can be round, obtuse, blunt as in Shahi, or pointed as in China. The varieties can also be distinguished depending upon the colour of the new flush and season of flushing. Shahi produces very light coloured flush while China has pinkish flush. Bedana has very dark pink flush. Emergence of the panicle and its shape also differs. Shahi has long panicles while Bedana produces short and compact panicles. The colour of the lychee fruit is pinkish brown or dark red depending on the cultivar. Colour of the skin varies and is also influenced by growing conditions.

Shahi

This is the most popular cultivar grown in North Bihar, Jharkhand, Uttaranchal and Uttar Pradesh regions of India. Besides having high quality fruit it has a distinct rose aroma and hence is called 'Rose Scented'. It is known as Shahi in Bihar, Rose Scented in Uttaranchal and Muzaffarpur in Western Uttar Pradesh.

The vegetative flush of this cultivar is light, and fruit weight ranges from 20-25 g. This cultivar is earliest in maturity, and ripens during the second week of May to the first week of June at various locations. It matures on 12-15 May in Jharkhand, the 25th May in North Bihar and by the first week of June in the Terai region of Uttaranchal. Trees of this cultivar are very vigorous and produce fruits ranging from 100-150 kg per plant.

Mature fruits are prone to cracking in zones with low humidity and poor moisture content in the soil. Fruits are globous-heart or obtuse in shape having rose madder and fuchsia purple background with red tubercles at ripening. Pulp is greyish-white, soft, moderately juicy and sweet, and TSS ranges from 19.00 to 22° brix. Seed size varies. On the same plant larger fruits have big seeds while seeds in small fruits are shrunken. The fruits are known for excellent aroma and quality. This cultivar occupies a major area under lychee in India.

PRODUCTION OF PLANTING MATERIAL

Lychee is generally multiplied by vegetative methods of propagation as plants raised through sexual method (by seed) grow slowly, have a long juvenile period and do not produce fruit true to the type. However, earlier introduction in different parts of the country was perhaps through seeds, which enabled the selection of superior types and perpetuation the cultivar through vegetative means. The most commonly practiced method of vegetative propagation is air-layering, though cutting, grafting and budding have been found to be successful.

Air-layering

Air-layering, known as 'marcottage' in China and 'goottee' in India, is commercially practiced for large scale multiplication both in public sector and private sector nurseries. When and how this practice was adopted is not documented but the process of development and modification in the method of layering suggests that the method has gone through transformation.

Earlier layering was done using clay soil having provision of watering, however, the air-layer practiced now uses growth hormone and nutrient mixed media of peat moss or coir pith, which is covered with polythene. For preparation of the air-layer a healthy terminal branch receiving good sunshine with a thickness of about 1.2-1.5 cm is selected and a 2.5 cm ring is made by removal of bark about 45-50 cm below the apical growth. The cambium layer is rubbed off and the woody portion is exposed. Rooting hormone (1000 ppm IBA) is used as paste or powder. A layer of moist sphagnum moss or coir pith is placed and wrapped with a piece (20 x 25 cm) of 400 gauge polythene sheet and tied properly at both ends to ensure supply of proper moisture which facilitates the development of roots. It is advised to enrich the rooting medium using organic nutrients. After about 50-60 days, the adequate root system develops from the upper end of the ring, which is visible through the polythene film.

The layer is removed by making a sharp cut about 5 cm below the lower end of the ring, preferably in 2-3 stages. The detached layers are planted in partial shade. Success in rooting of the layer is determined by temperature and humidity. When night-time temperature falls to less than 20°C the root becomes brittle. Thus, June is considered to be best time for air-layering. In order to enhance the success of the detached layer, defoliation of leaves up to 50 percent is advocated. At the time of planting excess vegetative growth may be removed to maintain balance between the top and newly developed root system. Regular irrigation and weeding is done to facilitate better establishment and growth. Beds are kept weed free. Lychee layers become ready for field planting in 4-5 months. Growing of layers in the greenhouse has been found to enhance success.

Pot Layering

Some nurseries practice, pot layering wherein a lower branch of mature wood is cinctured and the cut surface is buried in a pot or container filled with rooting medium. The pot is watered regularly. The roots develop in the cinctured portion of the branch in about 2 months. Then the branch is detached from the main plant by giving sharp cut, preferably in 2-3 stages. No repotting is required before transplanting in the field. Application of IBA improves rooting and survival of the layers.

Stooling

For large scale multiplication stooling is also recommended. In this method, planting is done closely at 1 x 2 m. Once the plant attains the required growth it is headed back to the stump during January-February which permits new shoot emergence from the stump within two months. A ring of 2 cm is made at the base of the newly emerged shoots and rooting hormone is applied. Then a mound of soil is raised around the shoots to encourage rooting and watering is done regularly. Profuse rooting occur in the stools within two months. These stools are detached and kept in the nursery for hardening and become ready for transplanting in July-August. In stooling, one must be careful not to allow the soil mound to dry, otherwise the rooting process is affected adversely. Therefore, the stool beds should be irrigated at weekly intervals from April-June.

Cuttings

Although this method is advocated it has not been practiced by nurserymen on a commercial scale. The propagation of lychee has also been tried through cutting under mist conditions. A high percentage of rooting was also obtained from the cutting treated with IBA and planted in April-May under mist. But this has not been adopted commercially.

Grafting and budding

Grafting in lychee is mainly practiced for changing scion cultivar or seedling tree or unproductive and old orchards by top working. The apical, side and approach grafting are mainly practiced. In apical grafting 10 cm long scion wood with at least 2 slightly swollen buds gives better results. The technique of splice or tongue grafting is successful. Apical grafting has not been commercially used for large scale multiplication. Grafting appears to be promising provided seedling growth and percent germination improves. A higher rate of growth in seedlings is possible under greenhouse conditions. Softwood grafting has been found to be successful in many nurseries. Budding of lychee has also been successful. However, much more work is required to be done before these methods become accepted practices.

Since, air-layering is a commercial practice, a large number of private nurseries have come forward for large scale multiplication of plants especially in lychee growing regions. It is estimated that about 300,000 lychee plants of different cultivars are produced annually. The regulatory framework to ensure the quality of plants is not in place, thus the creditability of public institutes or private nurseries determine the preference of growers. The cost of plants also becomes a factor in determining the preference of farmers.

Irrigation, Mulching and Water Conservation

Lychee being an evergreen plant, the maintenance of optimum soil moisture is critical for growth, development and fruit production. If the rainfall is evenly distributed lychee is grown successfully and supplementary water requirement depends upon cultivar and evaporation demand. Water requirement ranges from 600-800 mm. Investigations carried out to determine the irrigation needs have clearly indicated that irrigation is critical at the fruit development stage to get better yield and quality of fruits. Interestingly, differential management of water in the vegetative phase and reproductive phase is also suggested. To achieve faster growth of the plant no water stress should be permitted, while in the reproductive phase water stress is beneficial at the time of fruit bud differentiation. Light irrigation during summer and winter months and cleaning of the basin is advocated. Irrigation at the intervals of 2-3 days during the initial stage of plant establishment is considered essential. Further, the young plants should be irrigated during dry periods and winter months at intervals of 3-5 days. For young plants mulching with dry leaves or residues in the basin help in better moisture conservation. Experiments conducted at Ranchi indicated that irrigation of plants at alternate day intervals, 6 weeks before harvesting improves fruit retention, encourages better fruit development, and minimises the cracking, apart from the quality of fruits.

Certain physiological disorders like poor sex ratio, poor fruit set, heavy fruit drop and high fruit cracking, besides sunburn of the fruits can be minimised with proper water management. The basin or flood method of irrigation is normally practiced. However, adoption of drip irrigation has been found to be effective in the economic use of water and enhanced growth, especially in an area where water availability is not satisfactory. Moisture conservation through mulching using dried weeds or black polythene sheet has been found useful. Trials have also been conducted to conserve moisture using farm residues and polythene sheets. Through adoption of mulching, frequency of irrigation is reduced. In a trial conducted at Ranchi mulching with 3 irrigations was effective in reducing cracking and enhancing yield and quality of fruits. To check fruit cracking mulching with 3-4 irrigations during fruit growth has been found to be satisfactory.

Control of Pests, Diseases and Physiological Disorders

Lychee plants and fruits are affected by insect pests and diseases, which causes considerable losses, if not managed. Lychee plants as compared to many fruit bearing species are least affected by diseases. A few leaf spot diseases have come to light that are caused by fungal pathogens. No bacterial or viral infections have been reported so far. Powdery mildew (*Oidium* spp.), anthracnose or leaf spot (*Botryodiplodia theobormae Pat, Colletotrichum gloeosporioides Penz*) and red rust (*Cephalexros mycoides*) are some diseases which cause some damage to the lychee crop, but severity varies from season to season even in the same locality. Their control measures consist of 1-2 applications of proper fungicides, while for red rust sulphur washes in September-October and February-March is sufficient. Although about 40 insect and mite pests are reported to affect lychee trees and fruits at different stages of growth, erinose mite, lychee bug and fruit borer are the insect pests of most concern.

Lychee Mite

Lychee mite (*Aceria litchi*) is a serious pest in all the lychee growing regions in the country. The tiny nymph and adults stick to the under-surface of the leaf and suck the cell sap. Consequently, the young leaf turns yellow to greyish-yellow and a velvety growth develops on lower surfaces, which subsequently turn brown. The affected mature leaf develops continuous to scattered brown patches with curling, twisting and leathery structure, which ultimately result in blister-like gall formations. It spreads fast under favourable conditions and reduces the photosynthesis activity and increases leaf drop. As a result the tree becomes weak, and yield and quality of the fruit is severely affected. The pest is well studied. It is suggested to prune the affected twigs/branches and burn to avoid spread. Two sprays of karathene 0.05 percent at 7-10 days interval during the attack of the insect has been found to effectively control the pest.

Fruit Borer

This pest becomes serious especially in humid conditions at the time of ripening. The small caterpillars bore through the stalk end of the fruit, and feed on the seed and skin. As a result fruits become unfit for consumption. The excreta of the caterpillar is seen near the stalk end of the fruit. High humidity and intermittent rains favour the infestation. Besides the important pests described above, lychee are often affected by leaf eating caterpillars, leaf miners, bugs and aphids. Birds, bats and squirrels also cause damage to lychee fruits.

Fruit Cracking

Fruit cracking is one of the major limiting factors in the cultivation of lychee, especially early cultivars. The early varieties are more prone to the problem of fruit cracking in comparison to late cultivars. The low atmospheric humidity, high temperature and hot winds during fruit development and maturity stage favour fruit cracking. Light irrigation to maintain soil moisture and to improve humidity has been found to minimise this problem through maintenance of a better micro-climate. Mulching with farm residues and 3 irrigations significantly reduced the cracking in a trial conducted on the cultivar Shahi. In addition, spraying with either 100 ppm NAA or 0.2 percent borax during the developing stage of the fruits has been found to be highly effective in checking the cracking.

HARVESTING OF FRUITS AND YIELDS

Maturity Standard

Lychee being a non-climacteric fruit requires to be harvested after attaining full maturity on the tree. Studies have been conducted to determine the maturity standard for different cultivars under different agro-climatic conditions. Fruits have a sigmoid pattern of growth. First the pericarp develops, then the seed and aril is formed and the seed turn from green to brown.

Harvesting

The fruits are harvested in bunches along with a portion of the branch and a few leaves.

At the time of harvesting care is taken to harvest the selected bunch, which has attained the desirable maturity as determined by colour development and taste of the pulp. For distant market fruits are harvested when TSS attains 19° Brix and acidity 0.3 to 0.4 percent.

The fruits are harvested early in the morning when temperature and humidity are congenial, to have longer shelf-life of the fruit. At the time of harvest fruits are collected in a manner so that they do not fall on the ground. Use of mechanical tools for harvesting is practiced. The harvesting period is generally May-June, depending upon cultivar and location. However, in the hills of southern India lychee is harvested in November-December. Changes in the physicochemical characteristics of lychee after anthesis were observed at two locations. Interestingly, the cultivar Rose Scented had similar patterns of growth at both locations, but the maturity date was one month later in comparison with Muzaffarpur. This phenomenon of maturity at two locations provides an opportunity for extended harvest of fruits. Maturity of fruits at Muzaffarpur was one month earlier than Dhaulakuan (H.P)

Yield

The yield of lychee varies according to the age of the tree, agro-climatic condition and maintenance of the orchard. Usually about 80-150 kg fruit/tree is obtained from 14-16 year old trees. However, from a fully grown tree a yield of 160-200 kg/tree has also been recorded. Apart from a management practice, bee keeping in lychee orchards has been found to increase the yield of quality fruits by 15-20 percent, since lychee needs cross-pollination.

Post-harvest Management

Lychee deteriorates very fast after harvest. Pericarp browning is a major post-harvest problem, which renders the fruit unmarketable. Browning is associated with desiccation. Peroxidase activity coupled with ascorbic acid oxidation enhances anthocyanin degradation. Techniques to reduce browning and maintain the red colour and prolonged storage life include sulphur treatment and packaging in perforated plastic bags and storage under cold conditions. Sulphur dioxide (SO_2) fumigation is used as a post-harvest treatment to reduce browning. SO_2 treated fruits have a bleached pericarp which turns uniformly pink in colour after 2-3 days. Fumigated fruits absorb 30-65 percent of applied SO_2 There is increasing concern about the residue of sulphur and the residual limit is only 10 ppm. For sea transportation 600-650g sulphur is recommend for the duration of 50-60 minutes, while for air transport 300-400 g sulphur for 30 minutes are advocated.

Aril breakdown or softening of the aril involves a loss of turgidity and translucency where fruits become blunt in taste. The disorder starts near the pericarp and is prevalent at the end of the stem. Post-harvest decay also occurs due to bacteria, yeast and fungi. Lychee browning and fungal contamination is prevented by dipping fruits in hot benomyl. Since this chemical is being restricted from use, alternative methods are desirable. Irradiation of fruit is considered to reduce browning and post-harvest losses. Storage temperature of 2-5°C is considered to extend the shelf-life. Use of perforated polythene bags and storage at 3°C have also been reported to increase shelf-life. Controlled atmosphere storage is considered better for maintenance of the freshness of the fruits.

CONSTRAINTS IN LYCHEE PRODUCTION DEVELOPMENT

Despite the fact that the lychee is one of the finest fruits and has a growing demand in national and international markets, productivity continues to be low and a gap exists between potential and existing yield. The ratio in yield between the best managed orchards and national productivity ranges between 2 to 4 times at different locations.

The probable reasons for low yield are the narrow genetic base of the crop, non-availability of suitable superior cultivars, traditional production systems, poor technological support and incidence of insect pests, coupled with poor post-harvest management. The shortage of genuine planting material coupled with the long juvenile period of lychee are also the constraints. The low female/male flower ratio, premature fruit drop, and fruit cracking due to non scientific water and nutrient management also add to low productivity and production of poor quality fruits. The lychee tree has luxuriant vegetative growth, which causes problems in harvesting. Thus, canopy management to achieve the required plant architecture is essential. Lack of scientific information on critical stages for flower bud differentiation, and requirements of water and nutrients also significantly reduces the yield. The lychee has a short shelf-life. Practices that can enhance post-harvest life of fruits would be useful to achieve higher productivity.

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9

Commercial Production of Mangoes

Mango is almost grown in all states of India. It is mainly cultivated in Uttar Pradesh, Andhra Pradesh, Bihar, Orissa, Karnataka, Tamil Nadu, Gujarat, Kerala, Madhya Pradesh, Maharashtra and West Bengal. Mango tree is a large, branched perennial erect tree with wide evergreen crown which attains a great height. Flowers appear in large terminal inflorescences producing fruit which is a fleshy drupe.

PLANTING

Prior to planting, field should be deeply ploughed, harrowed and levelled. The planting distance varies according to variety, the fertility level of the soil and general growth conditions in the area. Where the growth is excessive, the distance should be 12 x 12m, but in the dry zones where the growth is less, it can be regulated to about 10 x 10m. For high density planting, the distance can be 5 x 3 or 5 x 2.5 or 3 x 2.5 or 2.5 x 2.5m. In locations where the soil is loamy and deep, pits of 0.5 x 0.5 x 0.5m be dug at desired distances. However, in shallow and hill soils, the pits should be of 1 x 1 x1 m size. The pits should be filled with the original soil mixed with 50 kg well rotten FYM. In the top two-third portion, the proportion of the manure and soil may be kept as 1:3. If the soil is having infestation of white ants, 200-250 g of Aldrex or BHC 5 per cent dust may also be mixed.

The pits should invariably be filled before the rainy season, so that there is maximum settling down before the advent of heavy rainfall. The best time for planting all over India is during the monsoon season when the humidity level is high. In the area of heavy rainfall, the best time of planting mango is the end of the rainy season. In tracts where the rainfall is less, the planting can be done in the early part of the monsoon season for better establishment.

