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New trends of apple (*Malus domestica*) production: A review

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Abstract

Apple (*Malus domestica*) belongs to rose family Rosaceae of Angiosperms. Apple farming is an important activity and profession of farmer communities in the Himalayan states of India. China is the world's largest producer of apples while India holds the second place in world trade market. The most common varieties of apples in India are Red Delicious and Granny Smith. In North West Hill Region, Jammu and Kashmir contributes 80% of India's apple production, Himachal Pradesh which is the second largest producer accounts for 12.5% and Uttarakhand produces 5% of India's apples. In North East Hill Region, Arunachal Pradesh is the only major apple producing state outside the north-western hill region in the country producing Black Bendavis, Royal gala, Jonathan, Red Gold, Gani Gala, Rich-A-Red, Royal delicious, Red delicious, Golden delicious, Cooper- IV, McIntosh, Crofton, Granny smith, Starkrimson, Fokla, Ruspippin, Rajakori, Ganu and Mutsu apple varieties. The apples are a great source of fiber and pectin, and helps in controlling insulin levels, acts as anti cancerous, anti cholesterol and reduce risk of asthma and diabetes. The majority of farmers at low altitude and mid altitude reported decline in apple farming whereas 71% farmers at high hill areas refused decline in apple farming. About 73–83% farmers admitted delay in apple's harvesting period. At mid hills apple scab and at low hills pest attack on apple crops are considered as the indicators of climate change.

Keywords: *Malus domestica*, apple varieties, Arunachal Pradesh

1. Introduction

An apple is an edible fruit produced by an apple tree (*Malus domestica*). Apple trees are cultivated worldwide and are the most widely grown species in the genus *Malus*. The tree originated in Central Asia, where its wild ancestor, *Malus sieversii*, is still found today. Apples have been grown for thousands of years in Asia and Europe and were brought to North America by European colonists. Apples have religious and mythological significance in many cultures, including Norse, Greek, and European Christian tradition. Apple trees are large if grown from seed. Generally, apple cultivars are propagated by grafting onto rootstocks, which control the size of the resulting tree. There are more than 7,500 known cultivars of apples, resulting in a wide range of desired characteristics. Different cultivars are bred for various tastes and use, including cooking, eating raw and cider production. Trees and fruit are prone to a number of fungal, bacterial and pest problems, which can be controlled by a number of organic and non-organic means. China is the leading apple producer in world. In India, it is grown in Kashmir, Himachal Pradesh, hills of Uttarakhand. Apple cultivation also extended to Nagaland, Sikkim, Arunachal Pradesh and Meghalaya. India's share in the total apple production of the world is only 2.0%. In India, total area under apple cultivation is 250 thousand hectare producing 1470 thousand MT fruit with productivity of 5.9 tonnes/ha. In Jammu and Kashmir, total area under apple is 90.1 thousand hectare with production of 909.6 thousand MT. The state of J&K leads the other apple producing states in India, in terms of productivity with production of 10.1 MT fruits per hectare. Low productivity of apple orchards in the district can also be attributed to inadequate proportion of pollinizers, lack of pollinators, poor canopy management and incidence of other diseases and pests.

Apple (*Malus pumila*) is a well-known fruit, popular all over the world due to its health benefits. The plant, mainly originating from central Asia, has spread all over the world. The whole fruit is edible including the outer skin. Apple contains high amount of vitamins like vitamin C and vitamin B₁₂, minerals like calcium and phosphorous, and a rich source of carbohydrate.

Apple juice in various forms is popular among the masses and many studies have been conducted to improve the shelf life and nutritional parameters of this juice. Some of those studies are presented herein.



Fig 1: Apple Orchards with Fruiting



Fig 2: Apple Orchards with Fruiting

Origin and history of introduction

M. domestica is thought to have originated in Central Asia where its primary ancestor, *M. sieversii*, is native to the foothills between western China and the former Soviet Union (Figure 2) (Hancock *et al.* 2008; Harris *et al.* 2002; Velasco *et al.* 2010) [5, 6, 15]. Apples are the main forest tree in this region and *M. sieversii* is widespread in the Tien Shan mountains at elevations of 1200-1800 m (Luby 2003; Velasco *et al.* 2010) [15, 10]. *M. sieversii* is the only wild species that shares all the characteristics of *M. domestica*, in terms of fruit and tree morphology. Its fruits are highly variable and display the full range of colours, forms and tastes found in cultivated apples across the world. Humans have lived and practiced nomadic agriculture in this region for thousands of years, and it is thought that prior to deliberate domestication, there may have been a long period of opportunistic gathering of apples, and unintentional planting of trees via garbage disposal (Hancock *et al.* 2008; Luby 2003) [5, 10]. Bears and other vertebrates may also have contributed to dispersal (Ignatov and Bodishevskaya 2011; Juniper *et al.* 1999) [7, 8].

