APPLE PRODUCTION

PERENNIAL CROP SUPPORT SERIES

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1 Introduction

Apple is a temperate climate fruit. They are native in many parts of Europe and Asia temperate climates. The origin of apple is Central-Asia, and Afghanistan has many areas with native apples.. Wild apple varieties, such as Malus pumila, Malus silvestris and Malus orientalis are the most prevalent. In 1997, an amazing 44.7 million metric tons of apples were produced for human consumption. In 2006, production was 44.1million metric tons. The leading apple growing country is China, producing about 41percent of the world's apples, followed by the United States..

In this context the Afghan fruit producer sector can play a significant role covering the local and international market of the region. The Afghan apples from the southern and eastern regions are excellent quality for export to many countries in the region, which are, because the climate condition, are not able to satisfy the market demand in term of quality standards.

According to the FAO survey: “Afghanistan has proven favorable climatic conditions for the production of apple trees. The more accessible areas and local markets have heavy competition from imported fruits from Iran and Pakistan. Nevertheless, cultivation is still widespread and mainly aimed at satisfying the small rural local markets and the farmers’ subsistence production. The current apple production in the country largely depends on the few exotic varieties imported 20 years ago.” However, the quality of apple produced in Afghanistan is higher than the imported apple quality from Pakistan or Iran.

The proverb says: “If you want keep yourself in good health conditions, than eat an apple every day.” This statement reflects the importance and demand for apple by the food market. Apple production is not only important for the fresh fruit market, but it also develop favorable conditions for fruit processing industry, which is a significant step forward economy development in the country. Juice production and concentrate export is one of the most promising profit producer industries. From the world’s annual production in 2005, 36 percent of apples were processed into apple products; 18.6 percent of this is for juice and cider, 2 percent was dried, 2.5 percent was frozen, 12.2 percent was canned and 0.7 percent was fresh slices. Other uses were the making of baby food, apple butter or jelly and vinegar.

In Afghanistan, apple production is done mainly by small-holder orchard owners. Statistics shows that the apple production costs in Afghanistan is considerably lower than in other apple producer countries, therefore allowing the improved apple varieties to compete in international markets.

2 Scientific Classification

Kingdom:	Plantae
Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Rosales
Family:	Rosaceae
Subfamily:	Maloideae
Genus:	Malus
Species:	Malus domestica (Borkh)
Ancestor:	Malus sieversii
Origin:	Central Asia

3 Morphology

Source: F. Sandor (2009)

The tree naturally grows between 5m and 12m tall. The leaves are arranged alternately along the shoot. Their shape is a simple oval. The leaf is 5 to 12cm long and 3 to 6cm wide attaching to a 2-5cm long petiole with an acute tip. The flowers have five petals with a size approximately 3cm. The color of the flowers is white with a pink tinge. The fruit contains five carpals arranged in a five point star. Each carpal contains 1 to 3 seeds.

3.1 Main Characteristics of Apples

3.1.1 Shape

Source: Malus sieversii

The main shape types are: roundish, oblate, conical, and oblong. Roundish indicates that the height and diameter of the fruit are nearly equal. Oblate indicates that the height is much less than diameter. Conical, is when the fruit is roundish, having the apex end contracted. Oblong, is when the fruit is longer than broad, and having the apex and base of nearly the same breadth. Truncate conic, is when the fruit is flattened at the apex. Ribbed, or obscurely ribbed, when the surface has rising lines and channels from apex to base. Oblique, is when the fruit presents the appearance as of being one-sided, or when the axis is inclined to one side. Oblate fruit is when one side is less than the other. Corrugated apple means that it contains depressed lines, furrows, or wrinkles. Acute, when the fruit is narrowing to a sharp point. Abrupt fruit means that the depressed lines break off suddenly.

3.1.2 Axis

This is an imaginary straight line between the stem and the centre of the calyx. The axis is inclined when the fruit is oblique or lop-sided; short when oblate or the cavity and basin are deep; long when the fruit is oblong. The core-cells are axial when they meet the axis; abaxial when distant from it. When a section made through the apples at right angles to the axis is circular, it is regular; if so, it could be turned in a lathe, meaning it is very regular; it may be irregular, compressed, or flattened sidewise, angular, furrowed, or ribbed, rarely triangular, quadrangular, or pentangular.

3.1.3 Tube Stamens

The stamens can occupy three different positions in the tube. The position is marginal when the stamens are placed close to one of the two ends of the tube: marginal near to the outer end or marginal near to the inner end. The third position relates to when the stamens are placed near to the middle section of the tube (median).

3.1.4 Tube

In case of conical fruit, the outlines from the base of the sepals turn in on a curved line inwards - towards the core, forming a cone. These curves are generally made inward, but occasionally they are seen outwards. When funnel-shaped, the outlines are seen in a hollow cavity like the stem of a funnel.

3.1.5 Carpals

This is the core of the apple fruit. Usually the fruit contains five carpals, each one of them with 1 to 3 seeds. Its shape can be round, ovate, obovate or elliptical.

Source: M. Cranshaw (2005)

3.1.6 Eye

The sepals are commonly called the eye of the apple. When the fruit develops, the segments from the original calyx stay and gradually assume various directions. When the fruit matures, the segments take four distinct forms. When the segments are reflexed or recurved, it is known as the divergent form. When the segments are erected and pointed, the form is erect convergent. Flat convergent is formed when the segments are closing over the eye without overlapping each other. When the segments are overlapping each other, this forms a compact cone, making the eye connivent.

There are other characteristics like the size of the apple, its surface or the appearance of dots. The stem can also brown or green colored and its form can be straight, curved, fleshy or knobbed. Cavity is the depression in which the stem is inserted, and may be wide, deep, shallow, regular, irregular, wavy, uneven, or folded. In a few varieties, the cavity is nearly or quite filled up, and is then termed flat.

4 Apple Classification Systems

The first classification system was created by Johann Jonson in Wurtemberg, Germany (1668).

Manger (Potsdam, Germany) in 1780 divided apples in eight classes (round, elliptical, ovate, cylindrical, flat, hyperbolic, parabolic and irregular), which were condensed into three main classes.

4.1 Dr. Diel's first natural classification system (Germany, 1792)

- Class: Ribbed apples
  - Order: True calvilles
  - Order: Schlotter apples
  - Order: Gulderlinge
- Class: Rose apples

        - Order: Fruit pointed or longish
        - Order: Fruit globular or flat
    - Class: Rambours
        - Order: Core with wide cells
        - Order: Core with narrow cells
    - Class: Reinettes
        - Order: One- colored reinettes
        - Order: Red reinettes
        - Order: Gray reinettes
        - Order: Gold reinettes
    - Class: Stripelings
        - Order: Flat stripelings
        - Order: Pointed or tapering stripelings
        - Order: Oblong or cylindrical stripelings
        - Order: Globular stripelings
    - Class: Pointlings or Tapering apples
        - Order: Oblong, cylindrical or conical pointlings
        - Order: Sharp pointlings
    - Class: Flat apples
        - Order: Purely flat apples
        - Globular flat apples

The Diel's classification is the base of all used natural classification systems.

4.2 Diel-Dochnahl classification system (Germany, 1855)

- Section: Pleuroidea (angular or ribbed apples)
    - Class: Mala cydonaria (quince shaped)
        - Order: Calvilles
        - Order: Pseudo calvilles
    - Class: Mala pyraria (pear shaped)
        - Order: Tremaria (seeds loose)
        - Rambures
- Section: Sphaeroidae (Spherical)
    - Class: Mala mespilaria (medlar shaped)
        - Order: Apiana or rose apples
        - Reinetta (reinettes)
    - Class: Mala malaria (perfect or pure apple shaped)
        - Order: Striola (striped)
        - Order: Contubernalia (storing apples)

4.3 Diel-Lucas classification system

- Class: Calvilles (strawberry or raspberry apples)
- Class: Schlotter apples
- Class: Gulderlings
- Class: Rose apples
- Class: Pigeons
- Class: Pound apples

- Class: Rambour reinettes
- Class: One-colored or wax reinettes
- Class: Borsdorf reinettes
- Class: Red reinettes
- Class: Gray reinettes, Leather apples, Russets
- Class: Gold reinettes
- Class: Stripelings
- Class: Pointlings
- Class: Flat apples

4.4 Double classification system

In 1862, Dr. Lucas came up with most elaborate classification system, which recognizes 1,620 different groups of apple. He used a double classification method including natural and artificial classifications.

- Artificial: based on external characters and period of ripening
- Natural: based on internal characters and the fruit as a whole. In his artificial classification, Lucas first divides by the seasons into summer, fall, and winter; next he groups them into flat, round, tapering, oblong classes, thus giving 12 classes.

Each of these are divided into three orders according to color:

- Ground-colored
- Colored
- Striped.

Each of these is further subdivided into (making a total of 228 subdivisions):

- Calyx open
- Calyx half-open
- Calyx closed

4.5 John Warder American classification system (1867)

- Class: Oblate or flat having the axis shorter than the transverse diameter
- Class: Conical, tapering decidedly toward the eye and becoming ovate when larger in the middle and tapering to each end making the axial diameter shorter.
- Class: Round, globular, or nearly so, having the axial and transverse diameters about equal, the former often shorter by less than one quarter of the latter. The ends are often so flattened as to look truncated making the fruit appear to be cylindrical or globular-oblate.
- Class: Oblong, in which the axis is longer than the transverse diameter, or appears so. These may also be truncated or cylindrical.

Each class contains the following subdivisions:

- Order: Regular
  - Section: Sweet
    - Subsection: Pale or blushed, self colored and not striped
    - Subsection: Striped or splashed
    - Subsection: Russeted
  - Section: Sour

- Subsection: Pale or blushed, self colored and not striped
- Subsection: Striped or splashed
- Subsection: Russeted

- Order: Irregular
  - Section: Sweet
    - Subsection: Pale or blushed, self colored and not striped
    - Subsection: Striped or splashed
    - Subsection: Russeted
  - Section: Sour
    - Subsection: Pale or blushed, self colored and not striped
    - Subsection: Striped or splashed
    - Subsection: Russeted

4.6 J. Thomas classification system (USA, 1849)

- Division: Summer apples
- Division: Autumn apples
- Division: Winter apples

The classes and section of each division are:

- Class: Sweet apples
  - Section: Color striped with red
  - Section: Color not striped
- Class: Sour apples
  - Section: Color striped with red
  - Section: Color not striped

4.7 English artificial classification system (1876)

This system was created by Robert Hogg and he used the structural characteristics of apple for his classification system. These characteristics are: Stamens, Tube, Carpals and Sepals.