The planting should be done in the evening. If the sky is overcast, planting can be done during daytime also. The plant with earth ball intact should be taken out of the polythene bag or pot. The plant can then be placed in the centre of the pit by excavating as much soil as necessary to accommodate the earth ball or root ball. The moist soil of the pit is then pressed all around the root ball to complete the planting process. A small basin is then made and the plant is properly watered. The planting should not be done so deep as to bury the graft-union in the soil or so high as to expose the upper roots. It is always better to adjust it at the same height/depth at which it was in the pot/ polythene bag.

Figure 1. Mango tree: Plant parts

PROPAGATION

Mango can be raised from seed or propagated vegetatively. Several methods of vegetative propagation have been tried with varying degrees of success. Propagation from seed, though easy and cheap, is unable to perpetuate characters of the parent tree because most commercial varieties in India are cross-pollinated and monoembryonic. Plants also take more time to bear fruit. However, it is essential to raise seedlings to be used as rootstocks.

Stone Grafting

Stone/epicotyl grafting is a simple, cheap and quick method of mango propagation with a success rate of 75-80%. For this purpose, stones should be sown in June-July on raised beds of size 1x3 m. the beds should e prepared by mixing soil and FYM in the proportion of 2:1. After germination, seedlings with tender stems having coppery leaves are lifted with stones still attached. The roots and stones are dipped in O.1 per cent Carbendazırn solution for 5 minutes after washing the soil. The seedling stems are headed back leaving 6-8 cm long stem.

A 4-6 cm longitudinal cut is made running down through the middle of the stem. A wedge shaped cut starting on both sides is made on the lower part of scion stick. The scion stick should be 4-5 months old and 10-15 cm long containing plumpy terminal buds. The scion stick is then inserted in the cleft of the seedlings and tied with polythene strips. The grafts are then planted in polyethylene bags containing potting mixture. The bags are then kept in the shade protecting from heavy rain. The scion stars sprouting 15-20 days after grafting. Care should be taken to remove the sprouts on the rootstocks below the graft union during this period. July is the most suitable month for stone grafting.

Soft-wood Grafting

This method of grafting is done when the rootstock is overgrown and thus not suitable for stone grafting. Normally in this method, seedlings of 8-10 months old are selected. The grafting is done on newly emerged flush. The scion wood to be used is defoliated 10 days prior to the grafting and has same thickness as that of terminal shoot. The method of grafting is similar to stone grafting. July and August are the best months for soft-wood grafting.

Inarching

The method of inarching or approach grafting is quite cumbersome and time consuming, but it is still the leading method for commercial propagation of mango plants. The method consists of uniting the selected shoot of a desired parent tree with the potted or transplanted seedling by approach grafting. For this purpose, about one-year-old seedlings are most suitable when they attain a height of about 30-45 cm and thickness ranging from 0.75 to 1.5 cm.

These seedlings are either grown in pots or under the mother plant from which the grafts are to be prepared. Generally, one-year-old twigs of the scion tree about 60 cm in length and nearly of the same thickness as that of the stock is chosen for grafting. Young and non-bearing trees should not be selected as mother plants. A thin slice of bark and wood, about 5 cm in length, 7.5 mm width and 2 mm deep, is removed by means of a sharp grafting knife from the stem of the stock as well as from the scion branch. The cuts thus made should be absolutely flat, clean, boat shaped, even and smooth.

The ends of these cuts should be round and not angular. The cut surfaces of both, i.e., stock and scion are made to coincide facing each other so that there remains no hollow space between the two. Polythene/alkathene strips of about 1.5 cm in width are tied around the union. After about one month of operation, the scion below the graft union and stock above the graft union should be given light "V" shape cuts at weekly interval in such a way that the grafts can finally be detached while giving the fourth cut. In the last stage, the top of the stock above graft union should also be removed completely. Inarching should be done during the active growth period. The end of the monsoon in heavy rainfall areas and early monsoons in the light rainfall areas is the best period for inarching.

Veneer Grafting

This method of propagation possesses promise for mass scale commercial propagation. The method is simple and can be adopted with success. The rootstocks as mentioned for inarching are suitable for this method also. For conducting this grafting operation, a downward and inward 30-40 mm long cut is made in the smooth area of the stock at a height of about 20 cm.

At the base of cut, a small shorter cut is given to intersect the first so as to remove the piece of wood and bark. The scion stick is given a long slanting cut on one side and a small short cut on the other so as to match the cuts of the stock. The scion is inserted in the stock so that the cambium layers comes on the longer side. The graft union is then tied with polythene strip as recommended for inarching. After the scion remains green for more than 10 days, the rootstock should be clipped in stages. The scion wood to be used for veneer grafting requires proper preparation. The desired shoots should be defoliated at least one week prior to grafting so that the dormant buds in the axil of leaves become swollen.

SOIL AND CLIMATE

Mango is very well adapted to tropical and subtropical climates. It thrives well in almost all the regions of the country from sea level to an altitude of 600 m. The ideal temperature range for mango is 24° -30° C during the growing season, along with high humidity. A rainfall range of 890-1,015 mm in a year is considered as ideal for growing mangoes. However, mango can be grown in regions of both heavy (2540 mm) or scanty (254 mm) rainfall. Dry weather before blossoming is conducive to profuse flowering. Rain during flowering is detrimental to the crop as it interferes with pollination.

Fog, cloudy weather at the time of flowering from November to February results in poor setting of fruits and favours pest and disease incidence. Mango grows well on wide variety of soils, such as lateritic, alluvial, sandy loam and sandy. The loamy, alluvial, well-drained, aerated and deep soils (2-2.5 m) rich in organic matter with a pH range of 5.5-7.5 are ideal for mango cultivation.

VARIETIES

Alphonso (Happus)

State: Maharashtra, Gujarat, Karnataka and Madhya Pradesh. Fruit medium in size, ovate oblique in shape, orange yellow in colour; juice is moderate-abundant; excellent keeping quality, good for pulping and canning; mainly exported as fresh fruit to other countries; Flesh develops spongy tissue.

Bangalora (Totapuri)

State: Andhra Pradesh, Karnataka, and Tamil Nadu. Fruits medium-large, oblong shaped with pointed base with golden yellow colour; good keeping quality; used for processing; heavy and regular bearing variety; susceptible to bacterial spot.

Banganapalli (Baneshan, Safeda)

State: Andhra Pradesh and Tamil Nadu. Variety suited for dry areas; fruit large sized, obliquely oval in shape, golden yellow in colour; good keeping quality; good for canning; biennial in habit

Bombai (Malda)

State: Bihar, West Bengal and Madhya Pradesh. Variety is alternate bearer; fruit medium, ovate and yellow in colour; keeping quality medium. Bombay Green State: Uttar Pradesh and Haryana. Fruit size is medium, shape ovate oblong with spinach green colour; keeping quality is medium; early season variety; biennial in habit Highly susceptible to both vegetative and floral malformation.

Dashehari

State: Uttar Pradesh, Haryana and Punjab. Best varieties of the country; fruit size is small-medium, shape is elongated with yellow fruit colour, flesh is fibreless; good keeping quality; mainly used for table purpose; susceptible to mango malformation. Dashehari-51-regular bearing and yielding clone of Dashehari.

Fernandin

State: Goa. Fruit size medium-large, fruit shape oval to obliquely oval and fruit colour is yellow with a blush of red on shoulders; medium keeping quality; mostly used for table purpose.

Himsagar

State: West Bengal and Bihar. Fruit is medium sized ovate fruit with yellow colour; good keeping quality; early season variety and mostly used for table purpose.

Kesar

State: Gujarat. Fruit medium oblong with a red blush on the shoulders; good keeping quality; ideal for pulping and juice concentrates; early season variety.

Kishen Bhog

State: West Bengal and Bihar. Fruit medium oval oblique with yellow colour; keeping quality is good; bearing heavy.

Langra

State: Uttar Pradesh, Bihar, Haryana, Madhya Pradesh, Orissa, West Bengal and Punjab. Trees vigorous and spreading; fruit medium, ovate in shape with lettuce green colour; poor keeping quality; skin is very thin and pulp is very sweet; alternate bearing variety mostly used for table purpose.

Mankur

State: Goa and Maharashtra. The variety develops black spots on the skin in rainy season. Fruit is medium ovate and yellow in colour. Fruit quality is very good but keeping quality is poor.

Mulgoa

State: Tamil Nadu, Karnataka. Fruit is large roundish-oblique in shape and yellow in colour; high fruit quality and good keeping quality.

Neelum

State: Tamil Nadu, Karnataka and Orissa. Fruit is medium ovate-oblique in shape and saffron yellow in colour; good keeping quality; high yielding and regular bearing; ideal variety for transporting to distant places. This variety is mostly used for table purpose. Samarbehisht Chausa State: Uttar Pradesh and Punjab. Fruit large, ovate to oval oblique in shape and light yellow in colour, flesh fibrous; medium keeping quality; extremely sweet in taste; alternate bearing variety; shows apical dominance.

Suvernarekha

State: Andhra Pradesh and Orissa. Fruit medium ovate oblong fruit, green in colour with prominent red blush on the shoulders; good keeping quality; bearing is heavy.

Vanraj

State: Gujarat. Fruit medium, ovate oblong in shape with a blush of jasper red on the shoulders; good keeping quality.

Hybrid Varieties

Malika (Neelum X Dashehari)

Realising Institute: Indian Agricultural Research Institute (IARI), New Delhi. Fruit large, oblong elliptical yellow in colour; fruit and keeping quality is good and is mostly used for table purpose

Amrapali (Dashehari X Neelum)

Realising Institute: Indian Agricultural Research Institute (IARI), New Delhi. Dwarf, regular bearing and late maturing variety; suitable for high density planting; flesh is fibreless; average yield 16 tonnes/hectare.

Ratna (Neelum X Alphonso)

Realising Institute: Konkan Krishi Vidyapith, Maharashtra. Tree moderately vigorous, precocious, fruits are medium sized, attractive in colour and free from spongy tissue

Sindhu (Ratna back-crossed with Alphonso)

Realising Institute: Konkan Krishi Vidyapith, Maharashtra. Regular bearer, fruits medium sized, fibreless, free from spongy tissue with high pulp to stone ratio and very thin and small stone.

Arka Aruna (Banganapalli X Alphonso)

Realising Institute: Indian Institute of Horticulture Research (IIHR), Bangalore. Plants are dwarf regular bearing; Fruits oblong; skin is thin, rough and dull yellow in colour with slight red blush; pulp is soft, pale yellow in colour; free from spongy tissue and fibre, stone is small 35g, TSS 20° Brix; average fruit weight is 500g. The keeping quality is moderate and is mostly used for table purpose.

Arka Neelkiran (Alphoso x Neelum)

Realising Institute: Indian Institute of Horticulture Research (IIHR), Bangalore. Tree is semi-vigorous in nature; fruit is elliptical, medium size golden yellow in colour, average weight 270-280g; free from fibre and spongy tissue; keeping quality is good.

Exotic Varieties

Pakistan

Table Purpose: Fazli, Suvarnarekha, Gulab Khas, Langra, Alphonso.

Brazil

Table & Processing purpose: Embrapa Roxa 141, Embrapa Alfa 142.

USA

Table & Processing purpose: Haden, Irwin, Tommy Atkins, Keitt.

West Indies

Table purpose: Julie Peter.

HARVESTING

In western India, mango puts forth three growth flushes, the first are in the early spring (February-March), the second during March-April and the third in the beginning of winter (October-November). In Bihar, the first growth noticed in early spring, the second in April-May and the third in July-August. In UP, only two flushes are produced, in March-April and July-August. In Punjab, as many as five flushes are produced from April-August.

April and May flushes being found most heavy. In South India, mango usually gives two growth flushes, one in February-June and the other in October-November. In mango about 8-10 months old shoots under certain conditions cease to grow at least 4 months prior to blossoming. These shoots are capable of producing flower buds. Other shoots, which appear in subsequent flushes during late monsoon, do not come to flowering. These shoots flower during the next season after accumulating sufficient metabolites necessary for fruit-bud differentiation. Thus the fruits will be ready for harvest in April-May from a plant flowered during October-November. The major harvesting seasons in different states are:

States	*Month of Harvest*
Maharashtra	April-May (Ratnagiri)
	May-June (other areas)
Gujarat	May-June
Tamil Nadu	April-May
Andhra Pradesh	April-May (coastal districts) May (Rayalaseema)
Karnataka	May-July
Bihar, Uttar Pradesh and other parts of North India	June-August

The mango fruits should be harvested at green mature stage. In case of Alphonso mangoes the fruit is considered to be mature when the shoulder outgrow the stem and the external colour becomes light green with a yellowish red blush.

The harvest maturity in Dashehari and Langra cultivars reaches 12 weeks after fruit set, while in Chausa and Mallika it takes about 15 weeks. The best way to observe maturity in mango is the colour of the pulp, which turns cream to light yellow on maturity and hardening of stone. Mangoes are generally harvested at physiologically mature stage and ripened for optimum quality. Fruits are hand picked or plucked with a harvester.

During harvesting, the latex trickles down the fruit surface from the point of detachment imparting a shabby appearance to it upon storage. Therefore the fruits should be harvested with a 10-20cm stem attached to it. For efficient harvesting of mangoes a simple, low cost and portable mango harvesting device has been designed and developed at the Central Institute for subtropical horticulture, Lucknow. Mango fruits are taken into the pouch and held between the divider and knife and as the device is pulled, the blade cuts the stalk.

The fruits are then conveyed through a nylon chute to collecting boxes without bringing down the device every time. This saves time and protects fruits from mechanical damage due to impact. It also protects operator's hand from the sap, which oozes out from the point of detachment. On an average, a man can harvest about 800 to 1000 fruits per hour with the help of this device, depending on the skill of the worker, fruiting and height of the tree. It consumes 50 per cent less energy as compared to local methods.

Harvested mangoes should be placed in field containers of not more than 25 kg capacity for movement to the packing shed. The fruit should be kept in the shade and handled carefully at all times after harvest.

INTERCULTURAL OPERATIONS

Training and Pruning

Normally, mango trees do not require frequent pruning. However, the training of the plants in the initial stages is very essential to give them proper shape. Training becomes very important especially when the branches are placed at a low level. Therefore at least 75 cm of the main stem should be kept free from branches and the first leader/main branch is allowed to grow. The main branches should be spaced in such a way that they grow in different directions and are at least 20-25 cm apart. The branches, which exhibit tendency of crossing and rubbing each other, should be removed in the pencil thickness stage. Subsequently pruning is done only to remove the diseased and dead branches.

Weed Control

Immediately after planting the mango, the weed problem may not exist, but it is advisable to break the crust with hand hoe each time after 10-15 irrigations. However, subsequent hoeing may be done depending on weed growth in the basin. If the intercrops are not being raised in the pre-bearing stage due to some reasons, the area between the basins should be ploughed at least three times a year, i.e., pre-monsoon, post-monsoon and in the last week of November.

Interculture operations are equally important for the bearing mango orchards. First ploughing should be done before the onset of rains. This will help in checking run-off losses and facilitate maximum retention of water in the soil. Orchard may be ploughed again after the rainy season in order to suppress weed growth and to break capillaries. Third ploughing may be done in the last week of November or first week of December with a view to check the population of mealy bugs.

The young mango grafts often come to flowering soon after planting or even in the nursery bed. This is detrimental to their health and vigour, particularly when such flowers are allowed to set fruits. All inflorescences that may appear during the first four years should be removed immediately after their emergence.

Intercropping

Mango orchard provides an opportunity for utilising the land space to its maximum during initial years of establishment. Crops like green gram, black gram, vegetable crops such as cabbage, cauliflower, potato, brinjal, cucumber, pumpkin, tinda etc. and spices like chilies can successfully be grown as intercrops. The partial shade loving crops like pineapple, ginger, turmeric, etc. can be grown in fully-grown orchards. In addition to field crops, some short duration, less exhaustive and dwarf type inter-fillers like papaya, guava etc. can also be grown till these do not interfere with the main mango crop.

Irrigation

Amount and frequency of irrigation to be given depends upon the type of soil, prevailing climatic conditions, especially rainfall and its distribution and age of the trees. No irrigation is required during the monsoon months unless there are long spells of drought. During the first year when the plants are very young with shallow root system, they should be watered even at 2-3 days interval in the dry season. Trees in the age group of 2-5 years should be irrigated at 4-5 days interval. The irrigation interval could be increased to 10-15 days for 5-8 years old plants during dry season. When trees are in full bearing stage, generally 2-3 irrigations are given after the fruit set which results in increased fruitset, decreased fruit drop, and improvement in fruit size and fruit quality. Frequent irrigation 2-3 months prior to flowering season should be avoided. It is advisable to irrigate the mango plants in basins around them to economising water use. The intercrops need to be irrigated independently as per their specific requirements.

