SCIENTIFIC APPLE CULTIVATION

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1. Introduction

Apple (*Malus domestica* Borkh), a king of temperate fruits belongs to family Rosaceae. Among the total fruit production, apple alone covering 4.2% of the total area and 2.4% of total fruit production. Though there has been manifold increase in area, production and productivity, but the productivity has increased only 85-90% over 1960-61 to 2013-14 in India. Apple cultivation is mainly confined to Jammu and Kashmir, Himachal Pradesh, and Uttarakhand and partly in Arunachal Pradesh, Sikkim and Nagaland. The average productivity of Jammu and Kashmir is 10.2 t/ha, followed by Himachal Pradesh 6.9 t/ha and Uttarakhand 2.6 t/ha (2013-14) (NHB; 2014). The Jammu and Kashmir has 170.6 thousand hectare area of apple and 1775.0 thousand metric tonnes which constitutes 66.0% of the total area and 71 % of total apple fruit production. The china is the world highest producer contributing 2060 thousand hectares of area and 37000 Metric tonnes of production (FAO 2015).The world highest productivity is 53.84 in Austria which is too high as compared to India (8.0 t/ha). Further, there is great potential to reach the productivity up to 30-40 t/ha with the use of improved varieties and scientific production and protection technologies suited to the region.

2. Soil and Climate

Apple can be grown in wide range of soil but deep fertile loamy soil (2-2.5 m deep) is suitable for its cultivation. The presence of lime in the soil is good for apple cultivation. Proper drainage arrangements should be made in heavy flat soil for safe drainage of excess water from the field and pH range 5.8 to 6.2 is an ideal for apple cultivation.

Apple can be grown normally in areas where chilling hours varied from 800-1600 hours (Actual number of hours during which temperature remains at or below 7°C). Spring frost during blossoming cause severe damage to fruit set, reduces total fruit yields. Frequent rains during blooming may inhibit bee activity; prevent release of pollen grains and also causing washing of pollen grains. In general, the sites located on north-eastern aspect at lower elevations are suitable for apple cultivations. The areas near to Snow Mountains and having slope to north remains much cooler; so, in such areas lower elevations are suitable for its cultivations. For optimum growth and fruitfulness, apple trees need 100-125 cm of annual rainfall and equally distributed over the growing season. The optimum temperature for pollen germination and fruit setting ranges between 21.1 to 26.7°C and temperature below 4.04 °C at bloom inhibits bee activity and ultimately affect the fruit set. At higher temperature (24.4°C) anthocyanin production is inhibited, however low temperature (8.0 °C) night and (15.80°C) day enhances colour development.

3. Improved Cultivars

There are more than 10,000 apple varieties grown throughout the world both in the northern and southern Hemisphere but four apple groups i.e. Fuji, Golden Delicious, Red Delicious and Gala dominates the world apple scenario. Over 700 accessions of apple, 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. The delicious group of cultivars predominates the apple market. The areas covered under Delicious cultivars are: 83% of the area under apple in H.P., 45% in J&K and 30% in U.P. hills. In more recent times improved spur types and standard color mutants with 20-50% higher yield potential are favoured. The important selections are:

- Spur types – Red spur, Starkrimson, Golden spur, Red Chief and Oregon spur.
- Color mutants – Vance Delicious, Top Red, and 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 – Florina,Liberty,Freedom,Prima,Priscilla, Firdous, Shireen

New Hybrids – Lal Ambri (Red Delicious x Ambri), Sunehari (Ambri x Golden Delicious); Akbar (Ambri X Cox's Orange Pippin) Shireen (Lord Lambourne X Melba X R 12740-7A), Firdous (Golden Delicious x Prima x Rome beauty), Shalimar apple-1 (sunehari x Prima), Amred (Red Delicious x Ambri), Chaubatia Anupam & Chaubatia Princess (Early Shanburry x Red Delicious), Chaubatia Anurag (Esopus spitzen-berg x Red Delicious), Chaubattia Agrim (Early shanburry induced mutation), Chaubattia swarnima (Benoni x Red delicious), Chaubattia Alankar (Fanny x Red delicious) developed in India.

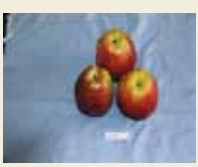
The Salient feature of important apple cultivars

Variety	Photograph	Silent Features
1. Early maturing cultivars		
Vista Bella		It is early maturing (90-95 Days After Full Bloom) variety which hit the market first, solid flesh, color, weakly defined stripes, obloid fruit shape, high yielding, fruit weight (145-160 g), fruit length and diameter (55-60 and 75-80 mm) respectively and TSS (15-17 oB). The drawback of this cultivar is high fruit drop, highly susceptible to powdery mildew, scab and poor shelf life.