Ancient trade routes that linked China to the Middle East and Europe are thought to have facilitated the repeated short- and long-distance dispersal of *M. sieversii* to the east and west from its area of origin in Central Asia (Harris *et al.* 2002; Velasco *et al.* 2010) [6, 15]. Travellers on foot as well as

camels and pack horses are thought to have used parts of the Old Silk Road as early as the Neolithic period (~9000 BC) and the route was well established by the Bronze Age (~2500 BC), providing untold opportunities for the dispersal of fruit and seeds, either intentionally or unintentionally (Hancock *et al.* 2008; Harris *et al.* 2002; Luby 2003) [5, 6, 10]. As a result of this movement, hybrids could have occurred to the east with species native to China (e.g., *M. baccata*, *M. mandshurica*, and *M. prunifolia*) and to the west with European species (e.g., *M. orientalis* and *M. sylvestris*) (Hancock *et al.* 2008; Juniper *et al.* 1999; Luby 2003) [5, 8, 10].

2. Description

The apple is a deciduous tree, generally standing 2 to 4.5 m (6 to 15 ft) tall in cultivation and up to 9 m (30 ft) in the wild. When cultivated, the size, shape and branch density are determined by rootstock selection and trimming method. The leaves are alternately arranged dark green-colored simple ovals with serrated margins and slightly downy undersides [1]. Blossoms are produced in spring simultaneously with the budding of the leaves and are produced on spurs and some long shoots. The 3 to 4 cm (1 to 1+1/2 in) flowers are white with a pink tinge that gradually fades, five petaled, with an inflorescence consisting of a cyme with 4–6 flowers. The central flower of the inflorescence is called the "king bloom"; it opens first and can develop a larger fruit [1, 2].

The fruit matures in late summer or autumn, and cultivars exist in a wide range of sizes. Commercial growers aim to produce an apple that is 7 to 8.5 cm (2+3/4 to 3+1/4 in) in diameter, due to market preference. Some consumers, especially those in Japan, prefer a larger apple, while apples below 5.5 cm (2+1/4 in) are generally used for making juice and have little fresh market value. The skin of ripe apples is generally red, yellow, green, pink, or russeted, though many bi- or tri-colored cultivars may be found [3]. The skin may also be wholly or partly russeted i.e. rough and brown. The skin is covered in a protective layer of epicuticular wax [4]. The exocarp (flesh) is generally pale yellowish-white [7] though pink or yellow exocarps also occur.

3. Taxonomy

The genus *Malus* belongs to the rose family (Rosaceae) which includes over 100 genera and 3000 species distributed worldwide, most commonly in temperate regions (Velasco *et al.* 2010) [15]. Species of agronomic importance include: almond, apple, apricot, cherry, peach, pear, plum, quince, raspberry, sour cherry, sweet cherry, and strawberry (Shulaev *et al.* 2008; Webster 2005a; Westwood 1993) [14, 16]. Other non-edible species with ornamental value include: rose, hawthorn, potentilla, cotoneaster, and pyracantha (Shulaev *et al.* 2008) [14].



Fig 3: Blooms of Apple (*Malus domestica*)