5 Soil Preparation

Apple likes cool and humid conditions. It is not very sensitive for soils. Apple can grow in wide range of soil types. However the best soil texture type is from sandy-loam to sandy clay loam. Soil drainage is maybe the most important factor to be considered. The soil should be well-drained up to 80-100cm depth. The acceptable soil pH for apple growth is between 5.7 and 7.6. The best pH range is between 5.8 and 6.5. The soil pH should be checked every three years.

Site preparation starts with the cleaning of the area. After cleaning the bush, the next step is to level the area and, if necessary, build up the terraces. Carefully avoid the complete removal of the topsoil during the process of leveling and terrace making. This usually happens where the soil depth is shallow. Slope should not exceed 10%. Slope exposure is important. Southern facing slope warms up to fast and western facing slope tends to be thinner. The recommended slope facing direction is east.

During soil preparation, avoid excessive or deep tillage practice. It is also very important to avoid tillage in dry soils, because it will turn up big pounds.

6 Planting Apple Trees

The saplings should be planted if the soil not too wet. First open a large hole to accommodate the root system. Before planting, any roots that are broken or kinked should be cut off. A planting board can help positioning the sapling on the top of the hole. Replace the planting board with the tree stem fitted into the central notch with the graft at least 5-10 cm above the soil surface. After that, fill the hole with soil until the root ball is fully covered. Gently firm the soil around the tree and level the soil. The tree should be planted to the same depth as it was in the pot (or the soil mark on the trunk in the case of bare-rooted trees). Water well if the conditions are dry.

Source: F. Sandor (2007)

Some varieties need to be supported (Staking) sometimes during the whole life of the tree. Stakes should be 5cm diameter and in general about 1.5m high - 60cm below ground, and the remainder above ground. The stake should be 8cm (3in) or so from the main stem. Tie the trunk to the stake in one or two places using plastic ties available from garden centers. Do not use wire or anything which could cut into the tree trunk. The saplings that need supporting stakes depend on the used root stock. M9, M26 and M27 definitely need it.

A doughnut shaped basin should be built around the planted tree, so the water drains away from the trunk. The size of the basin should be slightly wider than the planting hole. In this way the water can be applied to the entire root area and just beyond. Until the establishment of the roots, fill up the basin once or twice per week.

7 Orchard Layout

Usually the orchard layout follows a regular pattern. The process starts with establishment of a straight line from the edge of the field, which will be the base line. After establishing a right angle (90°) to the base line, begin taking reference point measurements. One base line forms a base row and the other line (running at right angle to the first) forms the line at which the first tree in each row is placed. Using the base lines as reference points, stretch tape along one line and place pegs at the desired intervals of tree spacing.

The spacing distance depends on the rootstock and the tree training system. Dwarf and intensive production systems require less spacing than standard type apple trees. Cordon type dwarf trees are planted in double or simple lined beds.

Commonly used planting distances of apple trees:

Row and plant distance (m)	Number of tree per Hectare
Single row	
5.00 X 5.00	400
7.00 X 4.00	358
6.00 X 4.00	417
5.00 X 3.00	667

8 Fertilizing Apple Trees

The nutrient availability of the soil depends on the soil pH. The farmer should adjust the soil pH between the following ranges:

Topsoil: Between 6.5 and 7.0
Subsoil: Between 6.0 and 6.5

Tree nutrition is probably the most important factor for successful orchard management, and it can be controlled through proper fertilization practices. The fertilization program is focused on two factors. First, during the initial phase, the adjustment of soil nutrient status is the focus. Secondly nutrients may need to be replaced if they were removed from the soil by the tree. Part of the nutrients accumulates in the “body” of the tree and a large amount of nutrients are removed by the fruit yield.

Table 1; Amount of nutrient removed from soil with 10 MT of fruit yield

Amount of nutrient removed from the soil by 10MT of fruit					
Type	**N (Kg)**	**P_2O_5 (Kg)**	**K_2O (Kg)**	**CaO (Kg)**	**MgO (Kg)**
Apple	6.0	2.0	15.0	3.4	2.5
Pear	5.5	1.5	16.0	3.4	2.0
Peach	13.0	6.0	28.0	4.0	2.0

Source: Gautier (1979)

8.1 Nitrogen status

Nitrogen influences the tree growth. Nitrogen is especially important during the young stages of tree development. It also helps keep balance in the tree physiology. The annual nitrogen use of a tree is 80% (based on the tree reserve) whereas only 20% comes from the fertilizer application. The tree stores the applied nitrogen fertilizer mainly in the root system. Therefore, leaf nutrient analysis is very important to adjust the tree’s nitrogen status. In bloom, the stored nitrogen in the tree is almost exhausted and the shoots growth in late spring becomes externally nitrogen dependent. Therefore, nitrogen should be applied twice during the growing season. Half should be applied during the post harvest period and the other half after bloom. Tree nitrogen status can be checked and monitored through five factors:

- Fruit Color: Fruit color development is delayed when N levels are too high.
- Fruit Size and Firmness: Size generally increases with higher N levels and the fruit tends to result in less firm fruit flesh.

- Biennial Fruit Production: Nitrogen stress will increase the biennial bearing tendency in many varieties, especially Golden Delicious and McIntosh. Reducing the N in these varieties to enhance color development may trigger the biennial bearing of these and other varieties.
- Vigor: Nitrogen status and terminal growth is related. Adequate vigor produces terminal growth between 20-25cm for non-spur varieties and between 15-20cm for spur varieties.
- Leaf nitrogen level: Leaf N tends to be higher in samples from trees that are carrying heavy crops. Off-year trees are generally lower in leaf N content. In general, a 10% increase or reduction in N application rates is usually reflected as a 0.1% change in Leaf N.

The tree's nitrogen requirement is influenced by many factors. Young trees generally use better additional nitrogen than fruit bearing trees. With fruit bearing trees there is always the risk that the fruit nutrient content will be too high, which will affect its market quality.

Variety and growing habit of the tree also influence the tree's nitrogen requirement. Standard size trees need more nitrogen than dwarf size trees.
Pruning practices strongly change the tree nitrogen requirement. Severely pruned trees need less nitrogen. Some pruning requires the suspension of fertilization during the present season avoiding excessive new shoots development.

Ammonium sulfate is the most common fertilizer to supply trees with nitrogen. The following equation allows calculating the required amount per tree:

[(Age of the tree in years x 5) / % of N fertilizer] x 459 = Gram Ammonium sulfate per tree

Table 2: General recommendation for ammonium sulfate application

Age of the tree	Gram per tree
1	0
2	110-120
3-5	115-150
6-7	225-235
Over 7	150-200 (Kg/Hectare)

Source: F. Sandor (2008)

8.2 Phosphorus status

The phosphorus is the most controversial nutrient in apple production. It is almost impossible to establish an orchard phosphorus status. Apple trees are deep rooting trees and they are able to absorb phosphorus from deeper soil layers. On the other hand, phosphorus is an immobile nutrient in soil. Therefore any conducted test can mislead the growers. For these reasons, phosphorus application simply is not recommended in early periods of growth.

When phosphorus deficiency occurs, it will appear on the shoots, petioles and leaves. The symptoms are the following:

- Shoots appear slender
- Petioles and leaves are upright
- Leaves are smaller
- The color of the leaves is dark green with reddish or purplish tinting of the midrib and larger veins

The applied phosphorus fertilizer should be superphosphate or NPK formulation. The P_2O_5 requirement of the orchard is the following:

Status:	**Low**	**Medium**	**Adequate**
New orchard	150-200 Kg/Ha	90-110 Kg/Ha	50-60 Kg/Ha
Established orchard	80-100 Kg/Ha	50-70 Kg/Ha	30-40 Kg/Ha

8.3 Potassium status

Potassium contributes to the improvement of fruit size and flavor quality. The tree's potassium status should always be determined by the ratio of nitrogen-potassium. If this ratio is too high, the improving effect of added potassium will not be seen. The proper ratio varies according to the cultivars in the orchard. Some varieties require a ratio of 1:1 while others, like Red Delicious, needs a ration of 1.25:1 up to 1.5:1.

Potassium deficiency unlikely occurs in the Eastern Region of Afghanistan, but if it happens the preferred fertilizer is Potassium sulfate over potash avoiding chlorine toxicity.

The K_2O requirement of the orchard is the following:

Status:	**Low**	**Medium**	**Adequate**
New orchard	280-310 Kg/Ha	180-200 Kg/Ha	80-90 Kg/Ha
Established orchard	140-160 Kg/Ha	110-120 Kg/Ha	80-90 Kg/Ha

The nitrogen is not the only nutrient that should be monitored in relation to potassium. The magnesium-potassium ratio also strongly affects the tree's performance. When this ratio exceeds 1.5 K/Mg, lime application is required.

Other nutrients, such as Sulfur, Magnesium, Iron, zinc, etc. also play important role in apple production. The cheapest way to satisfy the needs of the tree is manure application. Manure is a complex, organic fertilizer.

Table 3: Recommended amount of manure per fruit tree

Recommended amount of manure per fruit tree		
Year	**Qty. in Kg/tree**	**Time**
1st	2.0-2.5	Monthly until leaves drop
2nd	2.5-3.0	Monthly from bud break to leaves drop
3rd	3.0-4.0	Monthly from bud break to leaves drop
4th – 5th	35.0-40.0	Bud break-After 6 weeks-After harvest
6th – 7th	40.0-50.0	Bud break-After 6 weeks-After harvest
8th – 9th	50.0-60.0	Bud break-After 6 weeks-After harvest
10th onward	55.0-65.0	Bud break-After 6 weeks-After harvest

Source: F. Sandor (2008)

Table 4: Nutritional imbalances that may interfere with production of high-calcium apples

Mode of action	Corrective measures
Excessive nitrogen (N) 1. The flesh of fruit from high N trees is more likely to have corking (direct effect) 2. High N trees normally are overly vigorous (indirect effect).	Regulate the N status of trees with the aid of leaf analysis and field observations. Keep other nutrients in balance so the desired vigor level can be attained with minimal N levels.
Excessive potassium (K) 1. Some calcium deficiency disorders appear to be related to high levels of K as well as low calcium 2. Direct cation competition between K and calcium in soil and at the root surface.	1. Regulate the K status of trees with the aid of leaf analysis. 2. Do not apply K unless it's definitely needed.
Excessive magnesium (Mg) 1. Some calcium deficiency disorders appear to be related to high levels of Mg as well as low calcium 2. Direct cation competition between Mg and calcium in soil and at the root surface.	1. Regulate the Mg status of trees with the aid of leaf analysis. 2. Do not apply Mg unless it's definitely needed. 3. Do not correct low soil pH with high magnesium (dolomitic) lime.
Deficient calcium (Ca) Many physiological disorders of apples are directly related to low fruit flesh Ca levels although low Ca may not be the direct cause.	1. Maintain a soil pH of 6.0 to 6.5 with high-calcium lime. 2. Use high-magnesium (dolomitic) lime only in cases with a proven need for large quantities of magnesium. 3. Apply Ca sprays. 4. Use all other parts of the program to increase fruit Ca levels
Deficient boron (B) 1. B deficiency can directly cause fruit flesh deformities. 2. Some B deficiencies appear to increase corking. 3. Some B deficiencies appear to interfere with normal translocation of calcium.	1. Regulate the B status of trees with the aid of leaf analysis. Maintain 35 to 60 ppm of leaf B. 2. Make ground applications of borax or tree sprays of boron when needed.