Mollies Delicious		It is precocious, regular bearer, early maturing (100-110 DAFB) cultivar and mature after Vista Bella, large fruit size. Fruit shape is cylindrical waisted, moderate fruit ribbing, strong fruit crowning at calyx end, fruit weight (200-210g), fruit length (65-70 mm) and fruit diameter (80-85 mm) and total soluble solids (10-12 oB).
June Eating		It is medium size, early maturing precocious bearer, obloid in shape, strong crowning at calyx end, solid flush, aperture of locules in transverse section is closed or slightly open , fruit weight (52-55 g), fruit length (38-40 mm) and diameter (45-50 mm) and total soluble solids (13-14 oB).
Prima		Very crisp and tart. An excellent eating apple. A scab resistant variety. The dry matter content ranged between 12 - 14% and total soluble solids (10-12 oB). fruit weight (129-151g), fruit length (53-60 mm) and diameter (67-72 mm) respectively
Benoni		Benoni is a fine dessert apple, very attractive in appearance and excellent in quality, fruit medium to small, roundish inclined to conic, faintly ribbed toward the apex; sides unequal, cavity acute, rather narrow, moderately deep, wavy, greenish-russet. Skin smooth, yellowish orange partly covered with lively deep carmine stripping, dots scattering, minute, whitish, ,fruit is fine grained juicy and crisp fruit weight (48-50g), fruit length (39-43 mm) and diameter (50-53 mm) respectively.
Fani		Fruit weight (146-160g), fruit length (54-63mm) and diameter (70-74 mm) respectively sweet, total soluble solids (12-13 oB)

(ii) Mid maturing cultivars		
Red Chief		It is a bud sport of Delicious, mid season maturing, broad width of stripes, cylindrical waisted in shape, moderate ribbing, strong crowning at calyx end, red purple group, medium depth of stalk cavity, large width of stalk cavity, aperture of locules on transverse section is fully open, fruit weight (213.0-220.0 g), fruit length, diameter (75-80 and 80-85 mm) respectively and TSS (11-12 oB). High demand in market due to attractive shape, color and appearance.
Starking Delicious		It is also known as Royal Delicious, a regular bearer mid season maturing, bud sport, fruits are large, conical in shape, strong fruit ribbing and strong crowning at calyx end, strongly broad defined strips, medium depth of stalk cavity, large width of stalk cavity, creamish flesh, fruit weight (205-210 g), fruit length and diameter (72-75 and 78-80 mm) respectively and total soluble solids (15-16 oB).
Starkrimson		It is bud sport of Red Delicious tree compact in size, mid maturing, precocious, regular and heavy bearer, fruit shape is cylindrical waisted, strong crowning at calyx end, red purple group, medium depth of stalk cavity, large width of stalk cavity, fruit weight (230-240g), fruit length and diameter (72-75 and 80-82 mm) respectively and total soluble solids (13-14 oB).
Hardiman		It matures early, regular bearer, cylindrical waisted fruit in shape, red purple color, flushed striped and mottled, aperture of locules on transverse section is fully open, fruit weight (260-270g), fruit length and diameter (75-78 and 78-82 mm) respectively with total soluble solids (15-16 oB). The fruits are high in demand by consumers due to attractive shape and color.

Oregon spur		It is a bud support of Delicious with large number of spur bearing branches, conic fruit shape, strong crowning at calyx end, red purple group, dark intensity of over colour, solid flesh, medium depth of stalk cavity and large width of stalk cavity aperture of locules is fully open, fruit weight (200-230g), fruit length and diameter (65-70 mm and 75-80 mm) and total soluble solids (13-15 oB). The fruits are ready to harvest after 115-120 days after full bloom.
Pink Lady		Pink lady has a pink blush over a greenish yellow base skin. Known as the Queen of apples, it is a crisp apple with a dense, firm flesh and an excellent, almost effervescent flavour. It has a high sugar content making it perfect for cooking.
Cooper -IV		It is mid maturing and regular bearing cultivar, fruit shape is cylindrical waisted ,strong ribbing, strong crowning at calyx end, purple red color, fruit weight (250-280g), fruit length and diameter (75-80 and 80-85 mm) respectively. Total soluble solids (13-15 oB) and fruit mature 15 days ahead of Red Delicious.
Vance Delicious		It is bud mutant of a Delicious, regular bearing, matures in mid season, fruit general shape is conical, weakly defined flush, strongly defined strips, purple red colour, strong crowning at calyx end, medium depth of stalk cavity, large width of stalk cavity, fruit weight (180-210g), fruit length and diameter (65-70 and 75-80 mm) respectively. The total soluble solids (11-13 oB) and fruit mature 15 days ahead of Starking Delicious.
Mc Spur		It is a regular bearer, matures in mid season, conic fruit shape, moderate ribbing, red purple group, solid flush color pattern, dark intensity of over colour, medium depth of stalk cavity, large width of stalk cavity, aperture of locules on transverse section is fully open, , fruit weight (140-160 g), fruit length and diameter (55-60 and 70-75 mm) respectively .