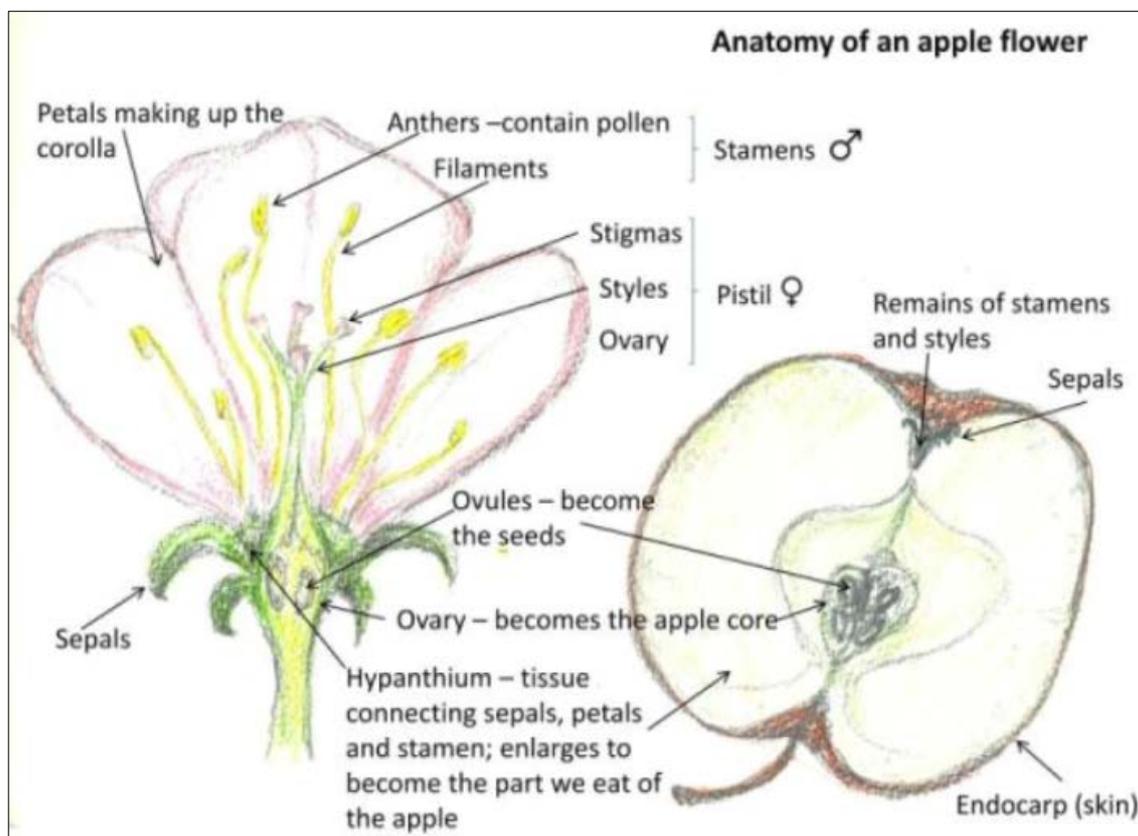


Fig 4: Anatomy of Apple Flower

The Rosaceae family has traditionally been divided into four subfamilies on the basis of fruit type. These include: Rosoideae (e.g., *Rosa*, *Fragaria*, *Potentilla*, *Rubus*, fruit an achene, $x = 7, 8$ or 9); Prunoideae (e.g., *Prunus*, fruit a drupe, $x = 8$); Spiraeoideae (e.g., *Spirea*, fruit a follicle or capsule, $x = 9$), and; Maloideae (e.g., *Malus*, *Pyrus* and *Cotoneaster*, fruit a pome, $x = 17$) (Luby 2003; Shulaev *et al.* 2008) ^[10, 14]. More recent phylogenetic analyses have resulted in the reclassification of Rosaceae into three subfamilies, namely Dryadoideae ($x = 9$); Rosoideae ($x = 7$) and Spiraeoideae ($x = 8, 9, 15$ or 17), with each of the latter two further divided into supertribes, tribes and subtribes. With less emphasis on fruit type, taxa formerly included in Prunoideae and Maloideae (including apples and pears) were reclassified into Spiraeoideae (Potter *et al.* 2007; Shulaev *et al.* 2008) ^[14].

The cultivated apple, *M. domestica* (also sometimes designated *M. x domestica* Borkh. to indicate its hybrid origin), is thought to be the result of initial domestication followed by inter-specific hybridization (Hancock *et al.* 2008; Luby 2003; Mabberley *et al.* 2001; Qian *et al.* 2010) ^[5, 10]. It is not a naturally evolved species; rather it has been collected, transported, hybridized and selected by people over millennia (Ferree and Carlson 1987). Its primary wild ancestor is thought to be *M. sieversii* (Ledeb.) M. Roem., whose range is centered at the border of western China and the former Soviet Union (Hancock *et al.* 2008; Luby 2003) ^[5, 10].

4. Climate

Temperature is one of the most important factors affecting apple cultivation. Most apple cultivars have a chilling requirement of 1000-1600 hours at temperature below 7°C to break rest. However, some cultivars have low (250 hours) chilling requirement. Therefore, such areas where

temperature in winters fall below 7°C for sufficient duration are suited for apple cultivation. Spring frost damages the blossoms of Delicious apples. Apple can be grown in a wide range of rainfall from evenly spread rains of 25-37 cm per year to heavy seasonal rains up to 125-175 cm during monsoons.

5. Soil

Apples grow best on a well-drained, loam soils having a depth of 45 cm and a pH range of pH 5.5-6.5. The soil should be free from hard substrata and water-logged conditions. Soils with heavy clay or compact subsoil are to be avoided.

6. Cultivars

6.1 Scab resistant varieties

Prima, Priscilla, Sir Prize, Jonafree, Florina, Macfree, Nova Easy Grow, Coop 12, Coop 13 (Redfree), Nova Mac, Liberty, Freedom, Firdous, Shireen.

However, Firdous and Shireen have been released as scab resistant varieties for cultivation in J&K.