MANURING AND FERTILISATION

Manuring mango plant starts right from planting operation in the orchard. Liberal applications of well-decomposed organic manure can be given each year to create proper soil physical environment and on account of several other beneficial effects.

Entire dose of the FYM and half dose of N, P and K should be given during monsoon while the balance half is applied during the end of monsoon. Before the application of fertilisers, the weeds should be removed from basins. The mixture of recommended dose of fertilisers should be broadcast under the canopy of plant leaving about 50 cm from tree trunk in old trees.

Age of the Plant (Years)	*Fertiliser Dose/Plant /Year*			
	FYM (kg)	*N (g)*	*P (g)*	*K (g)*
1	5	100	50	100
2	10	200	100	200
3	15	300	200	300
4	20	400	300	400
5	25	500	400	500
6	30	600	500	600
7	35	700	500	700
10^{th} onwards	50	1000	500	1000

The applied fertiliser should be amalgamated well up to the depth of 15 cm. To increase fertiliser use efficiency, fertilisers should be applied in 25 cm wide and 25-30 cm deep trenches dug around the tree 2 m away from trunk. The application of micronutrients is not recommended as a routine. Need based supplementation's are essential when these become limiting factor for production. It is advisable to apply micronutrients through foliar sprays.

MANAGEMENT OF DISEASES

Powdery Mildew (Oidium mangiferae)

Powdery mildew is one of the most serious diseases of mango affecting almost all the varieties. The characteristic symptom of the disease is the white superficial powdery fungal growth on leaves, stalk of panicles, flowers and young fruits. The affected flowers and fruits drop pre-maturely reducing the crop load considerably or might even prevent the fruit set. Rains or mists accompanied by cooler nights during flowering are congenial for the disease spread.

Control: Alternate spraying of Wettable sulphur 0.2 per cent (2 g Sulfex/litre), Tridemorph 0.1 per cent (1 ml Calixin/litre) and Bavistin @ 0.1 % at 15 days interval are recommended for effective control of the disease. The first spray is to be given at panicle emergence stage.

Anthracnose

It is of widespread occurrence in the field and in storage. The disease causes serious losses to young shoots, flowers and fruits under favorable climatic conditions (high humidity, frequent rains and the temperature range of 24-32°C). The disease produces leaf spot, blossom blight, withered tip, twig blight and fruit rot symptoms. Tender shoots and foliage are easily affected which ultimately cause die back of young branches. Older twigs may also be infected through wounds, which in severe cases may be fatal. Black spots develop on panicles. Severe infection destroys the entire inflorescence resulting in failure of fruit setting. Young infected fruits develop black spots, shrivel and drop off. Fruits infected at mature stage carry the fungus into storage and cause considerable loss during storage, transit and marketing.

Control: The diseased twigs should be pruned and burnt along with fallen leaves. Spraying twice with Carbendazirn (Bavistin 0.1%) at 15 days interval during flowering controls blossom infection. Spraying of copper fungicides (0.3%) is recommended for the control of foliar infection. Postharvest disease of mango caused by anthracnose could be controlled by dip treatment of fruits in Carbendazim (0.1%) in hot water at 52° C for 15 minutes.

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10

Organic Production of Fruit Crops

Organic fruit production is a practical option for some growers, but the viability of the enterprise will likely hinge on site, scale, type of fruit, markets, and managerial skills. In general, crops grown in the drier climates of the West have fewer disease and pest problems. This region may, therefore, be better suited to organic fruit production. Strawberries, bush fruits, and brambles are probably easier to grow organically in most sections of the country than grapes and tree fruits. Management requirements for organic production are likely to be higher in any region, and the producer must be closely attuned to local site conditions.

MARKETING AND ECONOMIC CONSIDERATIONS

To plan for economically successful enterprises, farmers must design their fruit production systems to match their marketing strategies. Good fruit production alone does not lead to a successful enterprise. Profitability depends on a combination of production volume, quality, size, and a reliable marketing strategy. Marketing channels range from direct markets to wholesale shippers. Growers must understand what each of their customers wants and be prepared to meet the expectations of the markets they intend to reach. For example, at farmers' markets, customers seek good tasting fruit at or near the peak of ripeness for prompt consumption, but supermarket distributors demand that fruit be uniform and shippable. It is important to market in an appropriate niche, one where the production of your operation can consistently meet the buyers' expectations of volume, quality, and timing. Premium pricing can be critical to the viability of organic fruit operations, because production costs are often higher than those for conventional orchards. Organic pest control, particularly labor costs for hand thinning and weed control, is generally more expensive than conventional practices. Yield and quality can vary widely, depending on the growing season and management practices.

In the past it may have been true that organic yields and pack-out rates were lower than in conventional production. Today, however, those differences have narrowed, and yields in some organic production systems can match or exceed those of conventional systems. To achieve good yields, organic growers must be prepared to develop innovative production and marketing strategies. Many commercial organic fruit producers, especially family-scale farmers, minimize waste and losses of potential revenue by processing fruit considered unsuitable for the fresh market.

There are tradeoffs in every marketing strategy. A successful grower must develop markets in which the price for organic produce adequately compensates for all production costs. Additionally, the marketing process must be compatible with the grower's personality and business skills. The particular combination of components in any grower's marketing strategy will depend on local marketing opportunities as well as the grower's desire to be directly involved in marketing, tolerance for stress, and ability to balance a variety of risk factors.

Cultural practices in fruit production begin with selection of an appropriate site, fruit crop, rootstock, and fruit variety, followed by site preparation and orchard layout.

These considerations will largely determine the productivity, health, and efficiency of operations in your orchard over the long term, and they cannot easily be changed once the orchard is established. If you are managing an existing orchard, you will continually need to take stock of its assets and limitations in relation to current markets, and either work within those limits or make plans for some degree of orchard renewal. If you are considering the purchase of an existing orchard, ask the owners about their financial history, and research the market to assess the economic feasibility of continuing with the business as it is currently practiced. Once you have made the most realistic cost estimates possible, you can develop a plan to adjust the production system, revise the marketing plan, or walk away while you still have your shirt.

PLANNING AND PLANTING AN ORGANIC ORCHARD

Site Selection

Fruit trees, like most crops, respond to good soil with vigor and productivity. Trees can successfully produce economic yields on hillsides, rocky soils, and other sites not suitable for frequent tillage. Look carefully at your site and take stock of its soil, slope, and aspect, water infiltration and drainage, frost patterns, maximum and minimum temperatures, length of growing season, distribution of annual precipitation, availability of water for irrigation, proximity of the water table, and wind and air circulation patterns. Most of these are beyond your control, and your planting plan must suit the natural conditions of the site. While farmers may be able to improve the soil over time, they cannot change the subsoil layers, influence the prevailing wind, or modify temperatures to any significant extent.

All the factors regarding site suitability for conventional fruit plantings apply-even more so-to organic operations. While conventional growers may fall back on chemical fertilizers and pesticides to compensate for some poor site decisions, organic growers cannot. Good drainage and air circulation are essential for disease control.

The presence of certain weeds and forage species is of particular concern to the organic grower. Bermuda grass, Johnson grass, quack grass, and several other pernicious species can be serious problems to fruit growers and are difficult to control with organic methods once an orchard is established. An assessment of physical and environmental factors will help the grower determine whether a crop can be grown easily, marginally, or not at all. While someone with a home orchard may consider it worthwhile to cover a lemon tree before each anticipated frost, or to nurse a few apricot trees through Midwestern winters in order to savor the delicious fruits two seasons out of seven, these would likely not be viable commercial enterprises. However, stretching the limits of production within reason can be worthwhile under certain circumstances.

Subtropical fruits grown in the coastal valleys of California bring a premium for their freshness and novelty, offsetting the expense of the extra care they require. Depending on the crop, harvesting either early or late in the season can also provide a market advantage. While California's San Joaquin Valley is not known for apple production, its warmer spring and summer temperatures can bring the crop to maturity a few weeks ahead of coastal producers.

The price premium for first-of-the-season organic fresh-market apples may offset the overall lower crop yields. Fruit grown in its primary growing region may be more difficult to distinguish from the rest of the fruit in the market, and so lose its competitive edge.

Pragmatism is critical in crop and variety selection. The fruit grower must take into account not only factors of yield, productivity, quality, and flavor, but also of marketability. Diversification of varieties and marketing channels is a prudent strategy. While one farm in California may receive a good return for the fruit from one lone jujube tree, there is no assurance that such a profit can be scaled up to an extensive orchard of specialty fruits.

Fruit Crop and Variety Selection

Because fruit trees are perennial and represent a considerable investment of both time and money, it is important to start by planting your orchard with the optimum varieties for your location and intended markets. Research on the front end can pay the grower back many times over. Information on species and varieties is available from Cooperative Extension, nurseries, and other local growers.

Many land grant universities have field stations where they have planted many varieties of fruit trees and gathered data and observations over several years. A visit to such a site can provide you with the invaluable opportunity to see the trees growing, talk with the manager of the experiment station about production challenges such as pests and diseases, and even taste the fruit.

Crop Species Selection

Clearly, the first decision is what species to plant. Is a tree orchard the best use of your land and talents? Or is your site and marketing plan better suited for a somewhat shorter-term investment in smaller plants such as blueberries, caneberries, grapes, kiwi, or even strawberries? If you are sure that you are willing to manage tree fruits and nuts, will your focus be to produce almonds, apples, apricots, avocados, cherries, figs, grapefruit, jujubes, lemons, oranges, pawpaws, peaches, pecans, pears, persimmons, plums, pluots, or zapotes?

Careful consideration of environmental conditions, as well as the locations of markets and suppliers, is of tantamount importance. For example, organic peach production in the East is greatly complicated by the presence of the plum curculio and by greater disease pressure than in the drier climates of the West. In general, the West's arid climate is better for organic fruit production. The small fruits are easier to produce organically than tree fruits in almost all locations. The availability of production supplies and markets in your region can be a critical factor in crop selection. Being the only one growing a certain fruit may provide you with a local marketing niche; however, the value of readily available supplies and services should not be underestimated. While some supplies can be easily and cost-effectively shipped by mail, others cannot.

Pest management materials such as codling moth pheromone traps can be efficiently shipped from a distant supply company. But how far do you have to drive to purchase boxes and bulky packaging supplies? How far to cold storage, a packing house, distributor, processor, or transportation terminal? Driving several hours to purchase appropriate boxes or to deliver fruit to a broker's cooler can make an otherwise viable enterprise unprofitable.

Variety and Rootstock Selection

Once the question of crop species is settled, the next decision is what variety to plant. Considerations include, but are not limited to:

- harvest season: early, mid, or late season, or a combination of these to achieve a more continuous supply or to ensure a crop during early or late marketing windows
- adaptability to the region: cold hardiness, temperature ranges for optimal growth, requirements for soil fertility or pH
- chill requirements for fruit set and flavor
- water requirements: need for irrigation or protection from waterlogging
- stature: dwarf, semi-dwarf, or standard
- resistance to diseases and pests
- marketability: color, flavor, nutritional value, storage requirements, shipability, uniformity, shelf life-any characteristics that define quality for your customer
- proximity to appropriate markets

You can select for desired characteristics, especially in grafted trees, with a combination of varieties of rootstock and fruiting wood.

Sources of Planting Stock

It is important to get clean planting stock. Buying from reputable nurseries that provide stock certified by state inspectors to be free of diseases and insect pests is best. Organic planting stock is required, if commercially available, for certified organic fruit production. If organic planting stock is not available, organic growers must document their search for organic stock and its lack of commercial availability.

Most certifiers interpret the organic standards as requiring organic management of non-organic planting stock for at least 12 months before harvesting a crop that is to be sold as certified organic. With newly planted tree crops, this is a non-issue, since they generally grow for at least three years before producing a marketable crop.

Type and Size of Planting Stock

The type of rootstock-standard, dwarf, or semi-dwarf-will determine the size of the tree at maturity. Tree size determines the spacing, number of trees per acre, training system, years to bearing, and timing of economic return. Orchard design should reflect the grower's production and cash-flow goals. For example, standard trees produce more fruit when mature, and initial purchase and planting costs are lower. Smaller trees have higher initial planting costs, since more trees are needed to achieve density. Dwarf and semi-dwarf trees generally come into production sooner.

Smaller trees simplify many field operations, including pruning, grafting, thinning, pest management, and harvest. Efficiency and safety are greater when a majority of operations can be accomplished from the ground as opposed to on ladders or by climbing. Weeds are less of a problem in the shade of a densely planted orchard. Depending on the species and variety, bareroot trees are often the most practical form of planting stock to ship, and the most economical to purchase. This is a good option for deciduous trees.

Other varieties, such as citrus, must be purchased in containers. Given the option of different sizes of bareroot trees, some walnut growers say that investing in a 1-inch tree over a 3/4-inch tree is worthwhile, because larger trees grow more vigorously. An experienced apple grower who produces without irrigation beyond the first year, however, stated his preference for 5/8-inch bareroot trees, which have a good balance of roots and are neither too big nor too small.

Disease and Pest Resistance

Genetic resistance refers to inheritable traits that enable a plant to inhibit disease and resist pest damage. A very important control measure for organic growers is to choose cultivars that are resistant to the pests-especially the diseases-most prevalent in their areas.

In some cases, such as that of bacterial spot in peaches, cultivar resistance is the best or only control for a particular disease. A cultivar may be quite resistant to one disease but still susceptible to another. Prima apples for instance, are very resistant to scab but very susceptible to cedar-apple rust. A planting stock resistant to a particular pest provides only relative resistance, not absolute immunity. A moderately resistant or tolerant variety may show symptoms of the disease but exhibit little to no reduction in yield.

Disease resistance must be weighed against other advantages. For example, walnut growers in the coastal regions of California have lost large numbers of trees in recent years to "black line," a fungal disease for which there is no treatment, only resistance. Payne variety is susceptible and Chandler is highly resistant to this disease. A trade-off is that Paynes mature sooner and can be harvested earlier in the fall, whereas Chandlers come in at least a month later when early rains can hinder harvest operations and make field preparations for planting a winter cover crop difficult or impossible.

While no fruit trees are resistant to insects that damage their fruit, it is possible to find stock that is resistant to insects that feed on other parts of the plant-*Phylloxera*-resistant grape rootstocks, woolly aphid-resistant apple rootstocks, and nematode-resistant peach rootstocks, for example.

As important as this resistance is, there is no cultivar of any fruit species with multiple insect pest resistance; therefore, an integrated pest management plan is necessary to protect fruit plants from a complex of several pest species. It will be important to identify the most troublesome pests for your crop and region in terms of frequency of incidence, severity of damage, cost of control, and economic consequences of the damage. Then seek out varieties that are resistant to those key pests and take into account any trade-offs you may make with other desirable characteristics, including seasonality, productivity, and flavor. Substantial crop-and variety-specific information on pest and disease resistance is available on the Web site of the University of California IPM project and other university pomology departments. Be sure to check with local suppliers of planting stock, and talk with other growers in your area about what has worked best for them.

Site Preparation

Important considerations in site preparation include alleviating soil compaction, enhancing fertility, adjusting soil pH, and managing weeds, pests, and diseases. Attention to the details of site preparation can help reduce weed and disease problems and assure a vital planting through soil improvement. What needs to be done depends on the previous use of the land, including crops grown, current vegetation, and the presence of pests and diseases. Many growers rip or chisel the soil to loosen layers of compaction before they plant a new orchard, since deep tillage will be disruptive once the trees are established.

Before establishing an orchard, it is important to adjust the soil pH to best suit the crop you've selected. Soil tests can assess current soil conditions, including pH, mineral levels, and their relative proportions. Traditionally, pH has been adjusted through applications of lime or sulfur. Most fruit plants perform best around pH 6.5, although they tolerate a pH range between 5.5 and 7.2. Blueberries are an exception. They require an acid soil-ideally pH 4.8 to 5.2. Soil test results help to guide applications of soil amendments such as compost, lime, gypsum, or other rock powders, to provide good soil conditions that meet the nutritional needs of the orchard.

In general, fruit crops do not require highly fertile soils for good production, though this varies with the species. Highly fertile soils, rich in nitrogen, can promote too much vegetative growth at the expense of fruiting in trees such as apples. A nutritionally balanced soil, proper soil pH, and plentiful organic matter are the fundamentals of an organic fertility management plan for fruits. Pre-plant soil improvement for organic fruit plantings usually involves some combination of cover cropping and applications of compost, natural minerals, or other organic fertilizers.

Weed Management Prior to Orchard Establishment

It's easier to manage weeds before an orchard is established. Cover crops produce a thick stand that will shade or choke out weeds. Combined with a well-planned sequence of tillage, cover cropping is an effective pre-plant weed suppression strategy that also contributes to soil fertility and stable humus.