Gala Mast		It is precocious, regular bearing mid maturing, high yielding, conic shape, moderate fruit ribbing, red purple colour, flushed and mottled , aperture of locules on transverse section is closed or slightly open, fruit weight (180-195g), fruit length and diameter (60-65 and 75-80 mm) respectively and total soluble solids (12-13 oB), high in demand due to attractive color and quality.
Red Spur		It is bud sport of Red Delicious from complete tree variation, fruits resembles to Rich-a-Red. Fruits attractive dark red colored, fruit weight (190-250 g), sweet, total soluble solids (18-19 oB) and ready to harvest 165 days after full bloom.
Super Chief		This strain starts out as a stripe and fills in to a solid red ten days ahead of harvest. Tree is a super-spur and stays compact even on semi-dwarf roots. It is a consistent, annual bearer even when not thinned aggressively. Fruit weight (150-160 g), sweet, total soluble solids (14-15 oB)
Scarlet Spur		Scarlet Spur has dark mahogany color, crisp white flesh, and excellent fruit production. Fruit weight (150-160 g), sweet, total soluble solids (13-14 oB)
Red velox		Mutant of Red Delicious, tree is of moderate vigour, fruit is of medium size, dark red in colour, with light stripes, colour development is full and 100%, shape typically of red delicious. Particular characteristics of the variety, is the early and homogenous colour on the whole tree. Fruit weight (92-109g), fruit length (50-54 mm) and diameter (60-65 mm) respectively, fruit is sweet and total soluble solids (13-15 oB).
Akbar		Developed from Ambri x Cox'x Orange Pippin. Fruit large in size, red coloured, matures in about 157 days after full bloom fruit weight (198-272g). Average fruit yield 245 kg tree-1 of 16-20 years of age. Fruit length (68-79 mm) and diameter (79-85 mm) respectively sweet, total soluble solids (12-16 oB).

Jonica		Fruit colour is bright red on a bright yellow-green background, substantially without stripes or bands. It is a variety of an apple with large fruit striped red over bright yellow. Firm, crackling, juicy, slightly tart, flesh. Superb, rich, full flavor. Finest dessert and eating quality having good cooking properties. Fruit weight (150-170g), fruit length (64-74 mm) and diameter (77-85 mm) respectively and, total soluble solids (16-17 oB).
Braeburn Gala		Fruit weight (165-216g), fruit length (61-66 mm) and diameter (70-76 mm) respectively, total soluble solids (12-13 oB).
Green Sleeves		Trees are semi dwarf and flower profusely. Fruits are green yellow, crisp, juicy, slightly acidic with attractive flavor. Green sleeves are a good pollinizer for cox, Worcester, fruit weight (170-232g), fruit length (62-67 mm) and diameter (81-87 mm) respectively sweet, total soluble solids (14-15 oB).
Shireen		Shireen a cross between Lord Lambourna x R-12740- 7A. The average fruit yield 50-60 kg tree-1. Fruit small to medium in size, sweet, juicy having good flavour and resistance to scab fruit weight (179-2118g), fruit length (61-71 mm) and diameter (75-78 mm) respectively sweet, total soluble solids (13-14 oB).
III) Late Maturing cultivars		
Coe Red Fuji		It is precocious regular bearer, late maturing, high yielding cultivar, globose fruit shape, moderate fruit ribbing, weak crowning at calyx end, solid flesh, aperture of locules on transverse section is moderately open, fruit length and diameter (70-75 and 80-85 mm) respectively.
Silver Spur		It is spur type, precocious regular bearer, late maturing, high yielding cultivar, fruit weight (150-170g), fruit length (60-64 mm) and diameter (70-75 mm) respectively.

Granny Smith		Popular light green apple noted for its late (November) ripening. Superior keeper, sprightly flavour. Good for cooking and eating. Originated in Australia as a chance seedling, 1868. One of a handful of antique apples still holding its own in the commercial market. Make a wonderful, tart apple. A late, green, tart apple maturing in early November. High quality eating apple with better storage life. Fruit weight (210-220 g), sweet, total soluble solids (11-13 oB).
Red Delicious		It is self unfruitful, moderate alternate bearing, late maturing, fruit is conical with strong protuberances near the calyx, skin colour is yellow, red colour, firm flesh, strongly defined stripes, good keeping quality, fruit weight (210-230g), fruit length and diameter (80-85 and 85-90 mm) respectively and TSS (14 0B).
Top Red		This variety is the bud support of Delicious, it matures late, fruit general shape is conic, moderate crowning at calyx end, red purple colour, solid flesh strongly defined stripes, medium depth of stalk cavity, fruit weight (170-180 g), fruit length and diameter (65-70 and 75-80 mm) respectively and total soluble solids (16-18 oB). Fruits are ready to harvest 165-170 days after full bloom.
Skyline Supreme		This variety is bud mutant of Starking Delicious, fruit shape is cylindrical waisted, red purple colour, strong crowning at calyx end, fleshed and mottled, medium depth of stalk cavity, large width of stalk cavity, fruit weight (195-230g), fruit length and diameter (75-80 and 85-90 mm) respectively.
Lal Ambri		This was evolved by SKUAST–K Shalimar by crossing of Ambri X Red Delicious. Fruits are attractive in apprearance, conical shape with blushed colored and good self life. Fruit weight (180-230g) with 15-16 oB of total soluble solids. Due to good shelf life, color and taste, this variety has high in demand.

Red Fuji		This is very productive and annual bearer and late maturing variety, fruit general shape globose, fruit weight (191.91 g), fruit length and diameter (60-65 and 75-80 mm) respectively.
Spartan		It is regular and heavy bearer, medium to late maturing and can be used as pollinizer. Fruit general shape is round, moderate, crowning at calyx end, red purple colour, solid flush, shallow eye basin with fruit weight (150-190 g) fruit length and diameter (65-70 mm and 80-85 mm) respectively.
Ambri		It is only indigenous cultivars of India due to high fragrance and long shelf life, it has high in demand. Fruits typical conical shape with variable shape, size, and color. CITH has collected number of variants of Ambri from Shopian, Anantnag and Pulwama Districts of J&K. The most of the clones are excellent in size, color and quality. Fruit weight (142-155 g) fruit length and diameter (64-67 mm and 69-70 mm) respectively.
Firdous		Fruit medium in size, sweet with slight acidic blend, crisp, juicy having resistance to scab and moderate resistance to Alternaria and San jose scale. Developed from Golden Delicious x Rome Beauty x Prima.Fruit weight (111-172g).Yield 50-60 kg tree-1 (12-15 mt/ha). fruit length (53-66 mm) and diameter (65-72 mm) respectively. sweet, total soluble solids (11-12 oB.
Low Chilling Varieties		
Michal		It very low chilling, early maturing variety. Fruits are medium in size slightly conical in shape, with smooth calyx end, stripped red coloured skin our green yellow ground, fruit weight (106-142g), fruit length and diameter (54-59 and 65-72 mm) respectively and total soluble solids (10-11 oB).