6.2 Hybrids

Lal Ambri (Red Delicious x Ambri), Sunehari (Ambri x Golden Delicious), Chaubattia Princess, Chaubattia Anupam (Early Shanburry x Red Delicious), Ambred (Red Delicious x Ambri), Ambrich (Richard x Ambri), Ambroyal (Starking Delicious x Ambri).

In J&K, two hybrids namely Lal Ambri (Red Delicious x Ambri) and Sunehri (Ambri x Golden Delicious) have been released though they are not being used commercially.

6.3 Pollinizing varieties

The most suitable pollinizing cultivars are: Red Gold, Golden Delicious, Tydeman's Early Worcester, McIntosh,

Lord Lambourne, Winter Banana, Granny Smith, Starkspur Golden and Golden Spur.

6.4 Low Chilling varieties

Michal, Schlomit, Anna, Tamma, Vered, Neomi, Tropical Beauty, Parlin's Beauty

6.5 Varieties recommended for J&K; H.P and Uttarakhand

Jammu and Kashmir: Golden Delicious (Late Season), Lal Ambri, Mollies Delicious, Starkrimson, Red June, Irish Peach, Benoni and Tydeman's Early

Himachal Pradesh: Golden Delicious (Late Season), Red Delicious (Mid season), McIntosh

Uttarakhand, Uttar Pradesh: McIntosh, Chaubattia Anupam

7. Propagation and Root Stocks

7.1 Seedling rootstocks

The apple plantations are raised on seedling rootstocks. The seeds of commercial varieties from fruit juice canning units are used by nurserymen for raising rootstocks. Apple seeds need stratification in moist sand at 4^o-7^oC for 60-90 days. The water soaked seeds are placed between 2 and 3 cm thick layers of moist sand in wooden boxes or polythene bags during December. The stratification can be accomplished in

the lower chamber of the refrigerator. The stratification requirement is also met with, in areas having very cool winters, by direct sowing of seeds in nursery beds in November-December. The pre-stratified seeds, as indicated by whitish tip at the micropylar end, are sown during February-March on raised beds. One-year-old seedling stocks are ready for grafting during February-March.

7.2 Clonal rootstocks

At the beginning of the 20th century, the East Malling Station in the UK screened 16 types of apple rootstocks, named from M1 to M16, from *M. pumila* var. *praecox* and *M. pumila* var. *paradisiaca*. In 1917, the East Malling Station initiated the first apple rootstock breeding and application program in the world. After that, many countries started the artificial hybrid breeding of apple rootstocks by using the M series rootstocks, and achieved numerous advancements. For example, in cooperation with Menton, the East Malling Station tried to cross M series rootstocks with Northern Spy and successfully created rootstock series MM101-115, which has resistance to woolly apple aphids. Other countries also crossed M series with their native materials and created rootstocks, such as the MAC series and CG series (USA), O3 (Canada), B series (the former Soviet Union), P series (Poland), JM series (Japan), and GM256 (China). The successful breeding of these rootstocks, especially those new dwarf rootstocks, has caused worldwide changes in the apple cultivation system.

Table 1: Scale of dwarf and close planting of major dwarf rootstocks used in the main apple-producing countries:

Country	Dwarf rootstocks	Ratio of dwarf and close planting
China	M9, M26, SH series, GM256, etc.	12%
USA	M9, B9, M26, Mac, MM106, MM111, G16, etc.	50%-55%
Poland	M9-T337, B9, P series, etc.	>80%
Italy	M9, M26, M4, M2, MM106, etc.	~90%
Russia	B9, B118, B54-146, NO.134, etc.	No data obtained
France	M9, M2, M5, M4, M26, CG30, etc.	~90%
UK	MM106, M9, M26, M27, MM111, M4, M25, etc.	~90%
Netherlands	M9-T337, M1, M2, etc.	>70%
Germany	M9, M4, M5, M7, etc.	~90%
Japan	JM series, M26, MM106, M9, M7, MM111, etc.	>75%

The breeding approaches for apple rootstocks mainly include seedling selection, bud mutation-selection, hybrid breeding, and molecular breeding. The core point is to require a stably expressed and inherited gene to control the target trait, facilitating an efficient, accurate, and quick selection during the early developmental stage. The size controlling clonal rootstocks of apple suitable for Indian conditions are listed below:

Category	Rootstock	Characteristics
Dwarfing	M 9	Short juvenile phase, weak anchorage, suitable for high density planting in flat and irrigated areas only.
Semi-dwarfing	M 4, M 7 and	Suitable for high density planting and well drained soils; resistant to woolly apple aphid but susceptible to collar rot.
Semi-vigorous	MM 111	Tree size is 70% of the standard, drought tolerant and resistant to woolly apple aphid

Clonal rootstocks of apple are propagated through mound layering. The rooted layers of the clone are planted in stool beds during winter at a distance of 30 cm in row and 60 cm apart rows. The 3-4 years old layers give rise to numerous

suckers during spring. The suckers are ringed or notched near the base during the rainy season and covered with soil to encourage rooting. The difficult to root rootstocks like M 9 are treated with 1000-2000 ppm IBA at the notched/ringed portion for quick root initiation. The rooted layers are separated at the onset of dormancy (December) and lined out in nursery beds for further grafting with scion varieties during February-March. The rootstock should be healthy and disease free and should attain the thickness of 0.9-1.25 cm at grafting height.