Source: Pennsylvania Tree Fruit Production Guide 2008–2009

Table 5: Causes of excessive vegetative growth that may compete for available calcium, their modes of action, and corrective measures

Mode of action	Corrective measures
Excessive pruning	
Severe pruning can over-invigorate an apple tree.	1. Reduce tree vigor so that moderate pruning can be used to maintain tree size.
	2. Maintain an annual, moderate pruning program.
Excessive nitrogen (N)	
Excessive N fertilization often results in overly vigorous trees.	Maintain a nutritionally healthy tree so that a minimum level of N can be used to maintain moderate tree vigor.
Inadequate spacing	
Planting trees too close together can result in a vicious cycle of excessive	Integrate variety, rootstock, soil type, and your management intentions into pruning followed by excessive vigor.

Mode of action	Corrective measures
Low fruit load	
Trees bearing a light crop normally divert growth into excessive vegetation.	Maintain a system of annual cropping to avoid excessive tree vigor.

Source: Pennsylvania Tree Fruit Production Guide 2008–2009

9 Pest and Disease Management

Pest and disease control begins with the use of pest-disease free planting material. The saplings should be healthy with good vigor. Do not buy saplings with unknown origins or without certificates. Replace chemical control with other methods when possible. It is in this way that the natural enemies of pests can effectively intervene with plant eating insects. Chemical use also kills the benevolent insects too. Tools such as pruning tools should be clean and disinfected frequently. These tools can transfer diseases from one tree to another.

Mechanical control can also help keep the orchard free from pests and diseases. Aphids and mealy bugs can be washed off the leaves with a strong water spray or soap. Larger insects can be picked up and destroyed. A paraffin lamp in a bowl of water is an effective insect trap. Fallen fruits often contain insect's eggs. Burying these fruit under the fruit trees destroy the eggs.

The most difficult task is to control viral diseases. Tree affected by viruses have no remedy. The tree should be removed and destroyed. The planting material should be virus free. Where possible, the grower should plant saplings with scions grafted into virus resistant rootstock. Virus vectors such as aphids and white flies should be controlled either with or without chemical use.

Spraying dormant trees with chemicals and oil reduces the pest's population before the growing season starts. When fungicide is added to the pesticide and oil it will destroy over-wintering fungus and bacterial spores. Common practice is for growers to use preventive spraying during a particular development stage of the tree. Farmers always apply one spray at petal fall and then again two weeks later.

A wide range of pests and diseases can affect the apple tree. The most important diseases are:

Source: Mildew (K. Russ, 2007)

Mildew: which is characterized by light grey powdery patches appearing on the leaves, shoots and flowers, normally in spring. The flowers will turn a creamy yellow color and will not develop correctly. This can be treated by eliminating the conditions which caused the disease and burning the infected plants are among the recommended actions to take

Apple scab: The fungus that causes apple scab on apples is Venturia inaequalis. Symptoms usually start on the undersides of leaves. Spots, at first, are small, irregular lesions that are light brown to olive green in color. Spots eventually turn dark brown to black. Infected tissue thickens, causing the upper surface to bulge upwards and the lower surface to depress. Leaves may curl and scorch at the margins. If the leaf petioles become infected, the leaves drop early. If the pedicels become infected, the fruits may drop early. Scab on the fruit appears as

nearly circular, velvety dark green lesions. The skin of the apple near the infected area margin ruptures. Older lesions are black, scabby, and cracked.

Source: Apple scab (K. Russ, 2007)

Infections occur during moist conditions. Keep plants vigorous. Remove and destroy infected leaves, flowers, and fruit as soon as possible. Grow resistant varieties when ever possible. The battle against scab is won or lost from bud break to fruit set. This is when scab gets started. A preventive fungicide application should be taken place during this period or during rainy wet weather on more susceptible apple varieties. Once leaves start to yellow and fall off the tree, it is too late to spray for control during the current growing season.

Source: Fire blight (K. Russ, 2007)

Fire blight: Fire blight is a devastating disease caused by the bacterium Erwinia amylovora and is very difficult to control. The disease develops rapidly in early spring during rainy weather and the tree is in bloom. Blossoms and young leafy twigs show the first symptoms, appearing wilted or shriveled and turning brown to black. The tips of infected young twigs wilt and die, forming a shepherd's crook as the disease moves down the branch. Dead leaves often remain attached to the branch. During wet weather, a milky-like, sticky liquid can be seen on the stems and branches.

To control infected tree remove all infected tree parts and burn them. Pruning cut should be 25-30 cm below the infected part. Disinfect carefully all pruning tools. Avoid excessive nitrogen application. Simple copper hydroxide or copper sulfate application is effectively prevent the disease.

Source: Black rot (K. Russ, 2007)

Black rot: The fungus is called Physalospora obtusa (Botryosphaeia obtusa) and it causes black rot. The disease begins on the leaf as a purple speck that enlarges to have a brown or tan center. Heavily infected leaves drop from the tree, which weakens the tree and reduces flowering the next year. Limbs may have slightly sunken, reddish brown areas called cankers. Infected fruits begin with tiny red or purple spots occurring opposite the stem end. After a few weeks the spots enlarge and have alternating zones of black and brown. The rot eventually affects the entire fruit, which wrinkles, mummifies and often remains attached to the tree.

Remove and discard dead branches and diseased fruit, where the fungus can survive during winter. The fungicides captan and thiophanate-methyl are effective if it is applied during early season.

Source: Leaf spots (K. Russ, 2007)

There are a number of pests which possibly can attack the apple orchard. From them the most important are:

Aphids: They are feeding on leaves, therefore they are considered as typical leaf pest. However the woolly apple aphid feeds on the bark of small twigs and the roots of the apple tree. The two important leaf aphid are the Aphis pomi and Aphis spiraecola, both of them with a green colored body. Aphids can be controlled easily without chemical spray. Spraying with water or with water-soap mix effectively keeps clean the tree. Chemical use also can kill the lady beetle, which natural enemy of the aphid.

Source: Aphids (W. Cranshaw, 2007)

Mite: Two-spotted spider mites (Tetranychus urticae) and European red mites (Panonychus ulmi) can be serious pests of apples. If mite populations are high, the feeding activity can reduce the quality of the current crop and reduce flower bud set for the following year. Two-spotted spider mites spend the winter as mature females hiding in protected places on the ground near the tree. In the spring, they begin feeding on the vegetation under the tree. Later, they move up into the tree and begin to feed on the apple leaves. European red mites spend the winter in the egg stage. The eggs are laid on the tips of the twigs around the rough bud scars. When numbers are high, the twigs will have a reddish appearance. The mites remain in the tree throughout the season. Often the mite is called spider, which is a mistake. They belong to the Acaricidae.

Source: Aphids (W. Cranshaw, 2007)

Their control is very difficult, because they have a series of generation during the year. Therefore chemicals should be used frequently. Systemic pesticide use is better, but they also can be controlled if we spray throughout the trees with high pressure water.

Source: Aphids (W. Cranshaw, 2007)

Codling moth: It is one of the most damaging fruit pests. It is called Cydia pomonella. The mature caterpillars (larvae) leave the apples in the fall and spend the winter in a silk shelter. In the spring, they change to the adult moth after bloom. The moths lay eggs on leaves near fruit clusters. The larvae penetrate into the young fruit at the calyx end where the petals were attached. The 2nd generation of moths appears in mid-summer. They lay eggs directly on the surface of the fruit. The larvae burrow to the fruit core and feed. A third generation occurs later summer.

During dormant stage all part of the tree, which visibly contains the silk shelter should be removed and burn. Preventive spraying (called “washing the tree) should be applied. Once the larvae enter the apple they will be protected.

10 Irrigation

The apple’s water need is high, about 800mm per year. The water use of the tree is divided to three periods. The first period is the increasing water use: This stage starts from bud break and finishes when the tree fully developed the first groups of shoots. The water use increases gradually. If the water availability is not adequate the fruit set not will happen. The second period includes the main water use stage. The water use is the maximum, because the foliar volume is huge and the heat causes the highest evapo-transpiration of the whole growing season. Lack of water in this stage severely affects fruit development and causes the falling of fruits in plum, apricot and peach. Finally, during the third period the water use decreases and the tree turn into the dormant stage.

Small holder farmers usually use surface irrigation. Three methods are important: Border, furrow and basin irrigation. The main concepts for irrigation are to avoid over or under irrigating the trees and irrigation application should follow a regular interval pattern.

11 Pruning Apple Trees

Proper pruning practices increases the quality and value of the crop. Apple tree must be pruned every year. The amount and quality of fruit are determined by the relationship between vegetative and generative growth. Excessively vigorous wood can result in fruit loss.

Apple tree needs full sunlight. Shade is a limiting factor for apple fruit development. Large penetration into the canopy of a standard and un-pruned apple tree is gradually decreases with the depth of the penetration. The top canopy layer still will have an 60-100% of full sunlight, while the middle layer will have only 30-59%. The lowest layer of the canopy even will be less than that. Therefore pruning is essential for apple fruit growth.

11.1 Root stock

There are many pruning systems. One of the most important factor to determine which kind of pruning system will be used is the type of root stock where the scion grafted or budded into. This also related to other aspects like production technology, tree density per area, etc.

The rootstock clones of apple are divided to three groups: strong growing (standard), medium-strong growing (semi-dwarf) and weak growing (dwarf) types. They form the ‘M” series. The “M” series had been selected in East Malling (M), England. For the identification of each clone in the series after the “M” every clone has a number. The “MM” series was created in Merton through cross breeding and their number series is between 100 and 120. The most important apple rootstocks are:

- Weak growing (Dwarf): M27, M9, M26 – Height: Between 1.8-3.0 m
- Medium-strong growing: MM106, M7, M4, MM104, M2 – Height: Around 4.0m
- Strong growing: MM111, MM109, M10 – Height: Between 4.8-5.5m

The following list is the description of some of the most typical root stock varieties:

Specific rootstocks (Source: Pennsylvania Tree Fruit Production Guide 2008–2009)

M.2 type rootstock

Malling 2 (M.2): An older rootstock that is reappearing in nurseries and orchards. It produces a semi-dwarf to semi-standard freestanding tree, depending on scion variety. Trees are strong, crop well, and do not have collar rot problems.