Maayan		Very low chilling, early maturing variety, with fruits medium in size. Fruits are globose to slightly conical in shape with smooth calyx end, stripped red coloured over green yellow ground, fruit weight (115-150g), fruit length and diameter (53-56 and 66-70 mm) respectively and total soluble solids (10-11 oB).
Anna		Low chilling, early maturing, trees are medium in vigour; fruits are oblong to conical with smooth calyx end, yellowish with red blush. fruit weight (116-195g), fruit length (58-80 mm) and diameter (68-76 mm) respectively , total soluble solids (11-12 oB)
Pollinizer cultivars		
Tydeman's Early Worcester		Early season maturing (second week of July),Trees are medium vigorous, fruits are roundish to slightly conical towards the base with smooth calyx end, bright dark red skin over yellow ground, most suitable pollinizer for low chilling cultivars, fruit weight (141-171g), fruit length and diameter (60-72 and 68-75 mm) respectively and total soluble solids (10-14 oB).
Red Gold		It is a regular and heavy bearer, matures in mid season and used as polliniser, fruit globose, slightly oblong, moderate crowning at calyx end, flushed and mottled, fruit depth of stalk cavity is medium, fruit width of stalk cavity is large, flesh colour is yellowish, aperture of locules on transverse section is fully open,, fruit weight (145-155g), fruit length and diameter (55-60 and 65-70 mm) respectively. Fruits are juicy, crispy and attractive in appearance.
Golden Delicious		It matures in mid season and used as pollinizer, fruit of Golden Delicious is round, oblong, greenish yellow with red blush on high reaches, flesh creamy, fine textured, crispy, juicy, pleasant flavour, fruit weight (225-240g), fruit length and diameter (70-75 and 80-85mm) respectively.

M. baccata		It is a species of apple, commonly known as crab used mainly for fresh fruit, pollination and raising of root stocks. The scions raised on this root stock are completely compatible in nature. It is native of eastern siberi, Russian far east, china, Korea, Bhutan, India, Nepal at 1500m elevation. Trees grow 10-14m height, due to abundant flower used for pollination purposes. The subordinate taxa include *M.baccata* var. *baccata*, daochengensis, gracilis, himalaica, mandschurica, xiaojinensis, fruits are red to yellow about 1 cm in diameter. They form dense clusters.

4. Planting

Best time of apple planting is spring season and before start of new growth. Winter planting is best for establishment due to winter rains. Pits should be deep enough to accommodate root system in its natural position. Generally in area having hard pan, pits dimension should be 1 × 1 × 1 meter. Pits should be dug in September - October when there is good sunlight and keep 15-30 days to destroy insect, pest and diseases. The 30 cm upper soil layer to mix with 10-15 kg FYM and 10 g/pit P2 O5 with 50g aldrin 15 % to avoid attack of root borers. Planting should be done in the centre of pit and soil be pressed gently so that roots are set properly and irrigation must be applied immediately in newly planted sapling.

Traditionally apple was being planted at 6-8 meter distance. With the advancement in propagation techniques, improved root stocks, training and pruning systems, the number of plant population has increased many fold ranging from 278 trees to 20,000 trees/ha in apple. Experiment on medium, medium high and high density planting system at CITH, Srinagar on clonal root stock have given promising results. In 2.5x2.5m spacing on MM106 root stock, cultivar Oregon Spur, Starkrimson, Mollies Delicious and Cooper IV resulted in highest yield (24.12, 34.05, 14.50 and 13.7 tons per ha), respectively and on 2.5x3.5m spacing on MM 106 rootstock, cultivar Starkrimson (46.69t/ha), Cooper IV (33.43t/ha) and Starking Delicious (67.73 t/ha) respectively.

5. Pollination management

Poor yield in apple is attributed to faulty pollination management with inadequate pollinizer and pollinating insects. They have to be suitably augmented in desired propotion to increase fruit set and yield. Bloom synchronization among the main varieties and pollinizers is essential with fruits of the pollinizers should preferably have commercial value as dessert, processing or ornamental. The pollinizers should be self fruitful diploid or reciprocally cross compatible, have

high bloom density, extended flowering period and should not be susceptible to any diseases or insects.