The basic strategy begins with plowing under or disking the existing vegetation, ripping or deep chiseling to loosen compaction, planting a cover crop to suppress weed growth, mowing down and tilling under the cover crop(s), and finally planting the fruit crop. Several cover crop and tillage sequences may be necessary before planting.

Specific cover crops and management strategies vary with location and purpose. The two cases below raise the kinds of questions you need to ask to choose an appropriate cover cropping system. The cover crops you choose for site preparation may be entirely different from those you want once the orchard is established.

Bart Hall-Beyer, co-author of *Ecological Fruit Production in the North*, provides one example of how cover crops can be used to suppress weeds in the growing season prior to fruit crop establishment. His program consists of fall plowing, to allow the sod to rot, then disking as soon as the soil is dry in the spring, followed by harrowing every 10 days for at least one month to kill germinating weeds. He next incorporates compost and mineral nutrients and seeds buckwheat as a smother crop. He then tills the buckwheat into the soil after it has started flowering but before seed-set. Hall recommends additional cultivations at 10-day intervals, followed with rye as a fall cover crop. The rye is incorporated the following spring and the fruit crop planted.

In the Mid-South, researchers at the Kerr Center for Sustainable Agriculture in Poteau, Oklahoma, evaluated a number of cover crops for weed suppression on heavy soils. They converted pasture land to horticultural production, using rotations of cover crops and tillage. By this method, they virtually eradicated Bermuda grass from the fields in one to two years. Among their general observations are the following.

- Dense warm-season cover crop plantings of several species demonstrated a high degree of weed suppression, whether close-drilled in 6-inch rows or planted on wider 32-inch rows and row-cultivated.
- The length of the warm season may allow more than one cover crop to be grown in succession. Some cover crops may also be cut and allowed to regrow.
- Legume cover crops of purple hull peas, crotolaria, and sesbania all demonstrated good-to-excellent weed suppression, while supplying nitrogen and biomass to the soil.
- Of these, sesbania produced the most biomass and was the most effective weed suppressant. When cut with a sickle-bar mower at flowering, it regrew well and continued to suppress weeds. It is very drought-tolerant. Seed cost and delivery, however, were quite high. If allowed to re-seed, sesbania can create a moderate weed problem the following year.

- Crotolaria was a better nitrogen producer, but a less effective weed suppressant than sesbania. It, too, can be cut at flowering with a sickle-bar mower and allowed to regrow. Like sesbania, it is very drought-tolerant. The cost of seed can be high. Crotolaria seed is toxic-especially to birds-and the plants should not be allowed to go to seed.
- Because crotolaria and sesbania are quite fibrous, they should be mowed with rotary or flail mowers prior to soil incorporation.
- Cowpeas produce somewhat less nitrogen than crotolaria, and less biomass than either sesbania or crotolaria. They are, however, less fibrous and, therefore, decompose faster.
- Allowing cowpeas to flower and produce mature, dry seed prior to incorporation creates an inexpensive, self-seeded succession cover crop.
- Sudan grass proved the most effective of all warm-season weed suppressants. It can be flail or rotary mowed several times if regrowth is desired.
- Winter cover crops can be planted in rotation with warm-season cover crops. A combination of grain rye and hairy vetch was the most effective in this location. Winter peas and oats, and winter wheat-often grown in combination-also have good competitive ability.

Soil Solarization

Soil solarization is placing transparent plastic films on moist soil to capture solar energy. Solarization takes four to eight weeks to heat the soil to a temperature and depth that will kill harmful fungi, bacteria, nematodes, weeds, and certain insects in the soil. Solarization can be a useful soil disinfestation method in regions with full sun and high temperatures, but it is not effective where lower temperatures, clouds, or fog limit soil heating. Other disadvantages of solarization as a weed control method include its expense and disposing of the plastics. Solarization is most commonly used in smaller areas, such as greenhouses and nursery beds, though it has been used experimentally to treat orchard soils, either prior to planting or during establishment. Experiments are underway to evaluate using biodegradable spray mulches for solarization. Researchers emphasize that solarization should be seen as just one component of an integrated pest management system, rather than as a "stand alone" technology.

Orchard Layout and Design

Orchard layout influences the long-term health of the trees and the ease of field operations such as pruning, irrigation, fertilization, and weed and pest management.

Everything is related: the decisions you make about the space between rows and between trees in the row will have an impact on everything from disease management to harvest operations. While the specific spacing and training of trees will largely depend on the species, the following questions offer general considerations that will save time, resources, and expenses throughout the life of the orchard.

What is the lay of the land? Which way does the water run? What is the angle of the sun during different seasons? How will these affect the movement of both water and air, and in turn, temperature and humidity levels, crop ripening, and incidence of diseases and pests? Do the rows need to be planted on the contour for soil conservation or to capture limited seasonal moisture? Or should they be sloped to drain excess moisture? Given the degree of slope, which direction will provide the greatest safety for operating equipment and ease of harvesting ?

What are the diseases and pests that affect this crop in this region? What are their life cycles? Alternate hosts? Natural enemies? What conditions favor their growth and severity? What design strategies might promote or reduce these conditions? Would a certain orientation of the rows provide better exposure to the sun or better air circulation? Will you rely on seasonal pruning to maintain an open canopy to increase air flow through the foliage and sun to the fruit?

What equipment will you use for field operations? Consider all possible tasks, including planting, mowing, cultivation, pruning, irrigation, application of materials for pest management, and fruit harvest. Be sure that your row spacing is adequate to allow entry and maneuverability of any tractor, trailer, spray equipment, string trimmer, wagon, wheelbarrow, or hand cart that you plan to use.

What crop density do you seek? How soon after planting? The decision will depend on the species and stature of your trees, the cost of purchasing and planting them, the years to maturity, the prevalence of weeds, and other considerations. Using close in-row spacing or double rows of trees may complicate weeding in the first year or two, but thereafter shading will greatly reduce the need for weeding the inter-row. Some farmers plant slower-growing trees using closer spacing, then remove every other tree when they reach a certain maturity. The estimated benefits of earlier harvests must be considered against the costs of planting, managing, and eventually removing the trees. Alternatively, annual crops can be grown between immature orchard trees.

MANAGING AN ESTABLISHED ORGANIC FRUIT ORCHARD

Orchard Floor Management/Cover Crops

The orchard floor-the tree rows and alleyways- can be managed in a variety of ways, using tillage or mowing with cover crops, grazing, or mulching. A system that provides full ground-cover provides the best protection against erosion. Some fruit growers have practiced "clean cultivation," eliminating vegetation throughout the orchard, but this system has many disadvantages, even if accomplished with allowed tillage practices instead of organically prohibited herbicides.

A bare orchard floor is prone to erosion, gradual depletion of organic matter, increased soil compaction, and reduced water infiltration. It's also difficult to move equipment through the orchard in wet weather. However, a ground cover that is actively growing in the summer uses up water. This is a severe disadvantage in irrigated orchards where water is limited and expensive.

Orchard floor management can control erosion, improve the soil, and provide beneficial insect habitat.

- Where they are adapted, orchard grass, fescue, and other cool-season grasses are practical because they go dormant during the heat of the summer, minimizing competition with the fruit crop for water. With proper fertility management, these grasses can also provide plentiful mulch. Likewise, grasses are a good choice in apple orchards, for example, where the excess nitrogen provided by legumes can actually reduce fruit yields.
- Many warm-season legumes are deep-rooted and compete with the trees for water. Normally, they should not be allowed to grow under the tree canopy. However, leguminous ground covers can provide significant nitrogen to fruit trees or vines. Grass and legume ground covers alike promote water infiltration and hold the soil in place during the rainy season. Ground covers help maintain and increase soil organic matter, which increases the soil's ability to retain moisture. Cool season legumes, such as fava or bell beans, vetches, and clovers, also can achieve these goals.
- Planting subterranean clover into established orchards can provide mulch, fertilizer, between-row ground cover, and beneficial insect habitat. This clover reseeds itself in early summer and dies back during the hottest part of the growing season, leaving a relatively thick, weed-suppressive mulch. This system is used in apple and peach orchards in Arkansas and for a variety of orchard crops in California, but not where winter temperatures regularly drop below 0° F. Subterranean clover can provide habitat for such beneficial insects as ladybeetles, syrphid flies, big-eyed bugs, soft-bodied flower beetles, and other predators.

Crop Rotation

In an organic orchard, crop rotation does not mean changing the economic crop itself, but diversifying the vegetation that grows around the fruit crop. California organic almond farmer Glenn Anderson describes how important maximum plant diversity is within the orchard and in the surrounding vegetation. He takes advantage of every practical opportunity to diversify vegetation: the orchard floor grows cover crops; the landscaping around the family home situated in the midst of the orchard provides shelter and food for a variety of beneficial species; the roadway, farm perimeter, and even the paths of the irrigation lines provide habitat for these beneficials. Research studies confirm the positive effects of organic practices on beneficial insects. Several articles compared yields, pest and beneficial insect populations, and water and air quality factors on Anderson's farm to those of his brother's adjacent, conventional almond farm and found favorable results with organic practices.

PEST MANAGEMENT

Organic pest management relies on preventative cultural, biological, and physical practices. Organisms-insects, mites, microorganisms, or weeds- become pests when their populations grow large enough to prevent growers from reaching production goals. Integrated Pest Management recognizes that the mere presence of a potentially damaging species does not automatically mean that control actions are necessary. Knowledge of pest life cycles and monitoring techniques developed in IPM programs are useful for organic growers as well, because they mirror some of the elements of the organic pest management standard.

Three tiers of pest management strategies are described in the NOP Final Rule.

1. First, the producer should use cultural management practices that prevent pest and disease problems. These include multiple components of a holistic, systems approach to organic farm management and crop production.
2. In the second tier of pest management, biological and physical methods provide additional protection and need no justification. These practices build on and complement good cultural practices, but cannot compensate for poor cultural practices.
3. The third and final tier-the last resort-may be applying an allowed material if the first two tiers of response are ineffective and if the conditions for their use are described in the grower's Organic System Plan (OSP). A material response may be necessary under some circumstances, but it will be just one component of an integrated pest management plan that is part of an overall OSP.

Common arthropod pests of fruits include insects and mites. Identification and preventative management are essential to organic production systems. Organic Fruit Tree Management provides a useful list of important fruit pests, their hosts, status, identification, life cycle, monitoring/thresholds, and management.

While there are many other components to insect and mite pest management, in recent years there has been a good deal of research on vegetation management to enhance natural biological control. Approaches to cover crop and vegetation management described by Bugg and Waddington include:

- resident vegetation that harbors beneficial arthropods (insects, mites, spiders);
- strip management of cover crops to ensure the continuous presence of habitat for both beneficials and pests;
- insectary mixes of plants attractive to beneficial arthropods;and
- use of mulch from mowing to harbor generalist predators.

There is also increasing evidence that managing vegetation adjacent to economic crops as habitat for beneficial insects has a positive impact on pest management. These areas often include native plants and shrubs that flower at different times of the year, providing sources of pollen and nectar for beneficial arthopods.

The long-term nature of growing fruit using cover crops and other resident vegetation management can sustain populations of predators, parasites, and other beneficial organisms. There are many possible trade-offs that emphasize the need for careful planning and the importance of research and monitoring.

- *Apples and pecans:* California apples and Georgia pecan orchards planted in a diverse mix of cover crop species provided habitat and food for an array of beneficial organisms, resulting in a decrease of orchard pests.
- *Peaches:* Some winter annual broadleaf weeds have been implicated in increased populations of tarnished plant bugs in peach orchards, and dandelions and chickweed can serve as hosts for viruses that affect peaches and apples.
- *Walnuts:* Two species of ladybeetles were more abundant in an orchard floor where a cover crop was maintained from February to May, and helped keep walnut aphid populations in check.
- *Apples:* Codling moth infestations of apples were lower where bell beans grew. Bell beans are known for their extrafloral nectaries that help sustain beneficial insect populations even when the flowers are not open. Insect-eating birds can also reduce codling moth populations, but not control them. The development of pheromone mating disruption has been a major breakthrough in the past several years, making organic codling moth management feasible and organic apple production competitive.
- *Cherries:* In regions of California where the mountain leafhopper transmits buckskin disease, growers should use caution in establishing permanent covers that include

cool-season alfalfa and clover species that harbor the leafhopper. This case emphasizes the importance of understanding and carefully considering the pest's life cycle, with respect to the presence of host plants where the pest can reproduce.

- *Citrus and avocado:* Wind-blown pollens from grasses and trees can be alternate food sources for the predatory mite Euseius tularensis in late winter and early spring, and may, therefore, help build and sustain populations of predatory mites that attack pest species that include the avocado brown mite, citrus thrips, citrus red mite, and scale insects.
- Some legumes are also known to attract hemipterous pests like tarnished plant bugs and stink bugs. Where these pests are a problem, legumes may be less desirable as orchard cover crops, unless they can be managed as trap crops for lygus bugs. Alternatives such as mustards, buckwheat, dwarf sorghum, and various members of the Umbelliferae and Compositae families support substantial numbers of beneficial insects without attracting as many pests. However, mustards flower and seed early, providing early season food for hemipterans, including stink bugs.

Conversations with several organic farmers reinforce these research findings. Many organic walnut growers plant cover crops that are mixtures of legumes-such as bell beans, vetch, or alfalfa-to produce nitrogen and create a beneficial insect habitat, in combination with cereals that produce organic matter and provide support for the legumes. Growers alternate rows when they mow or disc, intentionally leaving strips of cover crops in the orchard to provide areas with flowering plants that sustain populations of beneficial insects. In any orchard setting it is important to watch for gopher problems. In addition to their many benefits, cover crops can also provide food and cover for gophers.

DISEASE MANAGEMENT

Disease can be a significant limiting factor in organic fruit production. Diseases may be caused by fungi, bacteria, viruses, nematodes, mycoplasmas, or protozoans. Disorders caused by the weather or by nutrient imbalances can create symptoms that look like diseases. Proper identification and preventative management are imperative.

Some plants can serve as alternate hosts for diseases. Eastern red cedars, for example, are alternate hosts for cedar-apple rust. Wild blackberries can harbor blackberry rust, and wild plums can foster peach brown rot. A good defense against plant disease is to maintain the crop plants in excellent health and vigor, with sufficient-but not excessive-soil nutrients and moisture.

Many diseases of fruit crops only affect a particular species and variety of fruit. There are, however, some diseases that are common to almost all temperate-zone perennial fruit crops. For instance, because of the relatively soft nature and high sugar content of most mature or nearly mature fruits, fruit rots are common afflictions. Sunlight and circulating air help to dry leaf and fruit surfaces, thereby limiting fungal and bacterial infections. The organic grower can help to minimize fruit rots by allowing good air circulation and sunlight penetration into the interior plant canopy.

In tree crops, this would mean proper pruning and training. In brambles and strawberries, reducing plant density helps. In grapes, adequate pruning and removing leaves that shade fruit clusters is beneficial. All fruit crops need a site that allows good air circulation. Well-timed applications of allowed fungicides can be effective in an integrated disease-control program for mildew and fruit rots in certain fruit crops.

Another problem common to many fruit crops is root rot and intolerance to poorly drained soils. Blackberries, most pear rootstocks, and some apple rootstocks are relatively tolerant of heavy or poorly-drained soils, but even these crops will succumb to persistently water-logged conditions. Blueberries, raspberries, and Prunus species (peaches, plums, cherries, etc.) are very intolerant of poorly drained soils and are generally susceptible to root-rotting organisms common in such soils. Even in well-drained soils, blueberries and raspberries are often planted in hills or raised beds. Again, site selection is very important.

Soils can be made disease-suppressive through the addition of significant amounts of organic matter to the soil. This has been most vividly demonstrated in Australia, where liming and cover crops-combined with applications of chicken manure, cereal straw, weed residues, and other materials-are used in avocado groves to control Phytopthora root rot. This strategy, known as the "Ashburner system," is now common practice in many areas where avocados are grown. In contrast, mulching apple trees in humid areas, such as New York, may increase Phytopthora root rot.

PLANT HEALTH AND VIGOR

Maintaining plants in good health and vigor is important in insect pest management. For fruit plants, this adage is more applicable to indirect pests than to pests that feed on the fruit. For instance, an apparently healthy plum tree may set a good crop of fruit, yet lose it all to the plum curculio. That same tree might suffer significant defoliation by caterpillars early in the season; yet, if it is in good vigor, it can compensate and bounce back quickly-still producing a marketable crop that year. There are some cases where general plant health and freedom from stress do impart a form of "resistance"-not technically genetic resistance-to certain pests. Two examples are apple trees in good vigor that actually cast out invading flathead apple tree borers by smothering them with sap, and plants not suffering drought stress being much less attractive to grasshoppers.