M.7 type rootstock

Malling 7 (M.7): This rootstock produces a semi-dwarf tree that is freestanding in deep well drained soils. In rocky, steep, or shallow soils, it tends to lean. High budding and deeper planting may help remedy this problem. The rootstock may sucker profusely and is susceptible to collar rot. M.7a is a clone of the original M.7, but which has had some of the inherent viruses removed.

Geneva 30 (G.30) is currently available from commercial nurseries. The advantages of this M.7-size rootstock are early production, fewer burr knots, and less suckering. Tests at Rock Springs do indicate that trees on this rootstock come into bearing earlier and produce more fruit than M.7. Unfortunately, in the last two years questions have arisen about the graft compatibility of this rootstock with Gala. In tests around the country in the NC-140 trials, there have been occasions where Gala/G.30 have snapped off at the bud union during high winds. Therefore, it is recommended that if Gala is propagated on G.30, the trees be supported by two wires, one at approximately 36–40 inches above the ground and a second wire at 8–9 feet. Individual stakes or poles have not been sufficient because they allow excessive twisting of the trees in the wind.

Poland 1 (P.1): This rootstock appears to be about the size of M.7. It may, however, require some tree support.

M.9 type rootstock

Malling 9 (M.9): The traditional and best-known dwarfing rootstock. It should be planted on a well-drained site. Trees on this rootstock always require leader support. The rootstock is very susceptible to fire blight and can develop burr knots. Numerous clones of M.9 are now being sold by nurseries, including M.9 NAKB 337, the current dominant strain used. It is a virus-free clone from Holland and appears to be 5–10 percent less vigorous than M.9EMLA. M.9EMLA is a virus free clone from the

East Malling/Long Ashton research stations. It is approximately 25–30 percent more vigorous than M.9. Pajam 1 (Lancep) and Pajam 2 (Cepiland) are French selections that are relatively new. They are 35 to 40 percent more vigorous than M.9 NAKB 337. One other clone is M.9 RN 29, selected by Rene Nicolai in Belgium. In plantings at University Park with Gala, it is approximately 30 percent larger than M.9 NAKB 337.

Poland 22 (P.22): P.22 produces trees that are smaller than those grown on M.9. It is reported to be resistant to collar rot, apple scab, powdery mildew, and crown gall. P.22 is susceptible to fire blight and woolly apple aphids. Its major benefit may be as an inter-stem piece. In one trial planting with Gala, it has produced a tree slightly smaller than P.16. However, in a younger planting with Ginger Gold, it is slightly larger.

Budagovsky 9 (B.9 or Bud9) is a new dwarfing rootstock bred in the Soviet Union from the cross of M.8 x Red Standard (Krasnij Standart). Like the other stocks in this series, the leaves are a distinctive red. Trees on this stock are 25 to 35 percent smaller than M.9EMLA depending upon the cultivar. In a 10-year trial at University Park, York Imperial, Rome Beauty, and Empire on B.9 were approximately 25 percent smaller than the same cultivar on M.9EMLA; while Jonagold, Golden Delicious, and McIntosh were approximately 35 percent smaller. B.9 appears to be resistant to collar rot and is very cold-hardy. In limited trials, it has performed very well across a wide range of conditions. Trees will need to be supported.

Poland 2 (P.2) was developed from a cross between M.9 and Common Antonovka. Trees grown on P.2 are 15 to 25 percent smaller than M.9. The rootstock is resistant to collar rot and slightly susceptible to apple scab and powdery mildew. Young test plantings in Pennsylvania with Gala and Ginger Gold show that P.2 is nearly as precocious as M.9. Smoothee Golden Delicious on this rootstock produces a very smooth and straight union. However, Delicious grown on P.2 is reportedly as susceptible to apple union necrosis as the same cultivar grown on MM.106.

Geneva 41 (G.41) was released in 2005 as a rootstock that produces trees the size of M.9. The rootstock was developed from a cross between M.27 and Robusta 5 made in 1975. It was selected for resistance to Phytopthora and fire blight. Oldest planting with this rootstock is located at FREC in Biglerville and started in 1998 with Jonagold. Three-year-old trees at Rock Springs with Golden Delicious are 12 percent smaller than trees on M.9T337 and about 30 percent smaller than M.26. Finished trees should be readily available.

MARK: Formerly named MAC 9, developed in Michigan. It is an open-pollinated seedling of M.9. Trials in Pennsylvania indicate that this rootstock is not freestanding and is slightly larger than M.9. The central leader tends to lean. In recent years this rootstock has fallen into disfavor due to an abnormal growth proliferation at the soil line. Trees with this growth proliferation cease to grow and become spur bound; therefore, it is not recommended to be planted unless supplemental irrigation is provided. Very drought sensitive.

Geneva 16 (G.16): This is a recent rootstock released from Cornell University's breeding program. Like others in the series, it is resistant to fire blight. It is tolerant of collar rot and immune to apple scab. It is susceptible to woolly apple aphid and powdery mildew. Size is reported to be between that of M.9 and M.26. In a trial at Rock Springs at the end of the fourth growing season it is approximately 14 percent larger than M.9T337 and 8 percent smaller than M.26. It does appear, however, to induce wider branch angles in the scion cultivar. Geneva 16 is very sensitive to latent viruses in apple and should only be propagated with virus free scion wood on top. At this time, G.16 is recommended for trial only because of this problem.

Ottawa 3 (O.3): This relatively new rootstock was bred in Canada for its cold-hardiness, with one parent being M.9. Trees on O.3 are about the size of M.9EMLA but smaller than M.26. Induces earl bearing. Resistant to collar rot, but susceptible to fire blight and wooly apple aphids. Ottawa 3, although being available for many years, has not been popular with the nursery industry. Young

stool beds of O.3 produce few saleable liners, although with age the stool beds become more productive. Ottawa 3 is very susceptible to apple mosaic virus, so only material known to be virus free should be planted on this rootstock.

M.26 type rootstock

Malling 26 (M.26): A more vigorous rootstock than M.9. It can be used to produce either a dwarf or a semi-dwarf tree, depending on scion variety, production system, and soil type. It is susceptible to collar rot and fire blight and should not be planted in a wet site. Certain varieties, such as Rome, Stayman, Golden Delicious, and many triploids, when grafted onto this rootstock may exhibit signs of graft union incompatibility. When incompatibility occurs, the trees may break off at the union in high winds. Because exposed portions of the rootstock have a strong tendency to produce burr knots, the union between the scion variety and the rootstock should be set no more than 1 to 2 inches above the final soil level.

Vineland 1 (V.1): This is the newest rootstock to come from the breeding program at the Vineland station in Ontario, Canada. Tree size is comparable or slightly larger than M.26. Yield efficiency and fruit size are equal to or greater than M.26. However, unlike M.26, it appears to be highly resistant to fire blight. It should be in limited supply for the 2003 growing season.

Geneva 935 (G.935) is a 1976 cross of Ottawa 3 and Robusta 5. Size is reported to be slightly larger than M.26, but the rootstock has resistance to fire blight and crown rot. It is not resistant to wooly apple aphid. Production efficiency is rated equal to M.9. In the Golden Delicious trial at Rock Springs in 2006, tree size was about 9 percent larger than M.9 and 12 percent smaller than M.26. Production efficiency was not significantly different although slightly higher than M.9 in 2005. The rootstock seems to induce wider angled branching in the scion. Finished trees should be readily available in 2008.

Geneva 11 (G.11): The second release of the Cornell breeding program; only limited plantings exist in Pennsylvania. Reported to be similar in size to M 26 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. Availability limited. Tissue-cultured trees are larger than trees propagated by stool beds.

Geneva 202 (G.202) is a semi-dwarfing rootstock that produces a tree slightly larger than M.26. It was developed from a cross of M.27 and Robusta 5. It is fire blight and Phytopthora resistant as well as having resistance to wooly apple aphids. The rootstock has been mainly tested in New York and New Zealand. In New Zealand they are looking at this rootstock as a possible replacement for M.26 since it is more productive than M.26. In a 9-year study with the scion cultivar of Liberty, G.202 was about 50 percent smaller than M.7 but had much greater production efficiency.

Pillnitzer Supporter 4 (Pi.80), a cross between M.9 and M.4, has recently been introduced from Germany. It is reported similar in size and in anchorage to M.26. Yield capacity is reported to be better than that of M.26. A planting with McIntosh as the cultivar was established in 1999 at Rock Springs. To date, Supporter 4 is about 15 percent larger than M.7 EMLA. Yield in 2001 was nearly double that of McIntosh/M.7EMLA and 50 percent greater than McIntosh/M.26EMLA.

M.27 type rootstock

Malling 27 (M.27): A very dwarfing rootstock. Unless the central leader is supported, the tree will be very small. Little is known about disease or insect susceptibility. To date, most commercial nurseries are using this rootstock only 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.

Budagovsky 469 (B.469) induces dwarfing similar to that of M.27 and is very winter hardy. Its only use would be for an inter-stem. Test plantings of Ginger Gold with this rootstock at University Park

have not been viable. In New York State trials B.469 has shown very good compatibility between the scion, without the typical overgrowth.

Poland 16 (P.16) is from the same cross as the other Poland rootstocks and is reported to produce a tree about the size of M.27, although this has not proven to be the case in research trials in Pennsylvania. Test plantings of this rootstock at University Park with ‘Gala’ and ‘Ginger Gold’ show that trees are about 40 percent of the size of the same cultivar on M.9 rootstock. At this time this rootstock is suggested for trial only. P.16 is reported to be resistant to apple scab, powdery mildew, collar rot, and crown gall. It is susceptible to fire blight.

Geneva 65 (G.65) was developed by Dr. Jim Cummins at Cornell University. Due to errors in tissue culture buildup of this rootstock, the U.S. distribution of this rootstock has been hindered. Tree size once thought to be about that of M.9 is now considered to be closer to M.27. The rootstock is difficult to propagate in nursery stool beds. It is susceptible to tomato ring spot virus and apple stem grooving virus

MM.106 type rootstock

Malling-Merton 106 (MM.106): A rootstock, slightly larger than M.7, that produces freestanding, early-bearing trees. Trees on MM.106 are susceptible to collar rot when planted in wet soils and are not recommended for poorly drained sites. Delicious on MM.106 is susceptible to apple union necrosis.