On the basis of blooming period different pollinizers as indicated below have been identified which can be used for effective pollination.

a. Early Bloomer: McIntosh, Black Ben Davis, Tydeman's Early Worcester, Manchurian, Everest, Malus floribunda.
b. Mid Bloomer: Winter Banana, King of Pippin, Rus Pippin, Lord Lamdourne, Yellow Newton, Summer Queen, Snow Drift, Gloster, Red Gold, Red Flesh, Chestnut, Gala, Spartan, Commercial, Dolgo, Cox's Organ Pippin, Yellow Transparent, York Imperial, Jonathan, Spurtype Winter Banana, Lodi.
c. Late Bloomer: Golden Delicious, Golden Spur, Rome Beauty, Granny Smith, Worcester Pearmain, Golden Hornet, Starkspur Golden.
d. Crab apples as pollinizers: Crab apples are regular in flowering with high bloom index. Most crab apples bear flowers on spurs as well as on one year shoots and have a long flowering duration due to blooming first on spurs followed by flowering on shoots. Trees can be easily trained on pillar shape and tree volume can be regulated by pruning of current year shoots. Crab apples can also be planted as filler tree without interfering main variety spacing. In India Manchurian crab, Snowdrift, Golden Hornet and Japanese crab have been recommended as pollinizers. Bloosom colour of crab apples is important as honey bees or bumble bees if become habitual for foraging on pure pink, red or purple blossoms shows a foraging tendency only on trees with such coloured flowers thereby avoid white blooms on main varieties. White or white with slight pinkish ting blooming crabs are preferred as good pollinizers, as bloom colour of main apple cultivars is in this range.

Besides pollinizers, placement of honey bee hives in orchards as pollinators not only increases pollination, fruit set and fruit yield but also provides additional income through honey. For orchards with <15% pollinizers, 8 hives; orchards with >30% pollinizers, 2-3 hives and for high density orchards, because of more plant density per unit and higher bloom density of spur type cultivars 5-8 hives are recommended.

6. Propagation

Apple do not produce true to type plant if raised by seed hence, vegetative propogation technique has been found only option. Vegetative propagation employs budding and grafting on clonal as well as seedling root stock. In India, seedling rootstocks are commonly being used, however, with the introduction of clonal root stock, farmers are establishing the new orchard in High Density Planting system on clonal rootstocks. The apple cultivar Golden Delicious, Granny Smith, Yellow Newton and Mc Intosh is diploid and can be used for raising the

rootstock. Stratification of seeds can be done through refrigerator or at 3-5 0C for 2-3 months in sand helps in good germination or stratification can be done directly sowing in field in November-December which does not require any input.

T-budding is most successful technique in apple propogation. This is performed in July-August in Kashmir and June-July in Uttarakhand and Himachal Pradesh for better success. Chip budding is another promising technique of apple propagation. It is performed in dormant season (Oct-March). Wedge or clift grafting is very popular technique of apple propagation in india during dormancy (Jan-March).

Apple is mainly multiplied on Crab seedling/clonal root stocks. The clonal rootstocks are uniform in size and trees on these rootstocks are precocious in bearing with intensive planting. The clonal root stocks recommended in India are M-27 (ultra dwarf), M-9 (dwarf), M-7 and MM-106 (semi dwarf), MM-104, MM-109, and MM-111 are semi-vigorous in nature. EMLA series of root stocks are virus resistant and MM series root stocks are wooly aphis resistant. Pusa Seb Moolvrinth-1 is a dwarf type which has been developed from Malus baccata var. Shillong.

Salient feature of apple clonal root stocks

Name of the root stock	Salient feature
	Very Dwarf
M-27	This is most dwarfing rootstock. The leaves are large, leathery and puckered. Trees are approximately 1.2m to 1.5m in height and started cropping after second year after planting. Plants on this rootstock can be planted as closer as 0.5m between plants and 1.5m spacing between rows.
	Dwarf
M-9	It is a dwarfing rootstock, ideal for raising high density plantation in apple. The trees on this root stock are precocious and tolerant to a wide range of soil and climatic conditions. it produces a tree size approximately 25% -30% of the full size with most of the cultivars. The rootstock has poor anchorage and shallow root systems, hence requires assured irrigation and mechanical support to hold the tree. The wood of M.9 is brittle and will break suddenly under stress. Trees on M.9 stock need to be supported throughout their lifetime.M.9 will not perform well under poor drainage, but it is tolerant to collar rot and does well on heavier soils where drainage is adequate.M.9 readily forms burr knots and is prone to suckering, susceptible to woolly aphid and fire blight.

Bud-9	A dwarfing rootstock similar to M-9 in size but winter hardy and resistant to collar rot. Due to poor anchorage the tree requires support. Starts bearing 2-3 years after planting material tree has 1.8 – 2.5m height.
V.3 (Vineland 3)	This rootstock is similar to slightly vigourous than M.9 EMLA but similar to the M.9 clones M.9 T337 and M.9 Fleuren 56.Trees on V.3 are as productive as the M.9 clones, but are more yield efficient. This rootstock is moderately resistant to fireblight.
MAC-9 (Mark)	Dwarf rootstock produces plants larger to those on M-9, but precocious high yield efficiency and good anchorage. Easier to propagate on stool beds than M-9. Resistant to collar rot but susceptible to fire blight and woolly aphid apple. A conspicuous tumor like swelling surrounds the Mark rootstock at the soil line. The cause is unknown.
Pajam 1, (Lancep)	French apple rootstock, dwarfing and easy to propagate in comparison to M-9
Pajam 2 (Cepiland)	Similar or slightly more vigorous than M.9-EMLA, easier to propagate
G.11	Cornell University, M.26 × Robusta 5 cross .Similar in vigor to M.26 Similar or better yield efficiency than M.26, suckers, resistant to collar rot and to fire blight.
G.16	A 1981 cross of 'Ottawa 3' X Malus floribunda), G.16 is a fully dwarfing rootstock with tree growth and vigor similar to vigorous clones of M.9 (i.e. Nic28 or Pajam2. Precocity and cumulative yield efficiency have been similar or slightly better than M.9. It is essentially immune to fire blight with no tree death from this disease, and field trials. It has excellent performance in the stool bed and produces a large tree in the nursery. Tree growth in the first 2 years in the orchard is vigorous but with the onset of cropping tree vigor is moderated similar to M.9. G.16 appears to have wide soil adaptability and some tolerance to replant disease.
G.41	A 1975 cross of (Malling 27 X 'Robusta 5). G.41 is a fully dwarfing stock with vigor similar to M.9. It is highly resistant to fire blight and Phytophthora with no tree death from this disease in field trials. Its precocity and productivity have been exceptional surpassing M.9. It also has excellent fruit size and induces wide crotch angles. It produces a smaller tree similar to M.9. It also does not have the virus sensitivity of G.16. At the moment it appears that G.41 will be a possible replacement for M.9.