Time of grafting / budding

Tongue grafting: February-March

T-budding: June – July

Chip budding: August

Precautions for budding/grafting:

1. The scion should be collected from the mother plants of known pedigree.
2. It should be collected from bearing trees only, during dormancy.
3. One year old shoot growth is ideal for scion wood.

4. Scion sticks should have only vegetative buds and not the reproductive buds.
5. The scion should have 3-5 well developed buds with smooth internodes.

7.3 Planting

Before planting an apple orchard, proper decisions should be made on selection of varieties, rootstocks, tree size, spacing, placement of pollinizers and planting layout. In flat and valley areas the planting is done in square or hexagonal system of layout. However, on slopes, contour or terrace planting is preferred.

Time: An early planting of apple in December-January is desirable. However, in areas experiencing late winter snowfall planting can be delayed upto end of February. While planting, graft union should be kept 25 cm above the ground level to avoid collar rot and scion rooting.



Fig 5: Systems of Planting of Apple Rootstocks



Fig 6: Flowering of Apple Orchards

7.4 Spacing

Spacing depends upon climate, soil type, fertility, rootstock used, availability of moisture and vigour of the cultivar. Training system and length of growing season also determine the planting distance. Usually planting distance of 6.5-7.5 m is adequate for standard cultivars.

7.5 High Density Planting

The traditional systems of planting have long juvenile period, are labour intensive and low yielding with poor quality fruits. Whereas high density is easily manageable, has higher yield potential, with better quality fruits and higher returns/unit area. But it cannot be adopted in steep, unfertile, shallow & drought prone places.

There are 4 categories of high density planting which are

1. Low (less than 250 plants/ha)
2. Moderate (250-500 plants/ha)

3. High (500-1250 plants/ha)
4. Ultra high density: M 27 (more than 1250 plants/ha)

With the increase in planting density, the yield may increase, but beyond a threshold density, quality is deteriorated & may not be profitable in terms of economical returns. The trees should have maximum number of fruiting branches & minimum number of structural branches.

Principles of High Density Apple Production

With the advent of spur type cultivars and vigour controlling rootstocks, this system of planting is becoming popular especially in case of apple. High density orchards are precocious, easily manageable, has higher yield potential, with better quality fruits and higher returns/unit area. The high density planting cannot be adopted in very steep, unfertile, shallow and drought prone areas. The planting distance depends upon nature/vigour of the variety and the rootstock used.

8. Pollinizer

Since most of the commercial apple cultivars are self-incompatible, they do not set fruit if planted alone or with certain varieties. Therefore, adequate number of pollinizing cultivar(s) should be planted at the time of planting. The pollinizer variety should not be farther away than 2-tree rows. It is always desirable that more than one pollinizing variety may be selected for planting an orchard with 33% pollinizing trees. It is very convenient to plant one row of pollinizing variety after every two rows of commercial variety.

9. Irrigation

The most critical periods of water requirement are April-August and peak water requirement is after fruit set. Normally the orchards are irrigated immediately after manuring in the month of December-January. During the summer periods, the crop is irrigated at an interval of 7-10 days. After the fruit setting stage the crop is irrigated at weekly intervals.

10. Training and Pruning

The plants are trained to establish strong framework of scaffold limbs capable of supporting heavy yield with quality fruits, regulate annual succession of crops, expose maximum leaf surface to the sun, direct the growth of the trees so that various cultural operations like spraying and harvesting become economical, protect the tree from sun burn and promote early production. The training methods differ for standard and dwarf trees.

11. Training of standard trees

Trees are mostly trained to modified central leader. The central leader is allowed to grow to a height of 2-3 m when its growth is restricted. Modified central leader combines the best qualities of the central leader and open centre systems. A leader develops on young trees until it reaches the height of about 3 m, then its growth is restricted. One year old apple tree should be pruned to 45-60 cm above the ground immediately after being planted.

11.1 The first year dormant pruning

Three primary scaffold branches are selected. These should be spaced about equally around the trunk preferably with a vertical spacing of 10-15 cm between them. The primaries are headed back by about 1/4th to 1/3rd of their length. The

leader is also headed back by about 1/4th to 1/2nd of its length so that it is always higher than the primary scaffold limbs. If three well-spaced primary scaffold limbs are not obtained in the first year, the available limbs may be headed back to 45 cm from the trunk to suppress their development until a third scaffold can be selected at the end of the second growing season.