Inter-stems are becoming increasingly popular in Pennsylvania orchards. This stock is composed of an under stock such as seedling MM.111 or MM.106, onto which an intermediate stem piece of M.9 or M.27 is grafted. The variety is budded or grafted onto M.9 or M.27. Size control is directly related to the length of the intermediate stem piece. Inter-stem apple trees offer a strong root system while reducing the size of the overall tree. Inter-stem trees should be planted so that a portion of the inter-stem is buried. Test plantings in Pennsylvania indicate that inter-stems on either MM.106 or MM.111 sucker,
and very vigorous varieties and Stayman have not performed well on inter-stems.

Budagovsky 490 (B.490): This rootstock produces a tree the size of MM.106 and has the same favorable characteristic of inducing early bearing. Burr knots rarely occur. The rootstock has some resistance to collar rot and is reportedly moderately resistant to fire blight. Nurseries find this stock easy to propagate by hardwood cuttings and are grooming it to replace MM.106.

MM.111 type rootstock

Malling-Merton 111 (MM.111): A well-anchored rootstock, resistant to woolly apple aphids, and tolerant of drier soil conditions. It is the most cold-hardy rootstock readily available. Trees on MM.111 are semi-standard to standard in size. Planting depth of this rootstock is critical. The union should be no higher than 1 to 2 inches above the final soil line.

Poland 18 (P.18): This stock holds the most promise for those wanting a larger tree about the size of MM.111. Its other advantages are tolerance to fire blight and resistance to collar rot. It will probably perform better in wet or heavier soils.

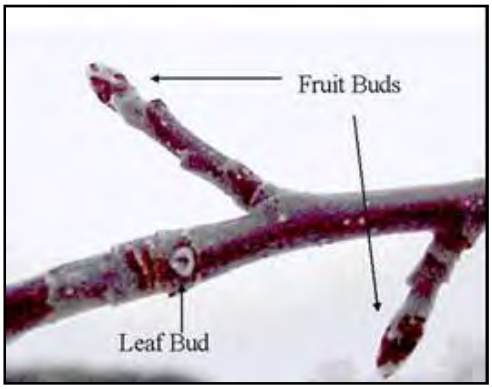
11.2 Principles of pruning apple tree

Pruning is the most confusing technique for growers. There are many techniques which vary according to the cultivar type, production method, etc. It also requires knowledge, skills and

considerable experience. Therefore the first thing to do is to visualize the purpose and goal of pruning.

Although pruning stimulates shoot growth it is also a dwarfing process to reduce tree size. However, pruning will not affect or change the overall growing habit of the tree. This is one of the reasons fruit trees should be pruned annually. Excessive pruning can alter the tree's balance even if it does not change the tree's growing habit, and will also stimulate the growth of water sprouts and suckers.

The pruning effect is localized to that particular part of the tree. Therefore it can always be expected that strong shooting effects will occur under the pruning cut area. However, be sure that the pruning cut is a clean, flush cut, which will help the healing process of the wounded part.



Source: R. Moran (2005)

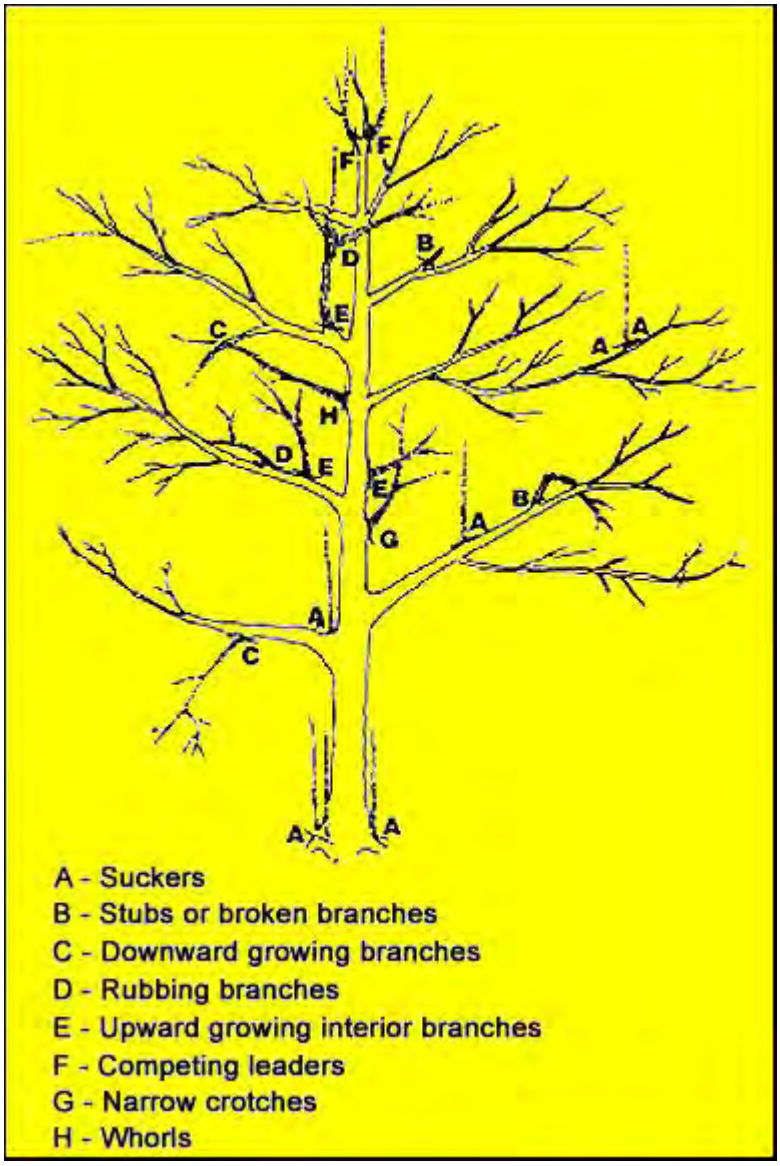
It is important to avoid mistakes that cannot be reversed. The first step is to recognize the difference between fruit and leafy buds. Fruit buds are larger and more rounded than leafy ones. Fruit buds can be located on the tips of the spur and short shoots rather than laterally on the shoots. Lateral shoots mainly contain leafy buds in addition to shoot tips.

Location of fruit buds:

Long shoot		Short shoot (spur)		Spur life
Laterally	**Terminally**	**Laterally**	**Terminally**	**(Years)**
Minor	Minor	-------	Major	8-10

The following list contains the main general recommendations for pruning practices:

- If pruning is taken place during the dormant season, the ideal time period is the late dormant season
- Summer pruning is advised to remove water sprouts, suckers and infected wood.
- Only use wound dressing for cuts that have a diameter more than 4-5 cm
- Prune the upper layer of the canopy more heavily than the lower one
- Prune on a horizontal plane and remove any branches that hang downward or rise straight upward
- To reduce length, it is preferable to use a thinning cut rather than a heading cut, which causes excessive shoot growth
- Remove all branches with narrow crotch angles (they are always weak branches), crossing branches or upright water sprouts
- Remove all broken, dead or diseased branches on regular basis
- Suggested pruning cuts:
  - Suckers
  - Stubs
  - Downward growing limbs
  - Rubbing and crossing branches
  - Shaded interior branches
  - Competing leaders
  - Narrow crotches
  - Whorls

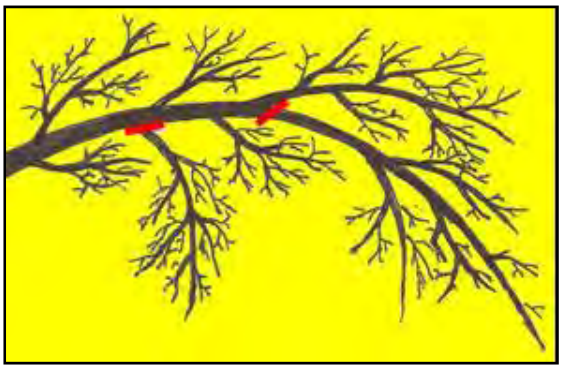


Source: W. Cranshaw (2007)

11.3 The growing habits of apple trees

The growing habits of the tree will affect how a tree should be pruned. There are three general growth habits of apple trees: spur types, tip bearers and intermediate types.

Spur types form most of their fruit buds at the tips of spurs. Delicious cultivars have a spur type growth habit. A spur is simply a short shoot. Spurs can be located on parts of the branch that are two years old or older and on the inside part of the tree canopy where shading occurs. They have an upright growing habit. This type tends to shade the fruit. Keep the top of the canopy thinned out. Tall limbs can be headed back to weak shoots.



Source: Pruning drooping limb (F. Sandor, 2008)

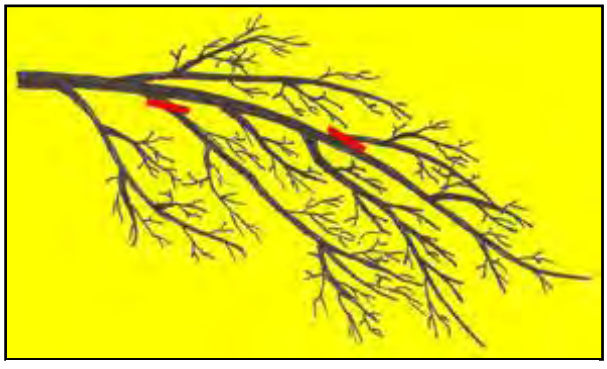
Tip bearing types have the fruit buds at the tips of the shoots; therefore the fruit set will be on the canopy's periphery. This type of tree has a drooping growing habit. During pruning be careful, because it is easy to prune out too many fruit buds. There is a tendency for excessive shading created by limbs that droop. These should be headed back to a horizontal shoot.

The intermediate type is balanced in its growing habit. These trees form fruit buds on both spurs and shoot tips. McIntosh has an intermediate growing habit. The tree also has a spreading habit rather than upright or drooping. Prune to discourage vigorous growth and to reduce shading.

A branch has three sections. The first section is the new wood or one-year old shoot. They do not have lateral shoots or spurs, only lateral buds for future shoot development. The second section is the two-year old shoot with lateral shoots and spurs. The third section is the three-year old wood.