G.65	This rootstock is from the Cornell university breeding program, New York state. It is a very dwarfing rootstock producing a tree smaller than M.9. It is precocious and productive. It is resistant to collar rot, almost immune to fireblight, but moderately susceptible to woolly aphid. It produces few suckers and burr-knots.
G.935	A 1976 cross of (Ottawa 3 X Robusta 5). G.935 is a semidwarfing stock that produces a tree slightly larger than M.26. CG.935 is the most precocious and productive semi dwarf CG rootstock. It has had similar efficiency to M.9 along with excellent fruit size and wide crotch angles. It is highly resistant to fire blight and Phytophthora but its resistance to woolly apple aphid is unknown. It has good propagability in the stool bed and produces a large tree in the nursery. It appears that G.935 will be a possible replacement for M.26 when released.
	Semi Dwarf
M -26	Ideal for high density plantings, the scions on this root stock are dwarf between M-9 and EMLA-7. The tree free stands on strong soil, susceptible to wooly aphid and fireblight, but showing good resistance to collar rot.
Jork 9 (J 9)	Developed in Germany, selected from open-pollinated M 9 seedlings. It is slightly more dwarfing than M-26 and hardier than M-9, moderately susceptible to scab and Powdery mildew .It is easily propagated in stool beds.
M-7	The most widely planted tree standing semi-dwarf rootstock exhibit an open spreading type growth. The trees are well anchored, hardy and fruit attain well size in dry season. The drawback is that when rootstock not planted deep produce rootstocks. Susceptible to crown gall and crown rot. Moderately resistant to scab.
Bemali	Hybrid rootstock developed in Sweden. It is dwarfing as M 26 and has advantage of easy propagation; it is precocious and has good anchorage. Freedom from woolly aphis and has having good productivity.
KC-1	It is semi-dwarf, productive than Malling root stocks, resistant to drought.

G.202	A 1975 cross of 'Malling 27' X 'Robusta 5'). G.202 produces a tree similar in size to M.26. In addition to fire blight resistance, like other CG stocks, it also has good resistance to woolly apple aphid which is an important rootstock pest in many countries. It performs very well in the stool bed and produces good quality nursery trees it has been found to be much more productive than M.26 and is one of the best stocks available. It appears that G.202 will be a useful alternative to M.9 and M.26 in regions that have problems with Woolly Apple Aphid. Presently it is only available in New Zealand.
Merton 793	It is semi-dwarf and tolerant to high temperature and high soil moisture comparatively resistant to SARD.
	Semi Vigorous
MM 104	The trees on this rootstock are vigorous and have a well developed root system. The rootstocks can be easily recognized by its zigzag stems and lenticels at the base of the shoots. Fully developed and mature leaves are up cupped.
MM-106	It is semi dwarfing root stock, roots easily in nursery. The root stock is free from wooly aphid and susceptible to collar rot. It bears crop early and heavily.
MM-111	A vigorous semi dwarf, produce trees larger than EMLA 106. Trees are well anchored, resistant to collar rot and wooly aphid. A good selection for heavy and poorly drained soils.
	Vigorous
Novole	Vigours, cold hardy and tolerant to latent viruses.
Alnarp 2 (A 2)	Originated in Sweden, well anchored and has a good tree form winter hardy and vigorous rootstock. It induces precocity and productivity.
Robusta No. 5	Developed at Ottawa Canada, as a selection of malus robusta, Winter hardy and vigorous. The trees on this rootstock are similar to those on M.2.
Northern spy	It is resistant to wooly aphid and is traditional rootstocks of many countries. It is used in breeding programs. This rootstock has been used in many rootstock breeding programmes to provide the resistant woolly aphid resistance on rootstocks.
Novole	It is a Geneva selection from a set of open-pollinated seedling of Malus prunifolia from Japan. Vigorous cold hardy easily propagated by cuttings and resistant to crown rot fireblight and latent viruses.