11.2 Second year dormant pruning

During second dormant pruning 5-7 secondary branches per tree usually 2 on each primary scaffold should be selected in the second dormant season besides 1 or 2 primary scaffold on the central leader. Secondary limbs should be left full length and not headed back until it is necessary to maintain balance with the primaries or other secondary's. The central leader should also be headed back as in the first year to stiffen it and to promote the development of lateral shoots. Shoots competing with central leader should be removed. Upright growing shoots should be removed.

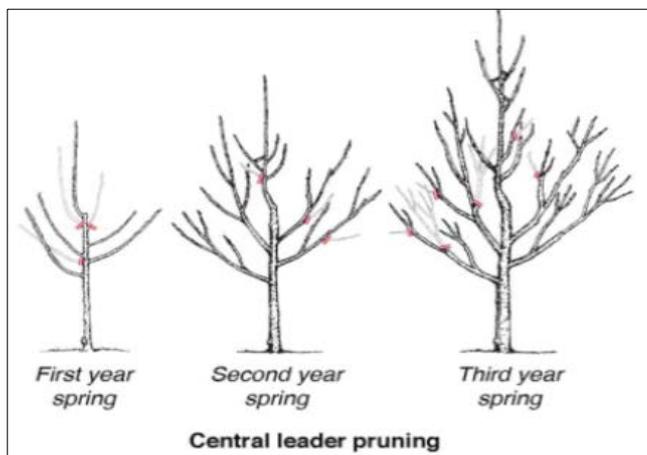


Fig 7: Central Leader Pruning of Apple Trees

11.3 Third year dormant pruning

The selection of primaries on the central leader should be continued and likewise secondary's on the lateral scaffold and tertiaries on the secondary limbs. These should be directed partially outward. Pruning of central and lateral leaders should be done as in the previous years to maintain growth. Further, training consists of thinning out on wanted branches and cutting others to desirable side limbs.

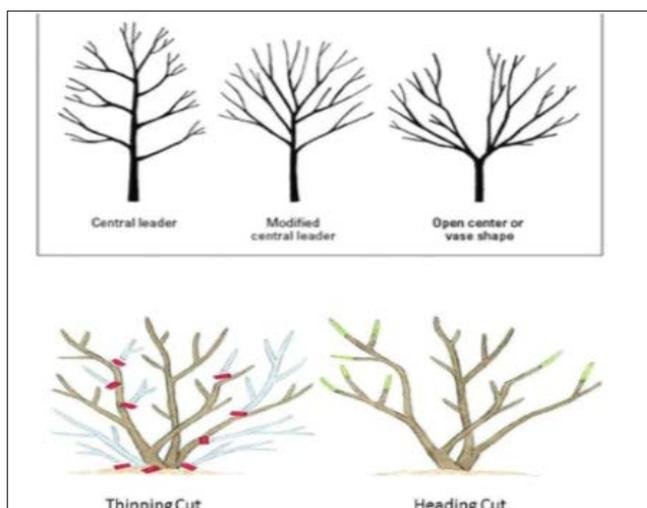


Fig 8: Training and Pruning of Apple Trees

11.4 Fourth dormant pruning

The selection of primary shoots on the central leader should be continued. The central leader should be pruned to a vigorous lateral shoot at 3 m height. The selection of other lateral shoot should be continued as in the previous years. By this time, training has been largely completed. Now pruning should be done in such a manner as to permit the best development of the crop. The tree should be thinned out. The remaining branches are cut to side limbs as is done in the third dormant pruning. A moderate number of small shoots should be left in the centre of the tree for fruit bearing wood. Adequate thinning out of branches and fruiting wood maintains a well distributed bearing branches and reduce excessive spread and breaking of branches. By the fifth summer after planting, most of the apple varieties produce enough fruits.

11.5 Object of Pruning

Partial or complete removal of vegetative growth of fruiting wood from a plant to control its size, remove broken or damaged tissues, alter plant shape, remove unnecessary growth or balance fruiting and vegetative growth is termed as pruning. The basic steps of pruning standard bearing trees are:

1. Start pruning at the top of the trees and work downward.
2. Cut upward growing limbs back to strong laterals.
3. Remove the crowding branches and thin out the remaining leaving the vigorous fruiting wood well-spaced along the length of limbs.
4. Remove dead, broken and diseased wood.
5. Remove parallel growing shoots causing crowding and shading and opposite growing shoots at a point on the stem.
6. Remove all water sprouts except the occasional ones, which may be needed to fill a vacant space in the canopy.