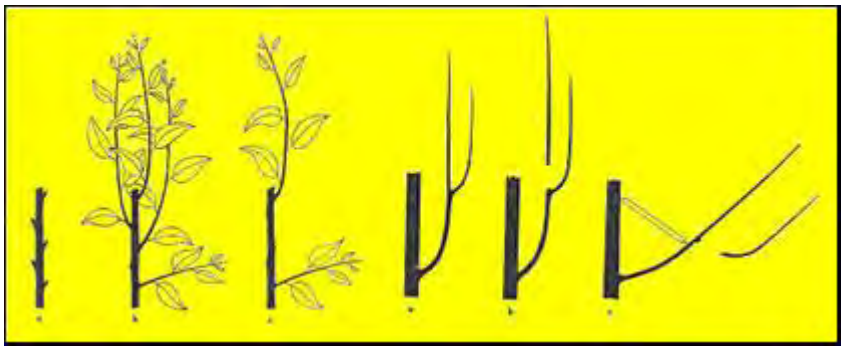
11.4 Pruning cuts

There are two types of pruning cuts: the heading cut and the thinning cut. The thinning cut removes the entire branch at its base. The heading cut removes only part of the branch. The thinning cut results in less vegetative growth afterwards, as compared to the heading cut. A heading cut always stimulates new shoot growth below the cutting point. The vigor of re-grow depends on which part of the branch was headed back. A cut into the one-year old shoot causes the removal of the tip, stimulating the lateral buds to grow. The result is a bushy re-growth. A heading cut into a two-year-old shoot increases the vigor of existing shoots and spurs and stimulates fruit set. Heading the three-year-old shoot will increase the vigor of spurs and shoots in the subsequent growth.



Source: Thinning out (F. Sandor, 2008)

11.5 Pruning young apple trees



Source: C. G. Forhsey (2006)

Pruning starts immediately after planting. For pruning the one-year old tree a sapling that has 3-5 lateral branches is needed. In the first year of pruning, head back the central branch to half or third its original size. If the tree has 4-5 lateral branches, remove the top strongest or the bottom weakest one. Cut back the lateral branches when they grow up to 60-90cm length. From the shoots, cut back the strongest ones to 1/3. The remaining buds will be on the first ¼ part of the branch. During the selection of the shoots, keep more strong shoots than weak ones. Next year new growth will arise, which should be cut back in a similar fashion. With the exception of the 2-3 best new shoots, the rest of the shoots should be removed.

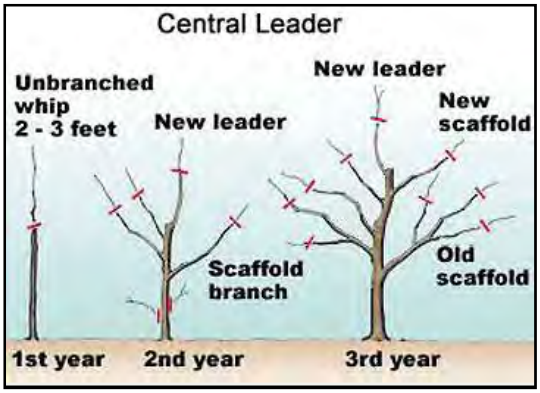
11.6 Training the apple tree

There are different types of training systems. The main concept is that the pruning system should fit the chosen type of cultivar, rootstock, planting distance and production technology.

11.6.1 Central leader system

Source: W. Cranshaw (2007)

This traditionally used training system can be used for standard and semi-dwarf trees. The first growing season will produce 2-4 vigorous shoots that are almost equal in size. One of them should be selected as the leader and the rest of the competing shoots should be removed. Cultivars vary in vigor. Some of them are characterized by having less vigor and by having the central leader develop naturally. Golden Delicious is a typical example of this. Others, like Delicious grow vigorously and produce many competing shoots, while the central leader produces excessive extension growth. As a consequence, the leader becomes weak and the lateral development of the tree will be insufficient for necessary main scaffolds. The leader should be headed by 1/4. The lateral branches should be positioned at a 45° angle through spreading them if necessary. When cutting back the branches make sure to consider the angle of the branch.



Source: W. Cranshaw (2007)

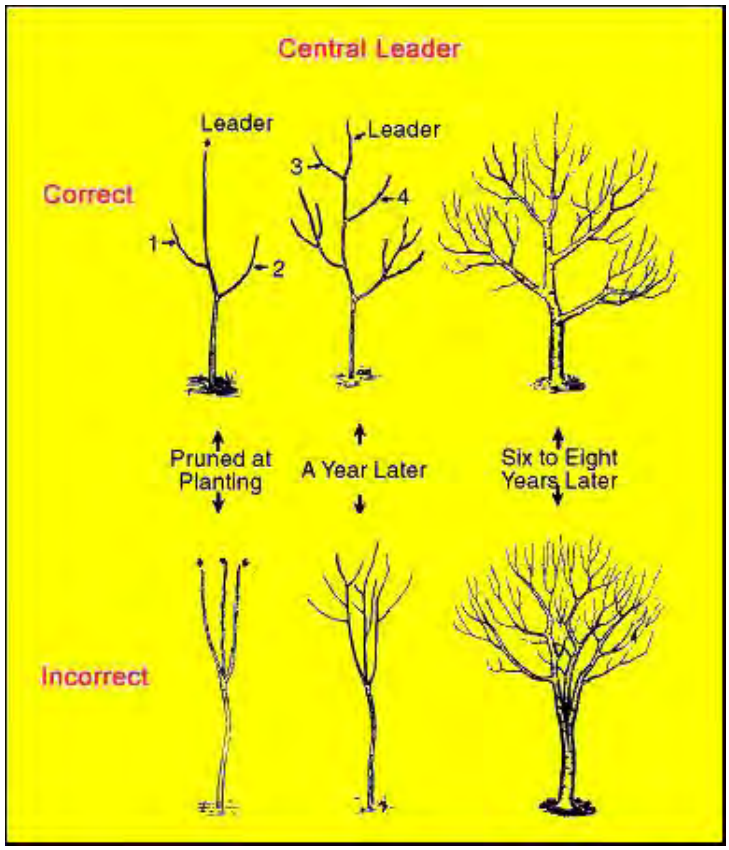
If the angle is less than 45°, cut back for an upward positioned bud. If the angle is bigger than 45°, cut back for a downward positioned baud. Cut back the lateral branches when they grow up to 60-90cm length. These primary branches will form the first layer or tier. From the shoots, cut back the strongest ones to 1/3. The remaining buds will be on the first 1/4 of the branch.

During the third year pruning, form the second tier of the tree. The second tier's branches should be offset

vertically from those of the first tier. Between the two tiers the distance on the leader branch should be 50-100cm. The leader branch should be cut back to 4-5 buds. Remove all branches that grow facing to the inside of the canopy (or crossing).

Thereafter, continue to develop the third or sometimes even fourth tiers. Continue to prune out water sprouts and unwanted branches.

If using a modified central leader system, position the branches not only horizontally (in tiers) but vertically too. All other branches should be cut back to 3-5 buds. After the full development of the co-dominant primary scaffold branches, the central leader should be removed.



Source: W. Cranshaw (2007)

The most important principles for central leader system development are the following:

- Make proper selection and practice proper training of the scaffold branches
- The first scaffold limb should be at least 45cm from the ground
- Additional scaffold limbs should be separated along the trunk by a minimum of 20cm and be well distributed around the trunk
- When the leader becomes too tall to harvest, it should be headed back into two-year old wood
- Branches that shade in excess should be removed
- Maintain the cone shape of the tree
- Remove shoots that are not productive
- Develop the central leader tree in five steps:
  - Maintain one leader
  - Remove excess limbs
  - Maintain cone shape
  - Remove excess shoots
  - Know when to quit

Recommendation for pruning:

Tree height	Tree spread	Yield	Annual heading	Scaffold limb removal
4.6m	4.9m	344Kg	No	No
4.5m	4.4m	284Kg	Yes	No
4.6m	4.8m	281Kg	No	Yes
4.6m	4.7m	251Kg	Yes	Yes

11.6.2 Open center system

Source: W. Cranshaw (2007)

An open center apple tree does not have a central leader. Instead, some major branches are distributed around the top of the trunk forming a vase shape. At the beginning of the first growing season, select 3-6 shoots that will become the primary scaffold branches and cut back all other upright shoots to 10 to 15 cm long. The leader should be removed. The lowest branch should be about 50-60cm above the ground. If the scaffold branches grow vigorously, they should be cut back during early summer time to 60-75cm length. By the end of the first growing season the main scaffold branches should be formed. During the 2nd and 3rd year, select the 5-7 secondary scaffold branches to fill up the space. Head back the secondary scaffold branches at 60 to 75 cm long to develop two to three "tertiary" branches from each secondary branch. During the 4th and 5th year another 10-12 tertiary scaffold branches will be selected to form the vase shape of the tree. All strongly upward growing branches and shoots should be removed.

Central leader and open center trees are typical for standard and semi-dwarf apple production. The density of population varies between 370 and 600 full sized trees per hectare. High density population (1,200-2,500 trees per hectare) characterizes the size controlled trees, which use dwarf rootstock varieties. The tree size is 35% or less of a full size apple tree. In these high density orchards, fruit production begins during earlier stages, but usually the orchard life cycle is also shorter than the traditional types of apple orchards.

11.6.3 Slender, spindle-type system

This system requires a permanent support structure (stakes and wire), where each tree is tied to a stake 25-30cm apart. The tree height is approximately 1.8-2.5m. The height always should be controlled. It is a misunderstanding that dwarf types of trees do not need height control. The tree has many limbs around the leader. At maturity, it has two permanent whorls of scaffold branches 25-30 cm apart. The branches above the second whorl of branches should be renewed every two-four years. The length of the spreading branches is approximately 90cm.

Source: C. G. Forshey (2007)

The pruning technique of the young planted tree follows the traditional leader development technique. The leader is headed back to a height of 75-80cm and a new shoot will be selected as the central leader (It should be a new growth with a length of 8-10cm). If the young tree is a feathered tree (well-branched) the leader is headed back 25cm above the highest usable branch. With poor lateral branch development it is necessary to use “weak leader renewal” technique. This means the removal of the vigorous central leader and its replacement with a weaker branch. This will stimulate branching on the tree.

The remedial technique helps to shape the tree. Approximately two weeks before bloom, a notch is made above each node in the un-branched region of the leader through the bark to stimulate branching.

Snaking the tree also helps to stimulate the branching process. The time for snaking is the growing season. In every 45-50cm, bend and tie the leader into the stake at an angle of 60°. The leader will have a shape like a snake.

Another technique that can be used for an un-branched leader is the “Bagging” technique. The leader is headed back to a maximum length of 80cm above the highest usable lateral branch and the headed leader is covered with a polyethylene bag. This should be done four weeks before bud break.

Later branch management is a very important process. All lateral branches should be spread at an 80°-85° angle which have a length of 8-10cm and be controlled in length. Using summer pruning the branches can be cut back into wood keeping the desired length. Thereafter, the main pruning work is lightening the tree. Thinning cuts should make to create distinct whorls of branches 25-30cm apart.