Biological Control

Biological control uses living organisms to manage pest populations. When a pest is endemic (not exotic), natural enemies are present, and biological control occurs naturally. The fact that it is occurring may not be noticed by growers. Researchers monitoring certain pests, such as leafminers, have found that pest populations actually increase after pesticide applications kill their natural enemies.

Biological control can be enhanced by cover crops and habitat management. However, where a known pest appears predictably and can be controlled by a specific biological agent, timed releases of beneficial insects may be in order. Many beneficial insects can be purchased from commercial insectaries for release in fruit plantings. Examples of beneficial arthropods that have been used to control pests in fruit crops include the predatory mites *Phytoseiulus persimilis* and *Metaseiulus occidentalis*, which attack spider mites; lady beetles and green lacewings, which feed on aphids; and Trichogramma wasps, which parasitize the eggs of several pests, including codling moth.

As a rule, beneficial arthropods are not a complete control for direct fruit pests, at least not for commercial growers who have a low damage threshold for fresh fruit. Usually, additional control measures are necessary. There are four essential components for successful use of beneficial organisms for pest control.

1. *Selection of the proper natural enemy for a target pest.* For example, *Trichogramma* wasps parasitize eggs and, therefore, do not directly control adult pests already active in the field.
2. *Proper timing of releases.* Release of natural enemies must coincide with a susceptible stage of the host and should be made early enough in the cropping season to assure success.
3. *Correct rate of release for natural enemies.* This is usually based on the planting density.
4. *Environmental provisioning.* Make sure environmental needs-such as nectar sources, alternate prey, and water-are available for adult beneficial insects. If the necessary environment is not available, beneficials may leave the release area, die, or spend so much time searching for nectar or pollen that they do not efficiently attack pests.

Applying Materials: Pesticides Allowed in Organic Production

Allowed materials include only natural materials that are not specifically prohibited, and specifically allowed synthetic materials. Most, if not all, allowed synthetic materials have annotations that closely restrict how they can be used. Before you apply any product, make sure it's allowed for use in organic agriculture. Read the label carefully. Are all the active ingredients allowed? What about the inert ingredients? If it contains any undisclosed inert ingredients, you must have documentation from the manufacturer to confirm that all inerts are allowed by the National Organic Program. If in doubt, ask your certifier before you use it.

Several new disease-control materials on the market are allowed for use in organic agriculture, including biofungicides, mineral-based essential oil extracts, and botanical fungicides. Growers in some regions are also using compost teas and plant extracts. The OMRI list provides information about the allowability of brand name products, but not their efficacy. You can ask your local Extension agent about any research or use in your region. Copper and sulfur compounds are fungicides that are allowed and have been used historically by organic growers, but they have several drawbacks. These materials can damage plants if applied incorrectly. Sulfur dust can cause acute eye and respiratory irritation in humans. It is also lethal to some beneficial insects, spiders, and mites, and can set the stage for further pest problems. Long-term frequent use of copper fungicides can also lead to toxic levels of copper in the soil.

Fertilization

Fruits, being largely water and sugars, remove relatively few nutrients from the soil, compared to other crops. Therefore, much of a fruit crop's fertility needs can be met through cover crop management and organic mulches and by the application of lime and other slow-release rock powders at the pre-plant stage. Supplementary fertilization may still be required for optimal growth and production.

The NOP Rule requires that applied raw manure be incorporated at least 90 to 120 days before harvest of crops for human consumption. Compliance is easy: move grazing animals to another pen or paddock at the appropriate time.

General Fertilizer Guidelines

- Organic fertilizers-especially uncomposted animal manures-should be incorporated into the soil to avoid nitrogen volatilization and to comply with organic standards. Use shallow tillage to prevent damage to plant roots and to minimize the potential for soil erosion. Manures should be incorporated into the soil at least three or four months before harvest to comply with National Organic Program standards.
- Soluble organic fertilizers such as fish emulsion, kelp, and soybean derivatives are suitable for use in drip irrigation and can provide quick supplemental fertility. Compost teas may be allowed and may contribute to disease control. Be sure to check with your certifying agency regarding current interpretations of the organic standards for compost production and any restrictions on the preparation or use of compost teas.

- Most organic fertilization programs focus on supplementing nitrogen as the key element, since it is needed in the greatest amount for the crop. You can calculate rates of organic amendments based on standard recommended rates for the crop, but be aware that many fertilizer recommendations still assume the use of synthetic materials. Organic systems behave differently. They generally use slower-release fertilizers and rely on biological activity to break them down into forms that can be absorbed by the plants. For example, only a portion of the nitrogen applied as stable compost may be available to plants in the first year. The rest is stored and released gradually. To compensate for this, the producer may apply twice as much nitrogen as is needed in the first year of organic management. In subsequent years, however, more of the nitrogen is released from the soil organic matter and becomes available. In a mature organic farming system, nutrients and organic matter are added to maintain, replenish, and build the bank of nutrients in the soil.
- When making fertilizer calculations based on nitrogen, growers need to credit the estimated contributions made by legume cover crops and/or mulches. A cover crop of subterranean clover, properly fertilized and inoculated, can fix from 100 to 200 pounds of nitrogen per acre annually in a "living mulch" system. Other legume cover crops may produce as much or even more, depending on things such as planting date, weather, and mowing.
- Consider the overall fertilizer analysis; basing application rates solely on nitrogen content can cause problems when the fertilizers are not balanced to meet the needs of the crop. For example, repeated use of poultry manure, which is very high in phosphate, can lead both to pollution problems and to zinc deficiency in the crop. These problems can be avoided by regularly monitoring and adjusting fertilizer selection and rates.
- The most reliable means for determining whether fertilization is adequate is to combine field observations with soil or tissue testing. Poor yields, unusual coloration of leaves, and poor plant growth are all clues to a possible nutritional imbalance or deficiency. On most fruit trees, slow elongation of branches often indicates a nitrogen deficiency. Yellowing between the veins of new blueberry leaves usually means the plant is suffering an iron deficiency. Corky bark on certain apple varieties can indicate an over-availability of manganese in the soil.
- Foliar analysis measures the nutrient content of the leaves and can identify a nutrient deficiency or excess well in advance of visible symptoms. It is more helpful than a soil test because the foliar analysis is a measure of what the plant is actually taking up, while a soil analysis only measures what is in the soil-which may or may not be available to the plant. Annual foliar analysis generally provides the best guide for adjusting supplementary nitrogen fertilization.

ORGANIC WEED MANAGEMENT

Some weed control methods, such as smother crops, are discussed in the Site Preparation section above. This type of cover cropping is an important tool for weed management that also contributes to good soil management, fertility, and pest management.

Mulches

Organic Mulch

Mulching is a powerful weed management strategy that can also contribute to good soil management, if appropriate natural materials are used. After a planting is established, weeds can be suppressed by applying thick layers of mulch. This can also create habitats for beneficial arthopods, including generalist predators such as big-eyed bugs, soft-bodied flower beetles, and spiders. Organic mulches are usually applied in a circle around tree trunks or vines, and down the whole row in blueberries.

Commonly, tree fruit growers keep mulches away from the tree trunks, particularly in winter, to prevent voles or mice from gnawing on the bark and damaging young trees. Keeping mulches 8 to 12 inches away from the trunk also reduces the likelihood of crown rot and other diseases in susceptible species-most notably apples on certain rootstocks.

Mulch materials may include straw, spoiled hay, leaves, yard trimmings, woodchips, and sawdust. Many of these materials are inexpensive. Still, it's wise to weigh the benefits and risks of each, including hauling costs and the risks of their containing impurities and prohibited materials.

Municipal greenwaste may be available, either raw or from municipal or commercial composting operations. Growers must monitor the incoming product and remove any trash to keep undesirable material out of their fields. Growers should ask compost producers about the sources of their materials and any pesticides that may persist in them. Of particular concern are clopyralid and picloram, herbicides that are extremely resistant to breakdown, even after composting. The sale and use of these materials is restricted in some areas.

Because organic mulches decompose over time, they require periodic re-applications in order to continue suppressing weeds. However, their decomposition provides other benefits. Mulching with organic matter enhances soil aggregation and water-holding capacity. Researchers from 1937 to the present have consistently found that mulching is the best orchard-floor management system for retaining moisture. In Michigan research, mulching was as effective as irrigation in encouraging tree growth. Organic mulches can have positive effects on tree growth, with improvements in soil quality and shifts toward beneficial nematodes. Mulch can also benefit the crop by moderating soil temperatures, thus reducing plant stress.

Organic mulches provide slow-release nutrients for the long-term health and fertility of the soil. Research indicates that potassium, phosphorus, and nitrogen are more available in mulched systems than in non-mulched systems. Some growers express concern that sawdust may acidify their soil or bind nitrogen in the soil. However, these effects are minimal if the sawdust is not tilled into the soil.

Raising organic matter on the farm is one way to ensure sufficient, clean mulching material. Farm-raised hay grown outside the orchard can provide weed-free mulch. Cover crops may be grown between tree rows, mowed, and gathered around the trees. Some small-scale growers use the biomass from orchard alleyways, cutting cover crops with a sickle-bar mower and hand-raking the material under the trees. Larger-scale operations often use forage wagons, straw-bale spreaders, or specialized equipment to mechanize mulching jobs.

Geotextiles

Geotextile mulches are paper or woven plastic fabrics that suppress weed growth. While they allow some air and water penetration, they may reduce water infiltration, whereas organic mulches increase infiltration. Geotextile mulches do not provide the advantages of adding matter and nutrients to the soil, and if synthetic, they must eventually be removed. Geotextiles have a high intial cost, though this may be partially recouped in lower weed control costs over the materials expected field-life-5 to 10 years for polyester fabric; 2 to 3 years for paper weed barriers. Still, some growers find them useful for weed suppression in orchard, tree plantations, and cane fruit culture.

Sheet Mulch

You can also create weed barriers by sheet mulching: laying down layers of cardboard or newspaper and covering them with organic material. Sheet mulching increases the efficacy of organic mulch as a barrier against emerging weeds. Organic growers should avoid cardboard that is waxed or impregnated with fungicide, as well as color print and glossy paper, in order to be compliant with the National Organic Program standards.

CULTIVATION

Cultivation-using mechanical tillage and weed harrowing implements-is the most widely used weed-management practice in fruit production. In systems that maintain permanent vegetation between rows, cultivation may be limited to the tree row under the dripline in an orchard, or extended 1 to 3 feet from the edge of the hedgerow in bramble plantings. The reverse is true where mulches are used in the tree row, and cultivation is used to control weeds and incorporate cover crops in the alleyways. In any case, cultivation must be kept shallow to minimize damage to crop roots and to avoid bringing weed seeds to the surface.

Hand cultivation-enhanced with the use of a wheel hoe-can be effective in small-scale plantings. In large-scale plantings of trees or vines, where in-row tillage is desired, "mechanical hoes" such as the Weed Badger or Green Hoe are very useful. These tractor-mounted, PTO-driven cultivators can till right up to the tree or vine without damaging the plant. Attachment options include powered rotary tillage tools and scraper blades that can move soil either away from or toward the base of the crop plants. Scraper-blade attachments, commonly known as "grape hoes," have been used in vineyards for decades.

Herbicides Allowed for Use in Organic Production

A few herbicides currently emerging on the market are allowable for organic production, with restrictions on the location of their use. There is ongoing research on using materials such as vinegar, corn gluten, and citric acid as herbicides, although they are not yet widely used by certified organic growers. Such materials may have applications in organic systems, such as for spot treatment of noxious weeds.

Weeder Geese, Chickens, and Ducks

For many years, farmers have used geese to control weeds in perennial and annual crops, including strawberries, blueberries, bramble fruits, and tree orchards. In Oklahoma, researchers at the Kerr Center for Sustainable Agriculture used weeder geese in commercial-scale blueberry and strawberry production, with portable electric fencing to keep the birds in a specific zone in the plant row. Investigators at Michigan State University studied the impacts of populations of domestic geese and chickens in a nonchemical orchard system. They found that the geese fed heavily on weeds-especially grasses-and also on windfall fruit.

ORGANIC FARMING: FUTURE CONCERNS

The market for organic products experienced a fast growth rate, between 20% and 25% per year. In 2005, it reached $33 billion. Because of the high demand, a substantial increase in organically managed farmland can be seen. Organic farming has almost 306,000 square kilometres worldwide. This represents approximately 2% of the total world farmland. Also, organic wild products are farmed on almost 62 million hectares.

Organic farmers use crop rotation, green manure, covers cropping, compost, and mulching to enrich the soil without any artificial elements. Some farmers use processed fertilizers, like seed meal, and many mineral powders like rock phosphate and greensand. These are very useful in controlling erosion, promoting biodiversity, and enhancing the health of the soil. Another problem organic farming has to deal with is pest control. This targets animal pests (including insects), fungi, weeds and disease.

Organic farming allows an acceptable level of pest damage and encourages beneficial organisms, careful crop selection and crop rotation. Sometimes, even mechanical controls like row covers and traps are used to control the pests. These methods also help the soil, fertilization, pollination, and water conservation.

A key characteristic of organic farming is rejection of genetically engineered products, including plants and animals. Conventional farming methods rely on pesticides to maintain higher yields. Because of this, most agricultural landscapes favor mono-culture crops and very little flora or fauna co-existence. Modern organic farms feature the removal of pesticides and the inclusion of animal manure, crop rotation, and multi-cultural crops, providing the chance for biodiversity to thrive. Is organic farming more profitable than conventional farming? Recent studies show that organic farms have lower yields than conventional farming in developed countries and much higher yields in developing countries. Several studies showed that organic farms withstand severe weather conditions much better than conventional farms and sometimes yield between 70% and 90% more than conventional farms during droughts. Organic farms have lower yields but require no synthetic fertilizer or pesticides. Because of this, along with the premiums which consumers pay for organic products, farmers obtain higher profits.

Because of the risks posed by pesticides and other artificial elements added to the crops. Conventional farming uses large quantities of pesticides in techniques such as crop dusting. According to several studies, people who work with pesticides have an increased risk of developing Parkinson's disease. On the other hand, organic farming uses few or no pesticides at all. The pesticides organic farmers use are natural and are not toxic to humans. In 2001, a study showed that children fed organic diets experienced significantly lower organophosphorus pesticide exposure than children fed conventional diets. It is clear that children whose diets consist of organic food items would have a lower probability of neurological health risks. If you are concerned with your or your children's health, consider buying organic products and helping the organic farming industry.

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11

Diseases of Fruit Crops

Thousands of fruit species exist in the tropics, most of which are important components of tropical ecosystems. Some, such as figs, are keystones that influence community structure, the composition and abundance of associated taxa, and the survival and reproduction of community species. Many tropical fruit species are significant food and habitat resources. Complex and interdependent webs of fauna and flora are common in tropical systems, and species of plants that produce fruit play prominent roles.

Only about 300 of these fruits are considered major, and 50 are well known and important commercially. All of these crops are Angiosperms, and with the exceptions of members of the Magnoliid complex and a handful of Monocots, the important species are all Eudicots. Some of these plants, such as coconut and cashew, produce edible fruits but are also significant sources of other products.

And other tropical plants that produce fruits are not considered here since their pulp or mesocarp are not significant; for example, only the seeds of cacao and coffee are important, and only the oil from the fruit of the African oil palm is utilised. Few of these fruit are important foods, either locally or globally. Only a dozen or so of the major crop plants worldwide are tropical fruit. Rather than great economic or food importance, they provide dietary variety. They are often nutritious and are usually significant sources of vitamins. They also contain important minerals and carbohydrates, and some, such as avocado, are uncommon botanical sources of fat. To the nutritional and organoleptic attributes of tropical fruits one must add their monetary value and international significance.

The annual production of six of these fruit exceeds 2 million metric tons, and another dozen or so are marketed worldwide. In international trade, tropical fruit and their associated products have an aggregate annual value of ca US$20 billion. More significant, however, is their value in local markets and situations. Only small percentages of most tropical fruits are exported outside the producing countries.

About 2.5% of all mangos and papayas are exported, and exported quantities of other important tropical fruit, such as durian and mangosteen, are probably lower. In some cases, processed products are significant. For example, more pineapple is shipped in cans than as intact fruit, and about one-third of all citrus fruit is processed as juice. The most notable tropical fruit is banana.

Over 100 million metric tons are produced annually, and it is the world's fourth most valuable food after rice, wheat and milk. As for most tropical fruit, a relatively small percentage of the bananas that are produced every year is exported. About 85% of the harvested total is consumed in the producing countries. For many people in Africa, the Americas and Asia, banana is a staple.