11.6 Precautions in pruning

When the limb larger than 3 cm in diameter is removed, the pruning cut should be made as close as possible to the branch from which the limb arises without leaving a stub. Large pruning wounds should be protected with Bordeaux paste or Chaubattia paste to check the entry of rot causing fungi. In 1 or 2 year old shoots, heading back can be done to promote growth of side shoots and quick wound healing. In 3 years old and older shoots, pruning should be shifted to thinning out cuts to reduce vegetative growth and promote fruiting.

The competing branches should be thinned out rather than headed back.

12. Manure and Fertilizers

The application of fertilizers may be supplemented with farm yard manure @ 10 Kg/year age of the tree with the maximum of 100 Kg. In bearing trees, farm yard manure along with phosphorus (P_2O_5) and potassium (K_2O) should be applied during December-January. Nitrogen (N) is applied during February-March, 2-3 weeks before bud break. The N can be given in two split doses, first 2-3 weeks before bud break and second one month after flowering, where the irrigation facilities are available. The fertilizer should be broadcasted in the tree basins 30 cm away from tree trunk to the canopy drip line and mixed well in the soil.

13. Harvesting and post-harvest management

Apple fruits continue their metabolic processes even after harvesting. The maturity of fruits do not coincide with ripening. The fruits usually do not attain fully ripe edible quality on the tree while harvesting. The fruits should be harvested at proper picking maturity to proper edible quality at ripening. There are several maturity indices which can be followed in proper fruit harvesting. The TSS (Total Soluble Solids) of fruit pulp, ease in separation of fruit from spur, change in ground surface colour from green to pale, change in seed colour to light brown, fruit firmness and days from full bloom to harvest are some reliable maturity indices for apple which can be considered singly or in combination.

13.1 Pre-cooling

After picking, the fruit should be placed in cool and ventilated place to remove field heat before packing. Before grading and packing, fruit should be properly washed and dried.

13.2 Grading

On the basis of appearance and quality apple is graded *viz.*, AAA, AA and A; A, B, and C; or extra fancy, fancy class I and fancy class II.

13.3 Packaging

Apples are packed in wooden boxes. Each box usually carry about 10 Kg or 20 Kg fruits. The fruits are packed by lining the inside of box with newspaper, sheets and keeping margins for the overhanging flaps. The wrapped fruits are initially padded with wood wool/pine needles at the bottom of box and later in between well-arranged intervening layers. The top layer of fruits is covered with paper by bringing together the overhanging flaps followed by nailing. The box is further reinforced eternally by clamping with a tight 14-16 gauge steel wire for distant markets. Besides wooden boxes, corrugated fibre board (CFB) cartons offer a variable substitute. The usual dimensions of CFB cartons with trays are 50.4 cm x 30.3 cm x 28.2 cm (outer jacket) and 50.0 x 30.0 x 28.2 cm (inner case).

13.4 Storage

Shelf life of apple can be prolonged by providing optimal storage conditions. The recommended storage temperature for apple is -1.1°C to 0°C which is about $0.8 - 1.8^{\circ}\text{C}$ above the average freezing point of most apple varieties. The relative humidity of 85-90% should be maintained in the cold storage. Most apple varieties can be stored for 4-8 months after harvesting. Ambri has the longest storage life.

14 Insect-Pests and Disease

A. Insects of Apple

1. Sanjose scale

It is a polyphagous pest; small, grey or brownish grey specks with a central nipple, twigs and fruits often surrounded by reddish or pinkish rings. Severely infested tree bark is covered with grey layers of overlapping scales, appearing as if sprayed with ash. Sanjose scale can be controlled by spray with chlorpyrifos (0.02%), dimethoate (0.03%) or phosphamidon (0.03%) to kill crawlers and newly settled scale insects in May.

2. Woolly apple aphid

Small, brown and greyish purple sucking aphid which attacks bark and roots forming a white waxy material, resembling little tufts of wool. Active from April-December but found in large numbers on aerial parts after rains (late

August-October). Aphids suck sap from branches, twigs and roots. However, in bearing trees, in addition to dormant sprays for sanjose scale, application of methyl demeton 25 EC (0.025%), dimethoate 30 EC (0.03%), malathion 50 EC (0.05%) between petal fall and June. Serious infestation near the harvest can be controlled by using dichlorvos 76 EC (0.05%). Use resistant rootstock of MM series and M 25.

3. Stem borer

Beetles damage the stem, and branches by drilling holes. Saw dust along with pallets can be seen hanging out from these holes. Clean the holes with flexible wire and then insert 0.5 g paradichlorobenzene (PDCB) and plug the holes with mud or insert cotton wick soaked in petrol or dichlorvos (0.15%). All badly infested trees or dying wood should be cut and burnt before leaf drop.