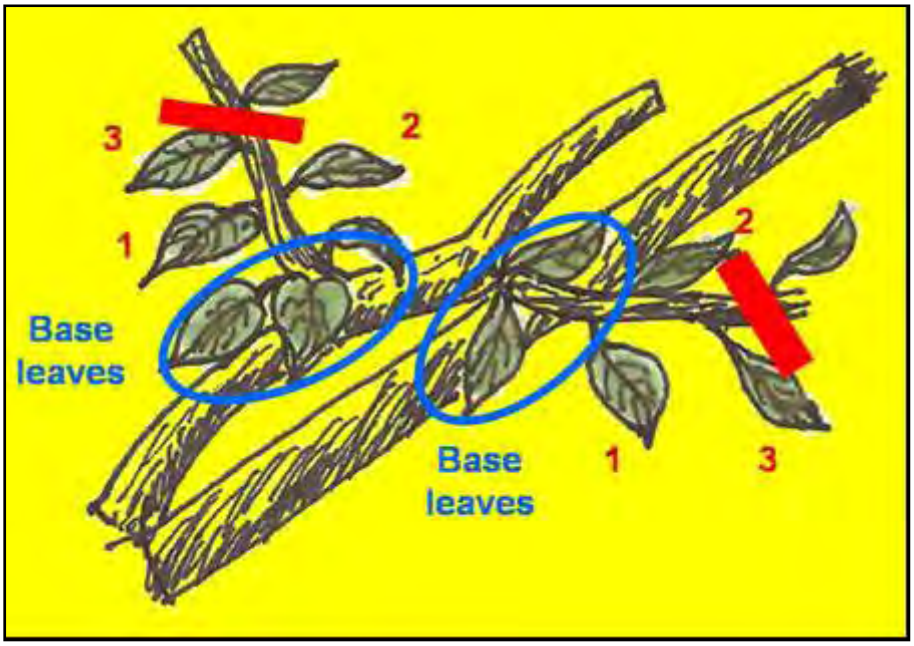
11.6.4 Cordon type system

Source: D. Marks (2005)

This is the easiest system to use for dwarf type apple trees. It really hardly can be called a tree. The cordon tree is a single stem with pruned, short side shoots (fruiting spurs). The sapling is planted at an angle of 45°. The cordon is built up from three 25mm wires that are 60cm apart from each other, making three levels from the soil surface, which are respectively 60cm, 120cm and 180cm height from the ground. Once the wires are fixed, tie the tree to the wire. For each tree, fix a stake approximately 2.4m long. All side shoots longer than 10cm should be pruned after the third bud (summer pruning).

Many of the production systems need a permanent support structure. The specific types of apple trees that need a support structure are determined by their rootstock type:

Rootstock	Width	Height	Staking
M.27	1.0m	1.0m	YES
Budagovsky 9	1.2m	1.2m	YES
M.9	1.6m	1.6m	YES
M.26	2.3m	1.8m	YES
Mark	2.3m	1.8m	YES
Ottawa 3	2.3m	1.8m	YES
M.7	3.0m	2.5m	NO
MM.106	3.6m	3.0m	NO
M.2	4.0m	3.2m	NO
M.4	4.2m	3.5m	NO
MM.111	4.5m	4.0m	NO

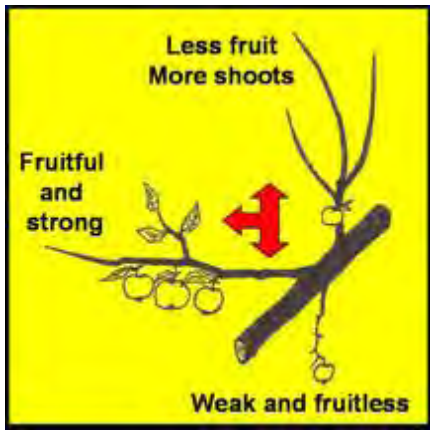


Source: F. Sandor (2008)

11.7 Pruning bearing trees

Source: F. Sandor (2008)

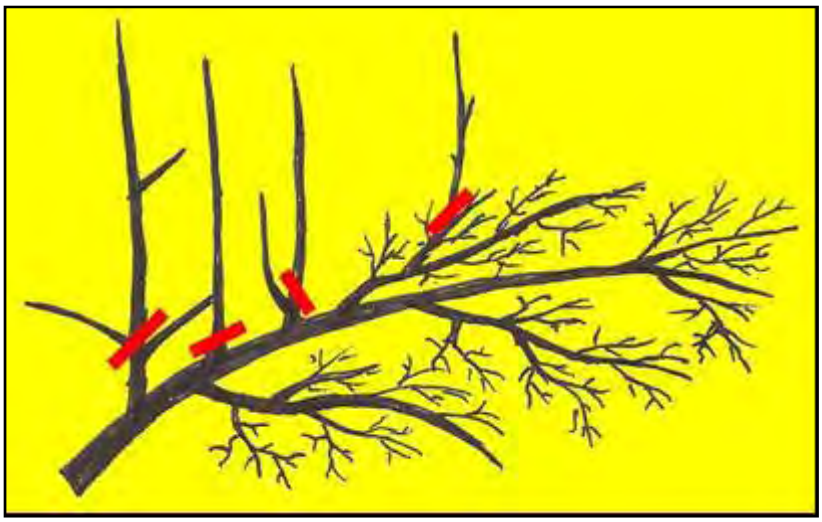
Typically, pruning takes place during the dormant period, but trees can be pruned in the summer as well. In fact summer time pruning is useful to treat specific problems or requirements such as thinning out fruits. When the fruit set is finished, the cluster must be thinned out immediately, which usually contains 3-5 fruits. First remove the central fruit (called king apple), because it is normally low quality and misshapen. Also remove all blemished and misshapen fruits.



Source: F. Sandor (2008)

Main concepts for pruning a bearing tree:
Upright branches are excessively vigorous and moderately fruitful, with the quality of fruit usually low.

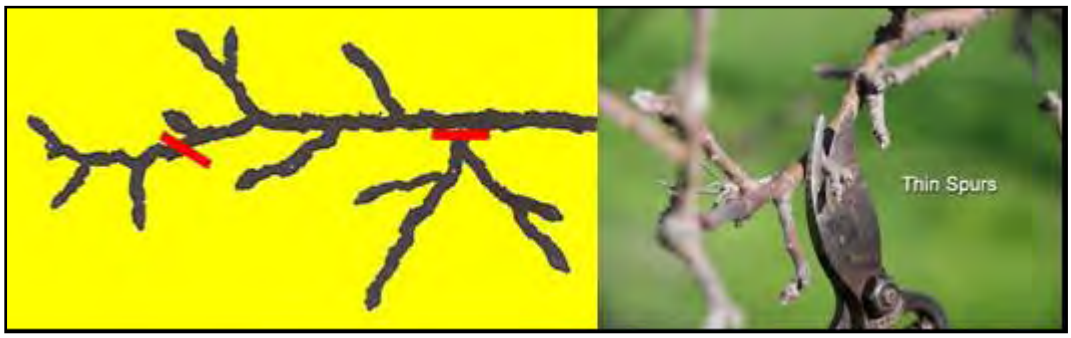
- Branches growing from the underside of larger branches are shaded; therefore weak in vigor and producing low quality fruit. These branches should be removed.
- Optimal branch position is close to horizontal
- Drooping branches that are low in vigor should be headed back to a lateral branch that is in a nearly horizontal position.
- Trees with high vigor produce many water shoots and upright shoots. The pruning concepts should be the following:



Source: F. Sandor (2008)

- Thinning out some upright growth
- Complete removal of vigorous shoots which grow from fruiting wood
- Heading back vigorous water sprouts to a horizontal branch that has moderate vigor
- Remove excessively vigorous shoots and leave one moderately vigorous shoot
- Improper pruning includes the heading back of all upright growth, heading back vigorous shoots to a very weak lateral and the removal of all fine wood.

- When the tree produces a profusion of fine wood near the end of the branches, the bearing wood should be thinned out evenly along the branch, allowing proper light exposure to all of the fruit.
- Spurs often need to be invigorated. The unfruitful spur has numerous, weak branches and weak small buds and should be headed back to a strong bud. While dead spurs should be removed completely.



Source: Graphic-F. Sandor (2008), Photo-W. Cranshaw (2007)

- If the branches of two trees are overlapping, do not head back the overlapping parts of the branches, otherwise the tree will produce bushy growth under the headed area. Instead, make thinning cuts to remove some of the overlapping limbs.
- Summer pruning includes the following pruning cuts:
  - Vigorous water sprouts should be removed entirely
  - Undesirable, but fruitful upright shoots should be headed back just above the cluster of fruits (It will be removed during dormant pruning)
  - Upturned branches should be headed back to a weak lateral

12 Harvest

For time scheduling, growers must estimate optimum harvest dates well before picking fruit. In addition, optimum maturity levels differ within the same cultivars, depending on intended use and storage life desired. Harvesting too early can result in fruit that is off-flavor or lacking flavor, poorly colored, small and subject to bitter pit and storage scald. Harvesting too late can result in softer fruit, the potential development of water core, and a shorter storage life. The best test for maturity is to sample one and taste it. Another method is to take the apple in the palm of your hand and give it a slight twist - if it drops off, it is probably ready to eat. When harvesting apples, take care not to bruise them - this will cause them to rot much more quickly, and if in storage, the rot will spread to other apples. The stem should not be separated from the fruit, because fruits without stems cannot be stored long without loosing quality.

Source: F. Sandor (2007)

Apples keep for the longest in cool conditions (3C°), which are well-ventilated, dark and slightly humid. Seeing as it is difficult to provide these ideal conditions, a compromise is necessary. A good option is to store the apples in a shed or garage, with the apples in plastic bags to retain moisture - leave a 2cm hole in each bag to allow some ventilation.
Maintain a relatively high level of humidity in the storage room. Apples are approximately 85 percent water and can quickly lose enough moisture to show signs of skin shrivel if kept at too low a humidity. Shrivel can appear after an apple loses as little as 3 percent of its fresh weight. Abrasions, bruises, and other injuries increase the rate of water loss. A single bruise can increase water loss nearly fourfold. Warm fruit is cooled by giving up moisture. As moisture is removed from the air by the cold refrigeration coils, a deficit gradient is produced that pulls more moisture out of the fruit, which can result in shrivel. Once the fruit has been cooled, the refrigeration coil temperature can be raised to reduce the amount of moisture being removed from the air.