7. Techniques of raising clonal root stocks

Clonal root stocks are multiplied by layering as well as by cutting. But layering has been found to be most successful method of clonal root stock Clonal stock multiplication through layering Clonal multiplication through cutting multiplication. The rooted clonal root stocks are collected from registered nursery as per variety and leveled properly. The well pulverized field should be used for establishing the mother stock. In winter, the clonal rootstocks are planted at 60 x 90cm spacing in the nursery beds and allowed to grow for one season. At the end of next dormancy, the mother stocks are headed back leaving 5 cm collar. In the growing season it will experience profuse shooting which is required to be mounded with soil covering leaving one third of the shoot with only tips open. Frequent irrigation is required for proper rooting. Extra soil is mounded on the layers. In January-February, rooted shoots are separated leaving stub of mother stock inside for sprouting and producing next crop, approximately 15-25 plants can be obtained from one stool.

8. Orchard nutritional management

Apple is a heavy feeder and trees requires substantial amount of manure and fertilizers. They should be provided timely and in appropriate quantity at right growing stages. It is recommended to apply well rotten farm yard ,manure in each tree at the rate of 20-25 kg/tree during December. Fertilizers doses should be applied on the basis of soil test and leaf tissue analysis. However, in general the following recommendations may be adopted depending upon the age of the tree.

At initial stage, 10kg FYM, 20g nitrogen, 5g phosphorus and 25g potassium/ tree should be applied. The doses may increase upto 15 years of age and the total quality of fertilizers required 600gN, 130g P and 750 g K + 50-60kg FYM/tree. The urea may be applied in 2-3 split doses, 1st half dose should be applied along with DAP (full) and MOP (full) at fortnight before expected bloom, 2nd dose (1/4th) of urea may be applied about 3 weeks after fruit set and third dose of Urea (1/4th) should be applied in May-June. Foliar spray of Urea 0.5-1.0 percent may also be applied for promoting fruiting bud formation and subsequent growth in the next season.

Incorporation of organic manures in the soil and biofertilizers is very important in orchard nutrition. Combination of organic manures, biofertilizers and fertilizers ensures balanced orchard nutrition package for better plant performance. There are many organic manures, however farm yard manure, vermicompost and some other commercial organic products manufactured by industries are commonly used. Organic manures improves the soil texture, increases beneficial microorganism strength in the root zone and facilitate availability of nutrient elements. Vermicompost NADEP, biodynamic compost, neem based manures and microbe mediated compost are some new organic preparations which can

be applied in combination with FYM. Similarly biofertilizers fix atmospheric nitrogen by symbiotic or non symbiotic association and facilitates availability of nutrients by transforming them from non-soluble to soluble state. Bio-fertilizers like Rhizobium, Azotobacter, Phosphorus Solubilising Bacteria and Fungi and Vesicular Arbuscular-Mycorrhiza can be applied directly into the soil except Rhizobium or may be fixed with dried FYM, compost or vermicompost in the ratio of 1:25. Seed treatment with 500g culture and root dip of seedlings in slurry of biofertilizers for 15-20 min. is also followed.

9. Orchard floor management

Orchard floor management is another important component, which involves orchard hygiene, soil aeration, soil moisture conservation, weed growth restriction, soil drainage, and ultimately facilitating better interaction among soil micro organisms, nutrient pool and organic matter. Clean cultivation involves regular weeding. However barren soil surface are very much prone to excessive moisture loss and lack of humus. Under sloppy terrain soil erosion and loss of soil fertility is also a problem. Therefore for adoption of total clean cultivation system, soil should be regularly hoed to break capillary action to prevent soil moisture loss from subsurface layer. To maintain humus and activity of soil microorganisms in the soil, addition of organic matters to the soil is necessary. Sod culture, Intercropping and cover crop are better.

10. Orchard irrigation management

Water is a life sustaining and renewable resource, getting depleted in terms of quantity as well as quality. Adequate, timely and assured availability of water is critical to plants, for obtaining assured yields. Although, India has the largest irrigation system in the world but its water use efficiency is not more than 40 percent. If it continues, water crisis would lead to reduced production and productivity, and also affect the quality of life of the people.

Due to the prevailing topography water in the temperate region is a main limiting factor. It provides irrigation only to 15-20% of the fruit area and as a result productivity of apple is very low (7.5 t/ha). Therefore, more efforts are needed to cover additional area with the existing resources to enhance the productivity through increasing water productivity using water harvesting and micro irrigation (drip/sprinkler) techniques and mulching etc. to save 40-70% of water and increase yields by 10-100%. If pre-monsoon showers fail then orchard face acute water shortage. However, success of fruit culture depends mainly on uniform distribution of rain during the year or where supplemental irrigation during the critical periods is available. The most critical periods of water requirement are April to July, and peak water requirement is after fruit set. In areas where irrigation is not a limiting factor, 114 cm water during whole year through 19 irrigations has been recommended for apple (Awasthi and Chauhan, 1996)).