SIGNIFICANCE OF DISEASES

Diseases are often the most important constraint to the production of tropical fruit. They indirectly reduce yields by debilitating the plant, and directly reduce the yield or quality of fruit before and after they are harvested. They range from esthetic problems that lower the marketability of the harvested product to lethal problems that devastate local or regional production. Virtually every important tropical fruit is affected by one or more serious diseases. Diseases determine how and where a crop is produced, what post-harvest treatments are utilised, in what markets the crops are sold, and whether production is sustainable and profitable.

GENERAL CATEGORIES OF PLANT PATHOGENS

Infectious diseases of plants, i.e., conditions that disturb or harm their normal growth or development, are caused by diverse pathogens. Among the prokayotes, i.e., organisms that lack a nucleus or nuclear envelope, only the Domain Eubacteria contains plant pathogens; none are known in the Archaea.

Pathogens in the Eubacteria include single-celled microbes without cell walls, or with Gram-positive or Gram-negative cell walls. The Eubacteria are more phylogenetically diverse than the relatively complex pathogens in the Domain Eukaryota. However, those in the Eukaryota predominate as plant pathogens. They include an array of multicellular life forms, including fungi, fungus-like oomycetes, nematodes, parasitic plants and protozoa.

A third group of pathogens, referred to here as nucleic acid-based pathogens, have unclear affinities to the above life forms. Viruses are single- or double-stranded RNAs or DNAs that are usually encased in protein or lipoprotein envelopes. They are simple pathogens, with genomes of a few thousand to a million nucleotides that encode 1 to 12 proteins; they replicate only within living cells of their hosts. Even simpler are the viroids, which are the smallest of all infectious disease agents. They are circular, nonenveloped molecules of a few hundred nucleotides, and a tropical fruit, avocado, is the host of the smallest of these pathogens, *Avocado sunblotch viroid* (246-250 nt).

TROPICAL FRUIT PATHOGENS

Fungi are the most prevalent and important plant pathogens. In descending order, significant but less frequent diseases are caused by viruses, bacteria, oomycetes, nematodes, phytoplasmas, viroids, parasitic plants and protozoa. Fundamental to understanding these disease problems is the host:pathogen interaction. The different causal agents can be divided into two categories, generalists and specialists. Generalists impact diverse host taxa. Examples include pathogens that affect seedlings and fruit. There is usually no host resistance to diseases that are caused by the generalists. Host-specific pathogens impact far fewer host species than the generalists. They can often be classified as coevolved or new encounter, based on whether or not they have had an evolutionary history with their host(s). Host resistance to coevolved pathogens is common and has been used extensively in the management of the diseases that they cause. Since host resistance to the new encounter pathogens is available less frequently, managing these diseases often relies on other measures.

Eukayota

About three times as many plant pathogens are eukaryotes than are the prokaryotic and nucleic acid-based pathogens combined. Eukaryotic pathogens utilise diverse ecological niches, reproductive strategies and life styles, and cause a wide range of symptoms on many hosts and host organs.

Kinetoplastida

Uniflagellate protozoans in the genus *Phytomonas* (Kinetoplastida, Trypanosomatidae) are rare plant pathogens. They are found in a variety of tissues, but cause disease only in some hosts. To distinguish different strains, recognition of the following sections was suggested: phloemicola, for phloem-restricted isolates; laticicola, for laticifer-inhabiting isolates; and frugicola, for those from fruit or seed. Isolates in sections laticicola and frugicola are genetically diverse and do not appear to be plant pathogens. For example, frugicola isolates from annona, citrus and mango are not associated with symptoms on these hosts. In contrast, genetically uniform isolates of *Phytomonas* sp. (formerly *staheli*), section phloemicola, cause hartrot, a lethal disease of coconut and African oil palm in tropical America.

Chromalveolata

Some of the most important plant pathogens are members of the Stramenopila

(Chromalveolata). These microbes are related to diatoms and brown algae, and are commonly known as "water molds" since the diseases they cause are prevalent in wet environments. Although they resemble fungi, they have diploid, coenocytic, vegetative hyphae, and cell walls that are made primarily of cellulose, rather than the chitin that true fungi possess.

Species in the Pythiaceae (Oomycota) are the most significant tropical fruit pathogens. They cause root rots, trunk cankers, foliar blights and fruit rots, and produce a variety of propagules including chlamydospores, hyphal swellings, oospores, sporangia and motile zoospores. *Pythium* spp. are usually generalists that cause root diseases on a wide range of hosts. They can kill seedlings and small plants, or cause significant losses of feeder and structural roots. In contrast, *Phytophthora* spp. are usually somewhat host-specific. They also kill seedlings, but are more serious problems on adult plants, usually causing root rots, trunk cankers and fruit rots. Five important species of *Phytophthora* are listed below. *P. cinnamomi* is an uncommon member of the genus in that it affects over 1,000 species of plants. Since it originated in New Guinea, virtually all of its hosts are new encounters.

The tropical fruit hosts include cherimoya, kiwifruit and pineapple, and it is the most important pathogen of avocado. *P. cinnamomi* produces distinctive corraloid mycelium. Its nonpapillate, noncaducous sporangia are elliptical to ovoid, but are rarely formed in culture. Terminal and intercalary chalmydospores are abundant in culture and hyphal swellings can also be abundant. *P. cinnamomi* is heterothallic. Its minimum temperature for growth is 5-15°C, the optimum is between 20 and 32.5°C, and the maximum is 30 to 36°C.

P. citricola causes diverse diseases of avocado, fig, guava, kiwifruit and mango. It causes trunk cankers on avocado genotypes that have been selected for resistance to *P. cinnamomi*. It produces noncaducous sporangia that vary from obovoid, obclavate and obpyriform to slightly flattened on one side. They are semipapillate and can have a single apex or be deeply bifurcated with two apices, or irregularly shaped with three or four apices. Chlamydospores are rare. *P. citricola* is homothallic. Its cardinal temperatures for growth are 3, 25-28, and 31°C.

P. citrophthora affects chempedek, citrus and kiwifruit. It produces variable, noncaducous sporangia. They range in shape from spherical, ovoid, obpyriform, obturnate, ellipsoidal to extremely distorted. They are persistent, mostly papillate, and often have two or more papilla. Chlamydospores are uncommon for isolates from citrus, and sex organs do not occur in nature although oospores can be induced when some isolates are paired on carrot agar. Its cardinal temperatures for growth are <5°C, 24-28°C, and 32-33°C.

P. nicotianae (aka *P. parasitica*) causes fruit, heart and root rots on carambola, fig, pineapple, rambutan and sugar apple. It forms noncaducous ellipsoid, ovoid, pyriform to spherical sporangia with usually a single papillum. They are produced either singly or in sympodia on stalks. The pathogen forms intercalary and terminal chlamydospores, and most isolates are heterothallic. Its cardinal temperatures for growth are 5-7°C, 27-32°C, and 37°C.

P. palmivora is a ubiquitous pathogen in the tropics with a wide host range. It causes bud, crown, fruit, heart and root rots of atemoya, avocado, breadfruit, coconut, durian, fig, longan, mango, papaya, pineapple, pond apple and soursop. Its hyphae are often irrégular and sporangia are prominently papillate and caducous with long pedicels. Chlamydospores are formed by most isolates.

Plantae

Parasitic plants, such as mistletoes, dodder and broomrape, are usually not important plant pathogens. A green alga, *Cephaleuros virescens* is the most common of these pathogens on tropical fruits. It causes algal leafspot (red rust) on avocado, breadfruit, carambola, citrus, durian, longan, lychee, mango, mangosteen and rambutan. The algal thallus is orange to rust colored and develops below the host cuticle. It produces sporangia on the terminals of erect stalks which produce biflagellate zoospores. Flask-shaped gametangia that are responsible for sexual reproduction are also formed in the thallus. Gametangia release biflagellate gametes in free water, which fuse in pairs to produce sporophytes. Algal leafspot is usually serious only in poorly managed orchards. In these situations mites, insects and other foliar diseases can increase the severity of the disease. Algal leafspot requires a humid environment to establish and spread. The alga's zoospores are the primary infective propagules, and they are dispersed by rain splash and wind.

Fungi

The Kingdom Fungi has been traditionally comprised of four groups, the Ascomycota, Basidiomycota, Chytridiomycota and Zygomycota. Recent phylogentic work indicates that the Chytridiomycota and Zygomycota are not monophyletic groups. Relationships among their members need further clarification, and they are not discussed further since their members cause minor problems. The Ascomycota and Basidiomycota are monophyletic and have been merged into the Subkingdom Dikarya; it contains more tropical fruit pathogens than all other pathogen groups combined.

Ascomycota

Botryosphaeria spp. Several important pathogens of tropical fruits have *Botryosphaeria* teleomorphs (Botryospaeriaceae, Botryospaeriales, Dothidiomycetes, Pezizomycotina). They produce uni- or multi-locular ascomata with multi-layered dark walls, singly or in clusters, and are often immersed in stroma. Some of the pathogens do not produce teleomorphs, but have been associated with this genus via molecular analyses. The associated anamorphs have been divided into two groups. One contains *B. rhodina* and *Diplodia, Lasiodiplodia* and *Sphaeropsis* anamorphs that produce conidia that are light to dark brown when mature and usually >10 μm in width. The other includes *B. dothidea* and *Fusicoccum* anamorphs that produce conidia that are usually <10 μm in width and hyaline.

B. rhodina (anamorph: *Lasiodiplodia theobromae*) is one of the most common plant pathogens in the tropics. It causes diverse fruit, foliar and branch diseases on *Annona* spp., *Artocarpus* spp., avocado, banana, carambola, durian, longan, lychee, mango, mangosteen and rambutan. *B. rhodina* produces fluffy, grey to black mycelium on oatmeal agar (OA) and potato dextrose agar (PDA).

B. rhodina attacks trees that are weakened by extreme temperatures, drought and other factors. It infects through wounds, and causes symptoms on fruit as they ripen. It is often an endophyte, and can also be found in soil, on dead twigs, mummified fruit and on organic debris beneath trees.

Ceratocystis spp. The genus *Ceratocystis* (Microascales, Hypocreomycetidae, Sordariomycetes) includes plant pathogens that cause a wide range of symptoms. They are found on woody and herbaceous hosts, often in the tropics. Many are vectored by flying insects. They produce brown to black perithecia with long necks that exude ascospores in a sticky matrix.

C. paradoxa (anamorph: *Thielaviopsis paradoxa*) is prominent on tropical fruit, and causes butt rot, fruit rot and a leaf spot of pineapple, stem bleeding of coconut; foot rot of fig; fruit rot of carambola; and black scorch, inflorescence blight, bud rot, heart rot and trunk rot of date palm. Conidia, which are also called endoconidia, and chlamydospores, are hyaline to slightly brown, cylindrical to slightly oval, and are extruded through the end of the conidiophore. Chains of thick-walled chlamydospores are produced in older cultures, and perithecia and ascospores are produced only occasionally.

Another species, *C. fimbriata* (anamorph: *Thielaviopsis* sp.), the first described in the genus, has been reported on *Annona* spp., *Citrus* spp., fig and mango. It differs from *C. paradoxa* by its longer conidia, nonornamented perithecia and hat-shaped ascospores. Recent work has shown that *C. fimbriata* is a species complex, and that host specialisation may have occurred in it several times. For example, isolates that cause lethal diseases of mango in Brazil (seca), Oman (sudden decline) and Pakistan are distinct, and those from Oman and Pakistan have been recently described as a new species, *C. manginecans*.

Recognition of these host-adapted populations will assist disease management and quarantine objectives.

Fusarium spp. Before molecular tools became available, *Fusarium* was a taxonomically difficult genus. Most problematic were taxa that did not produce teleomorphs, since they lacked distinguishing anatomical features.

The *Fusarium oxysporum* complex (FOC) includes saprophytes, as well as human and plant pathogens. It is a common soil inhabitant, and members do not produce a teleomorph. Among the plant pathogens are host-adapted, coevolved forms, the formae speciales. The most important ff. spp. cause vascular wilt diseases, the fusarium wilts, and several tropical fruit crops are affected (e.g. banana, citrus, date and passion fruit). These diseases occlude the xylem and are difficult to control; host resistance is most useful. The *Gibberella fujikuroi* species complex (GFSC) contains several distinct mating populations (MPs) that can be distinguished via sexual compatibility and the formation of perithecia. Molecular work has identified related taxa that do not produce teleomorphs, and the tropical fruit hosts include banana, fig, mango, and pineapple.

Glomerella spp. *Glomerella* spp. are among the most common and important above-ground pathogens of tropical fruit. They are facultative saprophytes and common endophytes that cause anthracnose diseases on fruit, leaves and twigs. Two species are described here.

G. cingulata (anamorph: *Colletotrichum gloeosporioides*) has a very wide host range. It causes significant problems on *Annona* spp. avocado, breadfruit, carambola, citrus, durian, fig, guava, jackfruit, lychee, mango, mangosteen, papaya, passion fruit and rambutan. It is most important as a fruit pathogen, but also causes branch and leaf diseases.

On PDA, colonies are whitish to dark grey with thick to sparse lawns of aerial mycelium. Conidia are hyaline, one celled, and cylindrical with obtuse ends. They form on light brown conidiophores in irregular acervuli, and upon maturity appear orange and slimy en masse. Acervuli develop in lesions on leaves, branches and fruit, and conidia in acervuli remain viable for long periods, even under adverse climatic conditions. The fungus is heterothallic and although the teleomorph can be readily induced in culture, it is observed rarely in the field. Appressoria are usually lobed. Conidia of *C. gloeosporioides* are epidemiologically important. They are produced on virtually all host tissues and are usually dispersed by rainsplash.

Moderate temperatures and free moisture are needed for optimum production, germination and infection. New leaf flushes are most susceptible. Although fruits can be infected at any stage of development, infections that occur before ripening usually progress no further than the formation of appressoria. Disease development usually commences after ripening begins.

G. acutata (anamorph: *Colletotrichum acutatum*) affects avocado, breadfruit, carambola, citrus, fig, guava, kiwifruit, lychee, mango and papaya. It causes anthracnose primarily on fruit, and is usually less important than *G. cingulata*. It is also responsible for a serious fruit set disease on citrus, postbloom fruit drop. Colonies are effuse, white becoming pale orange then greenish grey or black, often with a pink or reddish purple underside. Conidia are hyaline, one celled, straight, smooth, fusiform, and salmon-colored en masse. Appressoria are sparse, mostly light to medium brown, clavate to obvate with smooth margins. Acervuli are superficial to subcuticular.

C. acutatum differs from *C. gloeosporioides* in its orange to pink colony coloration during the first few weeks of growth, its fusiform conidia and spherical, rather than lobed, appressoria. The fungus is heterothallic, but perithecia have not been observed in the field.

Mycosphaerella spp. *Mycosphaerella* contains more than 3,000 named species, making it the largest genus of ascomycetes. At least 23 different genera of anamorphs have been associated with teleomorphs in the genus. They produce small, black, pseudothecial ascomata immersed in host tissue, either singly and superficially, or in a pseudoparenchymatal stroma. *Mycosphaerella* spp. are either saprophytes, weak pathogens, or cause serious diseases. The plant-pathogenic species are host-specific and usually restricted to a single genus or family. Host range plays an important role in species identification. Three species that are found on banana are discussed below.

M. fijiensis (anamorph: *Pseudocercospora fijiensis*) causes black Sigatoka; it is the most damaging foliar disease of banana and is found throughout the humid tropics. Its control is a major expense for producers of export bananas, who rely on the highly susceptible Cavendish subgroup of cultivars. It has replaced *M musicola* (anamorph: *Pseudocercospora musicola*), cause of Sigatoka or yellow Sigatoka, as the most important foliar pathogen of banana. The two pathogens are distinguished by examining the conidia of their anamorphs: those of *Pseudocercospora fijiensis* have a thickened hilum at their base, whereas those of *Pseudocercospora musicola* do not. The recently recognised *M. eumusae* causes eumusae leaf spot. Its symptoms mimic those of black Sigatoka and, as a result, it has an unclear host range, impact and distribution

Rosellinia spp. *Rosellinia* spp. produce superficial perithecia on host bark, usually in dense swarms of hyphae. Asci are unitunicate with an apical ring, ascospores are black and unicellular. Three types of species are recognised: strict saprophytes, endophytes that are occasionally pathogenic, and severe root pathogens. Three in the later group are important on tropical crops.

R. necatrix causes white root rot on avocado, cherimoya, citrus, fig and kiwifruit. The rare teleomorph has spherical, black perithecia that are embedded in mats of brown hyphae. Conidiophores of the more common anamorph are produced on brown, ropey, rigid synnemata composed of intertwined, laterally cemented hyphae. Conidia produced on synnemata are one-celled, solitary, elliptical to ovoid, colorless to pale brown and smooth. Peculiar pear-shaped swellings often occur near the septa on the hyphae, especially on older hyphae.