Table 6: Apples nutritional value per 100 g

Element/Compound	Amount
Carbohydrates	**1,3.81 g**
- Sugars 10.39 g	
- Dietary fiber 2.4 g	
Fat	**0.17 g**
Protein	**0.26 g**
Vitamin A equiv. 3 µg	0%
Thiamin (Vit. B1) 0.017 mg	1%
Riboflavin (Vit. B2) 0.026 mg	2%
Niacin (Vit. B3) 0.091 mg	1%
Pantothenic acid (B5) 0.061 mg	1%
Vitamin B6 0.041 mg	3%
Folate (Vit. B9) 3 µg	1%
Vitamin C 4.6 mg	8%
Calcium 6 mg	1%
Iron 0.12 mg	1%
Magnesium 5 mg	1%
Phosphorus 11 mg	2%
Potassium 107 mg	2%
Zinc 0.04 mg	0%

USDA Nutrient database (2008)

13 Apple Varieties

Almost all apple varieties need to be cross pollinated, although some varieties, such as Liberty, Empire, Jonathan, Jonagold, Gala, Golden Delicious, Rome and Granny Smith are self-fruitful, but they still set more fruit through cross pollination. Therefore the grower should plant different apple cultivars together in the same orchard. Also there are some cultivars which produce sterile pollen and cannot be used as pollinizers (Mutsu, Jonagold). Usually, in an apple orchard, every four rows is a pollinizer variety or within a row, every fifth semi-dwarf tree is a pollinizer. The maximum allowed distance between the tree and its pollinizer is 25 meters.

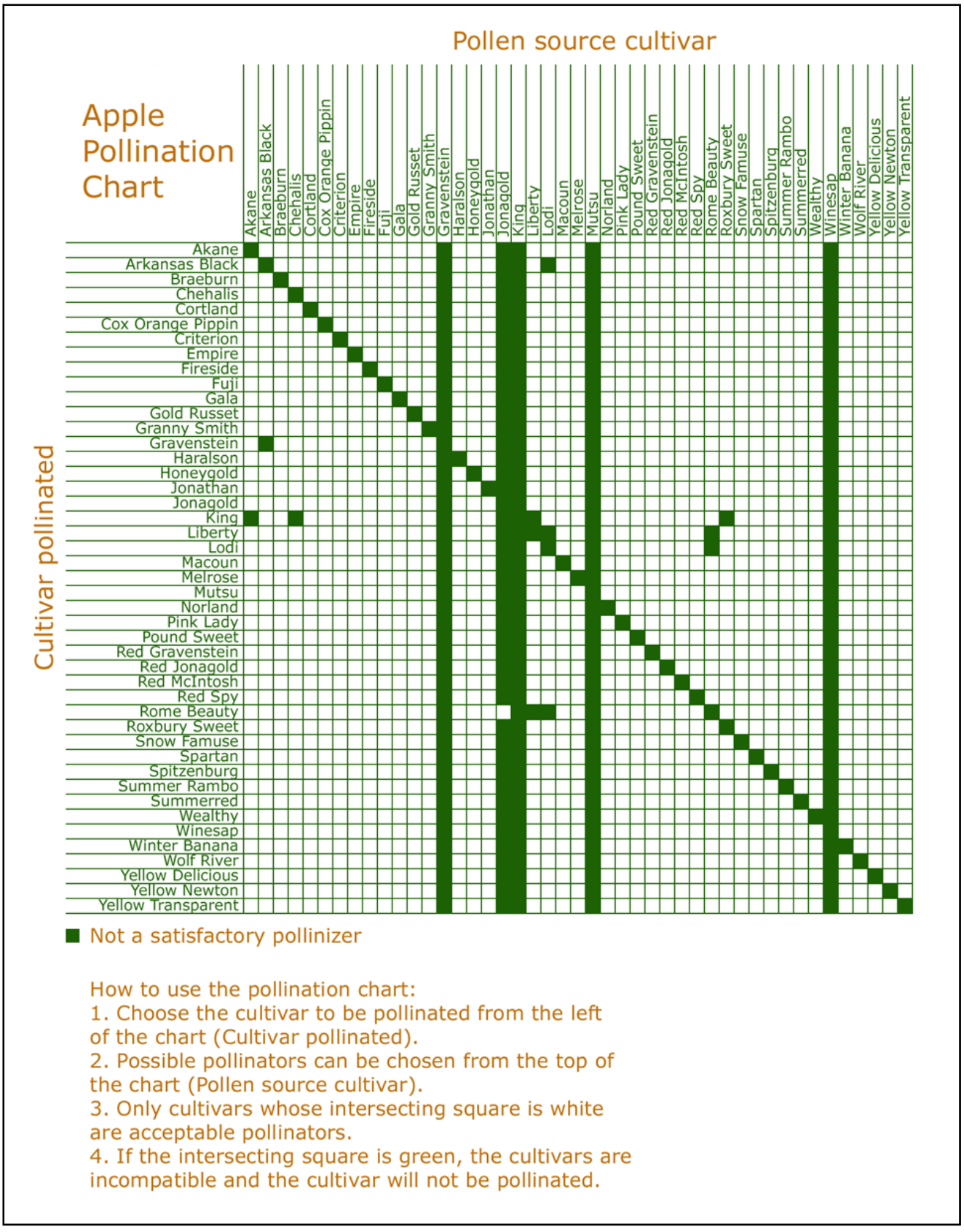
The compatibility between pollinizer and pollinated tree depends on the blooming time. There are three main groups: Early season, Mid season and Late season cultivars. If the grower plants an early season cultivar together with a late season pollinizer, the pollination will not happen. Therefore, during the selection of a pollinizer the grower should consider its bloom time period.

Apple pollination also needs a pollinator. The best pollinator is the honey bee. During the bloom period, if the farmer uses insecticides the bees can easily be destroyed as well and as a consequence it will cause a poor fruit set in the orchard. If possible, when the flowers open up, some beehives should be placed in the orchard. The recommended number of beehives per hectare is three for standard size apple, five for semi-dwarf and eight for dwarf type trees.

Source: F. Sandor (2007)

If pollination fails, graft a branch of a compatible variety onto the existing tree or put a bouquet of crabapple branches in bloom in a bucket of water, which will be placed inside the canopy of the tree.

There are around 7,500 known apple cultivars in the world. From this quantity approximately 1,000 are commonly used. Apple originates from Central Asia, therefore apple production is an important part of the Afghan horticulture. The following presentation contains a pollination chart and the most common apple cultivars used for apple production in Afghanistan.



Source: Apple pollination chart from a nursery catalogue

Species	Apple
Variety	July Red
Synonyms	
Origin	(Petrel x Early McIntosh) x (Williams x Starr); Introduced in 1962
Rootstock species	Apple
Rootstock variety	Mahali
Description	Very attractive, large, red fruit. Strongly scented with vinous or loganberry flavor; sweet, soft, juicy, white flesh.
Tree	Tree moderately vigorous

Species	Apple
Variety	Red Chief
Synonyms	Redchief Red Delicious
Origin	Delicious group, Possibly seedling from Yellow Bellflower; Peru, Iowa, USA , (Campbell cv.), USPP #3,578
Rootstock species	Apple
Rootstock variety	Mahali
Description	Deep red skin covers a sweeter flavored apple. Late
Tree	

Species	Apple
Variety	Double Red Delicious
Synonyms	Red One Red Delicious, Red Prince Red Delicious
Origin	Delicious group, Possibly seedling from Yellow Bellflower; Peru, Iowa, USA
Rootstock species	Apple
Rootstock variety	Mahali
Description	Red skin ripens yellow, a sweeter flavored apple
Tree	Non spur type

Species	Apple
Variety	Wel Spur
Synonyms	Well Spur Red Delicious
Origin	Delicious group, Possibly seedling from Yellow Bellflower; Peru, Iowa, USA
Rootstock species	Apple
Rootstock variety	Mahali
Description	Deep red skin covers a sweeter flavored apple
Tree	Spur type

Species	**Apple**
Variety	**Red Crimson**
Synonyms	**Crimson Crisp, Co OP 39**
Origin	**PRI (Purdue, Rutgers, Illinois Co Op)**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Small to medium. Very bright red over yellow. Extremely crisp. Very good, rich flavor. Moderately acidic, spicy**
Tree characteristics	**Moderately vigorous. Upright growth habit. Susceptible to mildew and to fire blight**

Species	**Apple**
Variety	**Jawrasi**
Synonyms	**Jefferies, Everbearing, Grantham**
Origin	**Pennsylvania, 1848**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Thin-skinned fruit, light red with darker red stripes, Flesh is juicy, crisp yet melting. Rich, pear-like flavor.**
Tree characteristics	**Tree is hardy, scab and mildew resistant. Bears regularly and heavily.**

Species	**Apple**
Variety	**Gala**
Synonyms	**Royal Gala**
Origin	**Kidd's Orange Red x Golden Delicious; New Zealand,**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Medium size, conical to round fruit with yellow skin patterned with bright orange-red. Firm, juicy, fine textured, yellow white flesh. Sweet slightly tart flavor.**
Tree	**Compact growth habit, prolific bearer.**

Species	Apple
Variety	Golden Delicious
Synonyms	
Origin	Chance seedling of Grimes Golden; West Virginia, 1900
Rootstock species	Apple
Rootstock variety	Mahali
Description	Large conic yellow fruit. Firm, crisp, juicy, flavorful flesh. High quality. Shrivels in storage. Bruises easily.
Tree characteristics	Moderately vigorous, round headed tree with wide crotch angles. Self fertile.

Species	Apple
Variety	Tur Kulu
Synonyms	
Origin	Afghanistan
Rootstock species	Apple
Rootstock variety	Mahali
Description	Medium to large reddish fruit. Firm, crisp, juicy, flavorful
Tree	

Species	Apple
Variety	Mutsu
Synonyms	Crispin
Origin	Golden Delicious x Indo; Japan 1930
Rootstock species	Apple
Rootstock variety	Mahali
Description	Good eating apple, first class cider and sauce. Green fruit ripens yellow.
Tree	Large vigorous tree. Triploid

Species	**Apple**
Variety	**Spur Golden, Golden Delicious group**
Synonyms	**Yellow Spur Golden Delicious**
Origin	**Chance seedling of Grimes Golden; West Virginia, 1900**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Large conic yellow fruit. Firm, crisp, juicy, flavorful flesh. High quality. Shrivels in storage. Bruises easily.**
Tree characteristics	**Moderately vigorous, round headed tree with wide crotch angles. Bears very young and annually if thinned.**

Species	**Apple**
Variety	**Jawrasi Golden**
Synonyms	**Jauras Golden**
Origin	**Afghanistan**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Medium to large conic yellow fruit. Patterned with red.**
Tree	

Species	**Apple**
Variety	**Kado Seb**
Synonyms	**Kado**
Origin	**Afghanistan**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Large conic yellow fruit. Firm, crisp, juicy, flavorful flesh**
Tree	

Source: F. Sandor (2007)

Species	**Apple**
Variety	**Nazak Badan**
Synonyms	
Origin	**Afghanistan**
Rootstock species	**Apple**
Rootstock variety	**Mahali**
Description	**Medium size, conical to round fruit with yellow skin patterned with orange-red. Firm, juicy, fine textured**
Tree	

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