4. European red mite

Damage apple foliage by feeding on green matter and sap, causing loss of chlorophyll, bronzing followed by leaf drop and weakening of buds. Feeding results in poor fruit size and quality of fruits get deteriorated. Excessive feeding results in fruit drop during the season, reduced blossom and fruit set in the subsequent years. Spray dicofol (0.05%) or wettable sulphur (0.25%) at pink bud stage and later when the mite population exceeds 15-20/leaf.

B. Diseases

1. Apple scab

The disease affects both leaves and fruits. Symptoms usually appear first on the under surface of leaves of fruit spurs, the side exposed when the fruit buds open in the spring. Once the entire leaf has unfolded, both the sides may be infected. Following protective spray schedule may be followed:

1. At silver tip to green tip stage spray Mancozeb (0.3%) or Dodine (0.1%) or Captan (0.3%).
2. At pink bud stage, spray Fenarimol (0.04%) or Bitertanol (0.05%) or Mancozeb (0.3%) + sulphur (0.2%).
3. At petal fall stage, spray Carbendazim or Thiophanate methyl (0.05%).

2. Powdery Mildew

Small, greyish or white powdery patches appear on young leaves. The infected leaves crinkle and curl up. The greyish white powdery coating covers the entire leaf. Infected foliage becomes hard and brittle. Spraying the trees at green tip, petal fall, 20 and 40 days after fruitlet stage with Dinocap (50g/100 L water) or Carbendazim (50g/100 L water) or Tridemorph (50g/100 L water).

3. Sooty blotch and flyspeck

Both the diseases appear as sooty blemishes on the external surface of fruits especially under high humidity during rainy season. To control this disease give one spray 40 days before harvest and other spray 15-20 days before harvest with captafol (200 g/ 100 L water) or Carbendazim (50g/100 L water) or Mancozeb (200 g/ 100 L water)

4. Collar rot

The disease appears mostly near the graft union or on the lower trunk or at pruning wounds. The bark of the diseased tree at soil level becomes cankered, soft and spongy. For the control of collar rot, clean the infected collar area with sharp knife and apply Bordeaux paste or Chaubatia paste. Raise the bud/graft union height to 40-70 cm from soil level. Pre-

plant dipping of seedlings in fungicides like Difoltan ((200 g/ 100 L water) or Copper oxychloride (300 g/ 100 L water).

5. White root rot

Affected trees show bronzing and yellowing leaves, sparse foliage and retarded growth. Roots turn brown and remain covered with white cottony mycelia mat of the fungus in rainy season. For curing the ailing trees, give at least 3 drenching of Carbendazim 50% WDP (0.1%) at an interval of 15-20 days during monsoon.

15. Harvesting

Normally the apples are ready for harvest from September-October except in the Nilgiris where the season is from April to July. The fruits mature within 130-150 days after the full bloom stage depending upon the variety grown. The colour of the skin at maturity ranges from yellow-red depending on the variety. However, the optimum time of harvest depends on fruit quality and intended period of storage.

16. Yield

The apple tree starts bearing from 4 year onwards. Depending on variety and season, a well-managed apple orchard yields on an average 10-20 kg/tree/year

17. Conclusion

More than 700 apple accessions introduced from USA, Russia, U.K., Canada, Germany, Israel, Netherlands, Australia, Switzerland, Italy and Denmark have been tried and tested during the last 50 years in India. The delicious group of cultivars predominate the apple market with the areas under Delicious cultivars are 83% of the area under apple in H.P., 45% in J&K and 30% in U.P. hills. Recently it has been found that improved spur types and standard color mutants with 20-50% elevated yield output are favored in Indian conditions. The important selections are: Spur types - Red spur, Starkrimson, Golden spur, Red Chief and Oregon spur Color mutants - Vance Delicious, Top Red, Skyline Supreme Low chilling cultivars - Michal, Schlomit Early cultivars - Benoni, Irish Peach, Early Shanburry, Fanny Juice making cultivars - Lord Lambourne, Granny Smith, Allington Pippin Scab resistant cultivars - Co-Op-12, Florina, Firdous, Shirean New Hybrids - Lal Ambri (Red Delicious X Ambri), Sunehari (Ambri X Golden Delicious), Amred (Red Delicious X Ambri), Chaubatia Anupam & Chaubatia Princess (Early Shanberry X Red Delicious) developed in India. In addition to above varieties, the varieties like Black Bendavis, Royal gala, Jonathan, Red Gold, Gani Gala, Rich-A-Red, Royal delicious, Red delicious, Golden delicious, Cooper- IV, McIntosh, Crofton, Granny smith, Starkrimson, Fokla, Ruspippin, Rajakori, Ganu and Mutsu are favorable for the climate of Arunachal Pradesh.

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Availability of data and material

All relevant data and material are presented in the main paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Not applicable.

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