The fungus also produces scattered, black, rough, irregular masses of microsclerotia that often unite to form irregular, flattened masses or sheets that enable long-term survival. Feeder roots are directly infected when they contact hyphae or microsclerotia. The infection spreads into woody roots and may spread from tree to tree in this manner. Two other species cause black root rot of avocado, banana and citrus in the tropics. *R. bunodes* is widespread in tropical America and in various locations in the east. *R. pepo* is less widespread in the west and Africa. Black root rot is particularly important in acidic soils with high organic matter content; because the responsible species have wide host ranges and persist in colonised organic debris, it can be difficult to manage.

Basidiomycota

Armillaria spp. *Armillaria mellea* causes root rot on avocado, cherimoya, fig, kiwifruit, lychee and soursop. It forms a number of structures including basidiomes, basidiospores, mycelia, white mats or plaques between the bark and wood, pseudosclerotial tissue and rhizomorphs on the surface of infected roots. Infected tissues have a distinct mushroom odor when moist. Basidiomes are often produced around the base of affected trees after rainfall, but have no known role in the disease cycle.

A. mellea is sometimes referred to as the honey mushroom or shoestring fungus. Its wide host range and ability to survive as a saprophyte make it a difficult pathogen to control. Infection results when roots contact infected plants or rhizomorphs of the fungus in the soil. Infected tree stumps and large roots of dead hosts are common sources of inoculum, and the fungus may persist saprophytically for 10 or more years.

Erythricium salmonicolor. Erythricium salmonicolor causes pink disease on a wide range of tropical crops including breadfruit, carambola, citrus, custard apple, durian, jackfruit, mango, mangosteen and rambutan. Distinct forms of the fungus occur on affected trees. The first, cobweb stage develops as a layer of vegetative mycelium under wet conditions. Eventually, the necator stage develops in which orange sporodochia and conidia of the anamorph are produced. It is followed by the pink incrustation stage of the teleomorph that produces basidiospores. Both conidia and basidiospores are infective and spread by wind.

Pink disease is most important under high rainfall, tropical conditions, and serious damage occurs only in areas where rainfall exceeds 2000 mm per year. The fungus penetrates intact or wounded bark and eventually kills the cambial layer. Ultimately, large diameter branches and entire trees can be killed.

Ganoderma spp. Over 200 species of *Ganoderma* have been described. Most of these are from temperate areas, but some affect trees in the tropics. They cause white rots and basal cankers, and produce conspicuous conks that have a varnished appearance on the upper surface. The ovoid, golden basidiospores are distinctive, but have an unclear role in disease transmission on most hosts. There is some confusion over the identity and importance of the tropical plant pathogens in the genus.

G. tornatum is apparently the most common species in the tropics, and causes heart rots and basal stem rots. *G. applanatum* affects a wide host range of Gymnosperm and Angiosperm trees in northern latitudes, but has also been reported to cause butt rot on avocado and concentric canker on citrus. Basal stem rot of coconut palm is caused by *G. boninense* in Southeast Asia and *G. zonatum* in the Eastern and Western Hemispheres; the later species also causes butt rot on avocado. *G philippi* causes red root rot of mangosteen.

Rigidoporus spp. *Rigidoporus* spp. cause white rots of roots and trunk bases of wide range of hosts. *R. ulmaris* and *R. vintus* affect avocado. *R. lignosus* affects carambola, durian and mango, and is probably restricted to Africa and Asia. Its large host range of woody perennials contains other important crops, including rubber, on which huge losses have been reported.

R. lignosus produces white rhizomorphs on the surfaces of roots and root crowns which later darken to a yellowish and then reddish color. The leading edge of the rhizomorph is well-defined and seldom appears above ground. It undergoes a morphogenic change to produce infectious hyphae that penetrate the host epidermis and, subsequently, degrade host lignin. The fungus is most damaging if orchards are established in old rubber plantations or newly cleared jungle sites. Previously colonised stumps and infected woody debris of rubber and other hosts are primary sources of inoculum.

Orange-yellow, bracket-like sporophores are produced during the rainy season on the root collar, trunk or exposed roots. Basidiospores produced on the sporophores are viable, and are thought to play a secondary role in disseminating the disease; at most, they probably colonise exposed stump surfaces. Rhizomorphs are more significant epidemiologically, since they grow rapidly and can advance great distances in soil in the absence of woody substrates. The most effective means for controlling white root rot rely on eliminating or avoiding colonised woody debris when new orchards are established.

Metazoa

Nematodes are the second most diverse group of animals after the arthropods. They are nonsegmented roundworms, and the plant pathogenic species have stylets, needle-like mouthparts that allow them to puncture plant cells and extract their contents. Most of the pathogens are soilborne root parasites that can be divided into endoparasites that cause root knots and cysts, enter the host, and feed within the root, and ectoparasites that cause general lesions and necrosis by feeding externally on root surfaces. Ten to 15 % of some crops are lost annually to these pathogens.

There are ca 2,000 species of plant pathogenic nematodes. Most are in the order Tylenchida. With two exceptions, the tropical fruit pathogens are restricted to three families in the suborder Tylenchina, superfamily Tylenchoidea: Pratylenchidae, Hoplolaimidae and Heteroderidae. Exceptions are the sedentary endoparasite *Tylenchulus semipenetrans*, cause of slow decline of citrus, and the red ring pathogen of coconut, *Bursaphelenchus cocophilus*.

Pratylenchidae. Two genera of important migratory endoparasites are found in this family. They puncture epidermal root cells, eventually colonise the root cortex, and can cause significant root necrosis alone and in combination with other pathogens. Lodging can occur in plants with severely damaged root systems. Lesion nematodes, *Pratylenchus* spp., are the most prevalent fruit pathogens in this family.

P. brachyurus is an important pathogen of pineapple and causes minor problems on citrus; *P. coffeae* is important on banana, but is minor on citrus and pineapple; *P. goodeyi* is also important on banana, but is found only in the Canary Islands and Africa.

The burrowing nematode, *Radopholus similis*, is the most important nematode on banana, on which it causes black-head toppling syndrome. It also causes spreading decline of citrus.

Hoplolaimidae. The reniform nematode, *Rotylenchus reniformis*, is found on a wide range of hosts in the tropics and subtropics. It affects papaya and passionfruit, and became a serious problem in Hawaiian pineapple production where chemical fertilisers reduced soil pH.

The spiral nematode, *Helicotylenchus multicinctus*, impacts breadfruit and jackfruit, and is an important problem on banana in subtropical or high elevation tropical production areas; on the later crop it causes less extensive cortical damage than *Pratylenchus* spp. and *Radopholus similis*.

Heteroderidae. The sedentary endoparasitic root knot nematodes, *Meloidogyne* spp., are the most common plant pathogenic nematodes. They are sedentary endoparasites, and usually have wide host ranges. *Meloidogyne* sp. affects breadfruit and jackfruit; *M. arenaria*, banana, date palm, fig, guava, kiwifruit, papaya and passionfruit; *M. hapla*, date palm, kiwifruit and papaya; *M. incognita*, banana, date palm, guava, kiwifruit, papaya, passionfruit and pineapple; *M. javanica*, banana, date palm, guava, kiwifruit, papaya, passionfruit and pineapple; and *M. mayaguensis*, guava. These nematodes can interact synergistically with other pathogens.

Eubacteria

The Eubacteria are phylogenetically diverse and include serious plant pathogens. Below are brief descriptions of some of the important tropical fruit agents.

Firmicutes

The Firmicutes include Eubacteria without cell walls, the Mollicutes, and those with Gram-positive cell walls; the later are not important on tropical fruits. Mollicutes include the phytoplasmas, unculturable pathogens in the order Acholeplasmatales. The genus "*Candidatus* Phytoplasma" has been created to accommodate members of this important group. Taxa in the genus include agents that are associated with, and presumably cause: yellow crinkle and mosaic of papaya; dieback of papaya; witches' broom disease of limes; diverse yellowing disorders of palm, especially coconut; phytoplasma-associated diseases of date palm. *Spiroplasma citri* is the culturable cause of citrus stubborn disease.

Proteobacteria

Tropical fruit pathogens are found in three divisions of proteobacteria. The α-proteobacteria includes the well-known crown gall pathogen, *Agrobacterium tumifaciens*. It affects a wide range of dicots. Also in the α-proteobacteria are the putative huanglongbing (greening) agents of citrus: *Candidatus* Liberibacter asiaticus, which was restricted to Asia, but detected recently in Florida; *Candidatus* Liberibacter africanus, found only in Africa; and *Candidatus* Liberibacter americanus, recently described in Brazil.

Huanglongbing is a destructive new encounter disease which is difficult to manage; it eliminates commercial production of citrus shortly after it becomes widely established in most areas. The probable cause of a serious disease of papaya in the Caribbean region, papaya bunchy top, was recently reported to be an unculturable relative of the Rickettsia pathogens of animals. In the â-proteobacteria are serious vascular wilt pathogens in the species complex, *Ralstonia solanacearum*. Phylotype II of *Ralstonia solanacearum* causes Moko, a new encounter disease of banana in tropical America, whereas phylotype IV causes blood disease of banana in Southeast Asia.

Diverse plant pathogens are found in the ã-proteobacteria. They include soft-rotting *Erwinia* spp. that affect fruit and plants; *Pseudomonas* spp. that cause blossom blight, leaf spots or cankers; and *Xylella fastidiosa*, which causes citrus variegated chlorosis. Most important, however, are various taxa in *Xanthomonas*: X. *axonopodis* pv. citri causes citrus canker, a serious disease of quarantine significance; X. *axonopodis* pv. *mangiferaeindicae* causes a serious fruit and foliar disease of mango, bacterial black spot; X. *vasicola* pv. musacearum causes a devastating, lethal wilt of banana, xanthomonas bacterial wilt; and

X. campestris pv. passiflorae causes the most important bacterial disease of passionfruit, bacterial spot.

NUCLEIC ACID-BASED PATHOGENS

Viruses

The 14 families and 70 genera of plant viruses are classified based on biochemical composition, replication strategies, particle structure, and genome organisation. Tropical fruit are affected by numerous viruses, especially those that are propagated by vegetative means; citrus and passionfruit are notable in the numbers and diversity of viruses that affect them.

Plant viruses, like all other viruses, are obligate intracellular parasites that do not have the molecular machinery to replicate without the host. The plant viruses are defined as viruses pathogenic to higher plants. While this article does not intend to list all plant viruses, it discusses some important viruses as well as their uses in plant molecular biology. Although plant viruses are not nearly as well understood as the animal counterparts, one plant virus has become iconic. The first virus to be discovered was Tobacco mosaic virus (TMV). This and other viruses cause have an estimated US$60 billion per year economic influence on crops worldwide. Plant viruses are grouped into 73 genera and 49 families.

Viruses are very small and can only be observed with an electron microscope. The structure of a virus is given by its coat of proteins, which surround the viral genome. Assembly of viral particles takes place spontaneously. Over 50% of known plant viruses are rod shaped (flexuous or rigid). The length of the particle is normally dependent on the genome but it is usually between 300–500 nm with a diameter of 15–20 nm. Protein subunits can be placed around the circumference of a circle to form a disc. In the presence of the viral genome, the discs are stacked, then a tube is created with room for the nucleic acid genome in the middle.

The second most common structure amongst plant viruses are isometric particles. They are 40–50 nm in diameter. In cases when there is only a single coat protein, the basic structure consists of 60 T subunits, where T is an integer. Some viruses may have 2 coat proteins are the associate to form a icosahedral shaped particle.

There are three genera of Geminiviridae that possess geminate particles which are like two isometric particles stuck together. A very small number of plant viruses have, in addition to their coat proteins, a lipid envelope. This is derived from the plant cell membrane as the virus particle buds off from the cell.

Representatives of viruses that infect fruit crops are discussed briefly below.

Potyviridae. Members of the *Potyviridae* have flexuous particles 650-900 nm in length, with a positive sense ssRNA genome. Two viruses in the genus *Potyvirus* are important tropical fruit pathogens.

Papaya ringspot virus-type P (PRSV-P) causes papaya ringspot, a limiting factor in papaya production worldwide. PRSV-P virions are 780 x 12 nm and encapsidated with a 36 kDa coat protein. It is transmitted nonpersistently by transitory populations of aphids (papaya is not a preferred host).

Passionfruit woodiness virus (PWV) is the most serious of the many viruses that affect *Passiflora* spp. Passionfruit woodiness, the most serious virus-induced disease of this crop, has a complicated etiology in that its symptoms, particularly a malformed, thickened and hardened pericarp, are associated with *Cucumber mosaic virus* and several potyviruses, including PWV.

Closteroviridae. Closterovirus virions are long, very flexuous particles. *Citrus tristeza virus* (CTV) causes tristeza decline and stem pitting of citrus, the most serious virusinduced problems on this crop. Over 50 million trees on the sour orange rootstock have been killed, and >200 million trees that remain on this rootstock worldwide are at risk.

Caulimoviridae. Virions in this virus family have circular, dsDNA genomes, and replicate via reverse transcription. The genus *Badnavirus* contains several viruses that are important in the tropics, and *Banana streak virus* (BSV) is one of the most significant on banana. BSV has bacilliform virions, 30 x 130 – 150 nm in size, with a 7.4 kbp genome. It is vectored by mealybugs, but also spreads in infected germplasm.

Circoviridae. This is one of the two families of plant viruses that contain ssDNA. The only plant-associated genus in the family, *Nanovirus*, contains the most important virus pathogen of banana, *Banana bunchy top virus* (BBTV). BBTV has a multicomponent genome of at least six circular components 1000 – 1100 nt in length. Virions are icosahedrons 18-20 nm in dia. Although BBTV has not conclusively been shown to cause bunchy top, virions are intimately associated with the disease, and are always detected in symptomatic plants. BBTV is vectored by the banana aphid, *Pentalonia nigronervosa*, and is also disseminated in vegetative propagation materials.

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12

Fruit Processing Techniques

In developing countries agriculture is the mainstay of the economy. As such, it should be no surprise that agricultural industries and related activities can account for a considerable proportion of their output. Of the various types of activities that can be termed as agriculturally based, fruit and vegetable processing are among the most important. Both established and planned fruit and vegetable processing projects aim at solving a very clearly identified development problem. This is that due to insufficient demand, weak infrastructure, poor transportation and perishable nature of the crops, the grower sustains substantial losses.

During the post-harvest glut, the loss is considerable and often some of the produce has to be fed to animals or allowed to rot. Even established fruit and vegetable canning factories or small/medium scale processing centres suffer huge loss due to erratic supplies. The grower may like to sell his produce in the open market directly to the consumer, or the produce may not be of high enough quality to process even though it might be good enough for the table. This means that processing capacities will be seriously underexploited.

The main objective of fruit and vegetable processing is to supply wholesome, safe, nutritious and acceptable food to consumers throughout the year. Fruit and vegetable processing projects also aim to replace imported products like squash, yams, tomato sauces, pickles, etc., besides earning foreign exchange by exporting finished or semi-processed products. The fruit and vegetable processing activities have been set up, or have to be established in developing countries for one or other of the following reasons:

- diversification of the economy, in order to reduce present dependence on one export commodity;
- government industrialisation policy;
- reduction of imports and meeting export demands;

- stimulate agricultural production by obtaining marketable products;
- generate both rural and urban employment;
- reduce fruit and vegetable losses;
- improve farmers' nutrition by allowing them to consume their own processed fruit and vegetables during the off-season;
- generate new sources of income for farmers/artisans;
- develop new value-added products.

Practically any fruit and vegetable can be processed, but some important factors which determine whether it is worthwhile are:

a) the demand for a particular fruit or vegetable in the processed form;

b) the quality of the raw material, i.e. whether it can withstand processing;

c) regular supplies of the raw material.

A particular variety of fruit which may be excellent to eat fresh is not necessarily good for processing. Processing requires frequent handling, high temperature and pressure. Many of the ordinary table varieties of tomatoes, for instance, are not suitable for making paste or other processed products. A particular mango or pineapple may be very tasty eaten fresh, but when it goes to the processing centre it may fail to stand up to the processing requirements due to variations in its quality, size, maturity, variety and so on. Even when a variety can be processed, it is not suitable unless large and regular supplies are made available. An important processing centre or a factory cannot be planned just to rely on seasonal gluts; although it can take care of the gluts it will not run economically unless regular supplies are guaranteed. To operate a fruit and vegetable processing centre efficiently it is of utmost importance to pre-organise growth, collection and transport of suitable raw material, either on the nucleus farm basis or using outgrowers.

FRUIT QUALITY

Fruit quality goes back to tree stock, growing practices and weather conditions. Closer to the shipper and processor, however, are the degrees of maturity and ripeness when picked and the method of picking or harvesting. There is a distinction between maturity and ripeness of a fruit. Maturity is the condition when the fruit is ready to eat or if picked will become ready to eat after further ripening. Ripeness is that optimum condition when colour, flavour and texture have developed to their peak.

Some fruit is picked when it are mature but not yet ripe. This is especially true of very soft fruit like cherries and peaches, which when fully ripe are so soft as to be damaged by the act of picking itself. Further, since many types of fruit continue to ripen off the tree, unless they were to be processed quickly, some would become overripe before they could be utilised if picked at peak ripeness. From a technological point of view, fruit characterisation by species and varieties is performed on the basis of physical as well chemical properties: shape, size, texture, flavour, colour/pigmentation, dry matter content (soluble solids content), pectic substances, acidity, vitamins, etc. These properties are directly correlated with fruit utilisation.

When to Pick

The proper time to pick fruit depends upon several factors; these include variety, location, weather, ease of removal from the tree, and purpose to which the fruit will be put. Oranges change with respect to both sugar and acid as they ripen on the tree; sugar increases and acid decreases. The ratio of sugar to acid determines the taste and acceptability of the fruit and the juice. For this reasons, in some countries there are laws that prohibit picking until a certain sugar-acid ratio has been reached. In the case of much fruit to be canned, on the other hand, fruit is picked before it is fully ripe for eating since canning will further soften the fruit.

Quality Measurements

Many quality measurements can be made before a fruit crop is picked in order to determine if proper maturity or degree of ripeness has developed. Colour may be measured with instruments or by comparing the colour of fruit on the tree with standard picture charts.

Texture may be measured by compression by hand or by simple type of plungers. As fruit mature on the tree its concentration of juice solids, which are mostly sugars, changes. The concentration of soluble solids in the juice can be estimated with a refractometer or a hydrometer. The refractometer measures the ability of a solution to bend or refract a light beam which is proportional to the solution's concentration.

A hydrometer is a weighted spindle with a graduated neck which floats in the juice at a height related to the juice density. The acid content of fruit changes with maturity and affects flavour. Acid concentration can be measured by a simple chemical titration on the fruit juice. But for many fruits the tartness and flavour are really affected by the ratio of sugar to acid.

Percentage of soluble solids, which are largely sugars, is generally expressed in degrees Brix, which relates specific gravity of a solution to an equivalent concentration of pure sucrose. In describing the taste of tartness of several fruits and fruit juices, the term "sugar to acid ratio" or "Brix to acid ratio" are commonly used. The higher the Brix the greater the sugar concentration in the juice; the higher the "Brix to acid ratio" the sweeter and lees tart is the juice.

HARVESTING AND PREPROCESSING

Harvesting

A large amount of the harvesting of most fruit crops is still done by hand; this labour may represent about half of the cost of growing the fruit. Therefore, mechanical harvesting is currently one of the most active fields of research for the agricultural engineer, but also requires geneticists to breed fruit of nearly equal size, that matures uniformly and that is resistant to mechanical damage. A correct manual harvesting includes some simple but essential rules:

- the fruit should be picked by hand and placed carefully in the harvesting basket; all future handling has to be performed carefully in order to avoid any mechanical damage;
- the harvesting basket and the hands of the harvester should be clean;
- the fruit should be picked when it is ready to be able to be processed into a quality product depending on the treatment which it will undergo.

It is worth emphasising the fact that the proximity of the processing centre to the source of supply for fresh raw materials presents major advantages; some are as follows:

- possibility to pick at the best suitable moment;
- reduction of losses by handling/transportation;
- minimises raw material transport costs;
- possibility to use simpler/cheaper receptacles for raw material transport.

Once it has left the tree, the organoleptic properties, nutritional value, safety and aesthetic appeal of the fruit deteriorates in varying degrees. The major causes of deterioration include the following:

a) growth and activity of micro-organisms;

b) activities of the natural food enzymes;

c) insects, parasites and rodents;

d) temperature, both heat and cold;

e) moisture and dryness;

f) air and in particular oxygen;

g) light and

h) time.

Reception

Fruit reception at the processing centre is performed mainly for following purposes:

- checking of sanitary and freshness status;
- control of varieties and fruit wholeness;
- evaluation maturity degree;
- collection of data about quantities received in connection to the source of supply: outside growers/farmers, own farm.

Variety control is needed in order to identify that the fruit belongs to an accepted variety as not all are suitable for different technological processes. Fruit maturity degree is significant as industrial maturity is required for some processing/preservation methods while for others there is the need for an edible maturity when the fruit has full taste and flavour.

Special attention is given to size, appearance and uniformity of fruit to be processed, mainly in the form of fruit preserved with sugar using whole/half fruits. Some laboratory control is also needed, even if it not easy to precisely establish the technological qualities of fruit because of the absence of enough reliable rapid analytical methods able to show eventual deterioration.

The only reliable method for evaluating the quality is the combination of data obtained through organoleptic/taste controls and by simple analytical checks which are possible to perform in a small laboratory: percentage of soluble solids by refractometer, consistency/texture measured with simple penetrometers, etc.

STORAGE BEFORE PROCESSING

This step has to be as short as possible in order to avoid flavour losses, texture modification, weight losses and other deterioration that can take place over this period. Some basic rules for this step are as follows:

- keep products in the shade, without any possible direct contact with sunlight;
- avoid dust as much as possible;
- avoid excessive heat;
- avoid any possible contamination;
- store in a place protected from possible attack by rodents, insects, etc.

Cold storage is always highly preferred to ambient temperature. For this reason a very good manufacturing practice is to use a cool room for each processing centre; this is very useful for small and medium processing units as well.

WASHING

Harvested fruit is washed to remove soil, micro-organisms and pesticide residues. Fruit washing is a mandatory processing step; it would be wise to eliminate spoiled fruit before washing in order to avoid the pollution of washing tools and/or equipment and the contamination of fruit during washing.

Washing efficiency can me gauged by the total number of micro-organisms present on fruit surface before and after washing - best result are when there is a six fold reduction. The water from the final wash should be free from moulds and yeast; a small quantity of bacteria is acceptable.

Fruit washing can be carried out by immersion, by spray/ showers or by combination of these two processes which is generally the best solution: pre-washing and washing. Some usual practices in fruit washing are:

- addition of detergents or 1.5% HCl solution in washing water to remove traces of insect-fungicides;
- use of warm water (about 50°C) in the pre-washing phase;
- higher water pressure in spray/shower washers.

Washing must be done before the fruit is cut in order to avoid losing high nutritive value soluble substances (vitamins, minerals, sugars, etc.).

Sorting

Fruit sorting covers two main separate processing operations:

a) removal of damaged fruit and any foreign bodies (which might have been left behind after washing);

b) qualitative sorting based on organoleptic criteria and maturity stage.

Mechanical sorting for size is usually not done at the preliminary stage. The most important initial sorting is for variety and maturity. However, for some fruit and in special processing technologies it is advisable to proceed to a manual dimensional sorting (grading).

TRIMMING AND PEELING

This processing step aims at removing the parts of the fruit which are either not edible or difficult to digest especially the skin. Up to now the industrial peeling of fruit and vegetables was performed by three procedures:

a) mechanically;

b) by using water steam;

c) chemically; this method consists in treating fruit and vegetables by dipping them in a caustic soda solution at a temperature of 90 to 100° C; the concentration of this solution as well as the dipping or immersion time varying according to each specific case.

CUTTING

This step is performed according to the specific requirements of the fruit processing technology.

HEAT BLANCHING

Fruit is not usually heat blanched because of the damage from the heat and the associated sogginess and juice loss after thawing. Instead, chemicals are commonly used without heat to inactivate the oxidative enzymes or to act as antioxidants and they are combined with other treatments.

Ascorbic/Citric Acid Dip

Ascorbic acid or vitamin C minimises fruit oxidation primarily by acting as an antioxidant and itself becoming oxidised in preference to catechol-tannin compounds. Ascorbic acid is frequently used by being dissolved in water, sugar syrup or in citric acid solutions. It has been found that increased acidity also helps retard oxidative colour changes and so ascorbic acid plus citric acid may be used together. Citric acid further reacts with metal ions thus removing these catalysts of oxidation from the system.

Sulphur Dioxide Treatment

Sulphur dioxide may function in several ways:

- sulphur dioxide is an enzyme poison against common oxidising enzymes;
- it also has antioxidant properties; i.e., it is an oxygen acceptor;
- further SO_2 minimises non enzymatic Maillard type browning by reacting with aldehyde groups of sugars so that they are no longer free to combine with amino acids;
- sulphur dioxide also interferes with microbial growth.

In many fruit processing pre-treatments two factors must be considered:

a) sulphur dioxide must be given time to penetrate the fruit tissues;

b) SO_2 must not be used in excess because it has a characteristic unpleasant taste and odour, and international food laws limit the SO_2 content of fruit products, especially of those which are consumer oriented.

Commonly a 0.25 % solution of SO_2 or its SO_2 equivalent in the form of solutions of sodium sulphite, sodium bisulphite or sodium/potassium metabisulphite are used.

Fruit slices are dipped in the solution for about two to three minutes and then removed so as not to absorb too much SO_2. Then the slices are allowed to stand for about one to two hours so that the SO_2 may penetrate throughout the tissues before processing. Sulphur dioxide is also used in fruit juice production to minimise oxidative changes where relatively low heat treatment is employed so as not to damage delicate juice flavour. Dry sulphuring is the technological step where fruit is exposed to fumes of SO_2 from burning sulphur or from compressed gas cylinders; this treatment could be used in the preparation of fruits prior to drying / dehydration.

Sugar Syrup

Sugar syrup addition is one of the oldest methods of minimising oxidation. It was used long before the causative reactions were understood and remains today a common practice for this purpose.

Sugar syrup minimises oxidation by coating the fruit and thereby preventing contact with atmospheric oxygen. Sugar syrup also offers some protection against loss of volatile fruit esters and it contributes sweet taste to otherwise tart fruits. It is common today to dissolve ascorbic acid and citric acid in the sugar syrup for added effect or to include sugar syrup after an SO_2 treatment.

FRESH FRUIT STORAGE

Some fruit species and specially apples and pears can be stored in fresh state during cold season in some countries' climatic conditions. Fruit for fresh storage have to be autumn or winter varieties and be harvested before they are fully mature. This fruit also has to be sound and without any bruising; control and sorting by quality are mandatory operations. Sorting has to be carried out according to size and weight and also by appearance; fruit which is not up to standard for storage will be used for semi-processed product manufacturing which will be submitted further to industrial processing.

Harvested fruit has to be transported as soon as possible to storage areas. Leaving fruit in bulk in order to generate transpiration is a bad practice as this reduces storage time and accelerates maturation processes during storage. In order to store large quantities of fruit, silos have to be built.

FRUIT DRYING AND DEHYDRATION TECHNOLOGY

General technical data for fruit dehydration in tunnels are presented in Table 1.

Table 1: Technical data for fruit dehydration in tunnels

Fruits	*Drying Conditions*		
	Load kg/m²	*Temperature °C*	*Time*
Plums*	15	I. 40-50	6 H
		II. 75-80	14 H
Apples (Rings)	10	75-55	5-6 H
Apricots (Halves)	10	70-60	10- 15
Cherries (w. stones)	10	55-70	6-8
Pears	15	70-65	15-22
	15	70-60	10-15

For fruit with a high sugar content drying temperatures have to be lower at initial stage and then increase to the maximum acceptable; for fruit with lower sugar level the temperatures are applied in a reverse order.

Osmotic Dehydration

Osmotic dehydration is a useful technique for the concentration of fruit and vegetables, realised by placing the solid food, whole or in pieces, in sugars or salts aqueous solutions of high osmotic pressure. It gives rise to at least two major simultaneous counter-current flows: a significant water flow out of the food into the solution and a transfer of solute from the solution into the food.

Main process variables are:

a) pre-treatments;

b) temperature;

c) nature and concentration of the dehydration solutions;

d) agitation;

e) additives.

In the light of the published literature, some general rules can be noted:

- water loss and solid gain are mainly controlled by the raw material characteristics and are certainly influenced by the possible pre-treatments;
- it is usually not worthwhile to use osmotic dehydration for more than a 50% weight reduction because of the decrease in the osmosis rate over time. Water loss mainly occurs during the first 2 hr and the maximum solid gain within 30 min.;
- the rate of mass exchanges increases with temperature but above 45 ° C enzymatic browning and flavour deterioration begin to take place. High temperatures, i.e. over 60° C, modify the tissue characteristics so favouring impregnation phenomena and thus the solid gain;
- the best processing temperature depends on the food; mass exchanges are favoured by using high concentration solutions;
- phenomena which modify the tissue permeability, such as over-ripeness, pre-treatments with chemicals (SO_2), blanching or freezing, favour the solid gain compared to water loss because impregnation phenomena are enhanced;
- the kind of sugars utilised as osmotic substances strongly affects the kinetics of water removal, the solid gain and the equilibrium water content. Low molar mass saccharides favour the sugar uptake;
- addition of NaCl to osmotic solutions increases the driving force for drying.

The effects of osmotic dehydration as a pre-treatment are mainly related to the improvement of some nutritional, organoleptic and functional properties of the product. As osmotic dehydration is effective at ambient temperature, heat damage to colour and flavour is minimised and the high concentration of the sugar surrounding fruit and vegetable pieces prevents discoloration.

Drying

Air drying following osmotic dipping is commonly used in tropical countries for the production of so-called "semi-candied" dried fruits. The sugar uptake, owing to the protective action of the saccharides, limits or avoids the use of SO_2 and increases the stability of pigments during processing and subsequent storage period.

The organoleptic qualities of the end product could also be improved because some of the acids are removed from the fruit during the osmotic bath, so a blander and sweeter product than ordinary dried fruits is obtained. Owing to weight and volume reduction, loading of the dryer can be increased 2-3 times. The combination of osmosis with solar drying has been put forward, mainly for tropical fruit. A 24 hour cycle has been suggested combining osmodehydration, performed during the night, with solar drying during the day.

Two-three-fold increase in the throughput of typical solar dryers is feasible, while enhancing the nutritional and organoleptic quality of the fruits. A two-step drying process, OSMOVAC, for producing low moisture fruit products was described. The osmotic step is performed with sucrose syrup 65-75 Brix until the weight reduction reaches 30-50%. By osmotic dehydration followed by vacuum drying puffy products with a crisp, honeycomb-like texture can be obtained at a cost comparatively lower than freeze-drying.

Commercial feasibility of the process on bananas has been studied, based on the results of a semi-pilot scale operation; the process scheme is reported in Figure 8.4.3. Osmotically dried bananas retained more puffiness and a crisper texture than simple vacuum dried ones, and the flavour lasted longer at ambient temperature. The combination of osmotic dehydration with freeze-drying has been proposed only at laboratory scale.

Appertisation

A combination of osmotic dehydration with appertisation has been proposed to improve canned fruit preserves. The feasibility of a process, called osmo-appertisation, to obtain high quality fruit in syrup, has been assessed on a pilot scale. The key point of this technique is the pre-concentration of the fruit to about 20-40 Brix, that causes, together with the enhancement of the natural flavour, an increase of the resistance of the fruit to the following heat treatment, especially for colour and texture stability.The products obtained are stable up to 12 months at ambient temperature and show a higher organoleptic quality than canned preserved alternatives. Furthermore, because of their higher specific weight and diminished volume, the filling capacity of jars or pouches is increased.

Freezing

The frozen fruit and vegetable industry uses much energy in order to freeze the large quantity of water present in fresh products. A reduction in moisture content of the material reduces refrigeration load during freezing. Other advantages of partially concentrating fruits and vegetables prior to freezing include savings in packaging and distribution costs and achieving higher product quality because of the marked reduction of structural collapse and dripping during thawing. The products obtained are termed "dehydro-frozen" and the concentration step is generally carried out through conventional air drying, the additional cost of which has to be taken into account. Osmotic dehydration could be used instead of air drying to obtain an energy saving or a quality improvement especially for fruit and vegetable sensitive to air drying.

FURTHER DEVELOPMENTS

So far only applications on a pilot plant scale are reported in the literature. For further developments on a larger scale, theoretical and practical problems should be solved.The industrial application of the process faces engineering problems related to the movement of great volumes of concentrated sugar solutions and to equipment for continuous operations. The use of highly concentrated sugar solutions creates two major problems. The syrup's viscosity is so great that agitation is necessary in order to decrease the resistance to the mass transfer on the solution side.

Another important aspect, so far not investigated, is the microbiological safety of the process, which should be studied thoroughly before further industrial development. In order to obtain an alternative to the canned fruit preserves and to maintain a high quality of the fruits, a research has been carried out on the osmoappertisation of apricots, a "combined" technique that consists in the appertisation of the osmodehydrated apricots. This technique could contributes also to the reduction of energy consumption, limits the cost of production and combines "convenience" (ready-to-eat, medium shelf-life) with many market outlets (retail, catering, bakery, confectionery, semi-finished products).

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