It includes one irrigation during December-January after application of manure and fertilizers, one before flowering in April, followed by irrigation at 7-10-day interval during critical summer and later on at 3-4 weeks interval till the onset of dormancy. Drip irrigation has been found to be adventitious for efficient water use by 2.6-2.9 times than conventional systems. Under sloppy lands minimum energy is required and for uniform water distribution pressure compensating emitters are required. During the season 3,840 litres/tree through conventional system and 1,695 litres/tree through drip system is required for apple. On an average 90 litres/tree per irrigation by drip is required. Fertigation with water soluble fertilizers like ammonium nitrate, calcium nitrate, urea, potassium chloride, potassium nitrate, and potassium sulfate has become important as it saves lot of nutrients. Urea and ammonium nitrate are highly soluble and clogging is very less. Fertilizers which raise water pH (>7.5) are not desirable as such water reduces micronutrient availability. The work carried out in apple indicated that fertigation through drip irrigation recorded higher fruit set (45%) and fruit yield and the cost of NPK also got substantially reduced to one third. The irrigation at 80% ET increased maximum fruit set (62-74%) in apple at Shimla and maximum fruit weight (186.3g) at Srinagar at 100%ET. Use of black polythene/dry grass mulch for moisture conservation in apple also found effective for increasing water productivity and gave maximum fruit set (62.5%) and fruit yield (63.4 kg/tree) besides saving moisture from 40-70%. In Kashmir, productivity of apple under high density increased many fold with micro irrigation and fertigation wherein, 111.0 kg N and 221.5 kg of K20 was saved by employing fertigation as compared to conventional system.

Today, there is a growing awareness for use of drip irrigation for increasing quality apple production. But to achieve wider adoption of this technology, research on the minimal and optimal fraction of the soil to be wetted under varying weather and soil conditions, critical stages of application of nutrients etc. needs to be worked out.

Water management plays an important role in productivity enhancement of apple. The water must be applied at critical stages of fruit growth and development of apple. Micro-irrigation system is an irrigation system with high frequency application of water in and around the root zone of plant system. It consists of a network of pipes along with a suitable emitting device. It can be installed at surface of the tree row called surface micro-irrigation. The sub surface installations are generally preferred in semi-permanent or permanent installation especially in fruit crops. The laterals are laid 45-60cm below the soil surface to avoid any damage during the inter cultural operations. The micro-irrigation saves water up to 50-70% and productivity enhances 40-100% with high quality fruits. The other advantages are saving of labor cost, reduce salt concentration in root zone, reduce incidence of pest and diseases, saves 40-60% fertilizers and increase fertilizer use efficiency. The most commonly applied fertilizer is nitrogen although potassium and chelated forms of micro nutrients are also applied. Drip

irrigation is most suitable irrigation system for temperate orchards for enhancing water and fertilizer use efficiency.

Rain water harvesting and moisture conservation techniques

Rain water harvesting system play an important role in apple production under rainfed conditions. There is number of rain water harvesting techniques and mulching for conservation of moisture for plain as well as sloppy land conditions. The encouraging findings were obtained at CITH, Srinagar in apple at 4×4 m spacing.

i) Sloppy land condition

Half moon water harvesting system:

Half moon water harvesting system is one of the important water conservation technique for rain fed undulating topographical conditions. In this system, semi circular bunds are created at downstream side of the plant. The shape and design of the structure is semi circular bunds having 30 cm width and 30 cm high at a radius of 1.7 m away from the tree trunk and 5% outward slope for rain water collection and storage from micro catchment area of tree. This is a low cost and economically viable technology for conservation of soil moisture during summer period for fruit growth and development.

Trench water harvesting system:

Trench water harvesting system is one of the important water conservation technique for sloppy land rain fed topographical conditions. In this system, trench is created upstream side one meter away from the tree trunk. The shape and design of the structure is 30 cm width and 30 cm deep and 1.5 m length of trench created for collection and storage of rain water from the catchment area. This is a low cost and economically viable technology for farmers of hilly area.

ii) Plain land condition

Full moon water harvesting system:

Full moon water harvesting system is one of the important *insitu* moisture conservation technique for rainfed plain land topographical conditions. In this system, circular bunds are created around the periphery of the plant. The shape and design of the structure is circular bunds having 30 cm width

and 30 cm high at the radius of 1.7 m away from the tree trunk and 5% inward slope for rain water collection and storage from micro catchment area of tree. There should be earthingup around the tree trunk in the radius of 30-40 cm to avoid water stagnation around tree trunk. This is a low cost and economically viable technology for conservation of soil moisture during summer period for fruit growth and development and suitable for resource poor farmers having plain lands.

Cup and saucer water harvesting system :

Cup and saucer water harvesting system is one of the important moisture conservation technique for plain land rain fed topographical conditions. In this system, trench is created 1.7 m away from the periphery of the tree having 30 cm width and 30 cm deep for collection and storage of rain water from the catchment area. This is a low cost technology and suitable for farmers having plain lands.

The above water harvesting system alonjgwith mulching (organic/ plastic) conserve more moisture during critical stages of fruit growth and development.

11. Canopy management

Canopy management determines the yield and quality of apple fruit which is a resultant of ease of execution of efficient orchard management practices, better light interception and distribution at tree as well as orchard scale. In general, 70% light is intercepted by tree canopy and rest 30% strikes orchard floor. Observations revealed that more than 30% full radiation is beneficial for spur development and flower initiation, whereas 50-70% radiation exposure is good for fruit size and colour. Overall, an orchard with less than 30% light interception is low in productivity in comparison to an orchard with 50-70% light interception. Traditionally modified and open centre training systems are practiced. High density plantation systems involves skill and therefore specialized training system has to be adopted by the orchardist to maximize the available land use efficiency as well as potential of any recommended cultivars for close planting. Such approaches not only enhances the tree efficiency and precocity but also easily manageable with very good fruit quality. Spindle bush has been

found suitable in Himachal Pradesh for apple (Chadha and Awasthi, 2005). Modified leader form in Kashmir has been found to be better for high density planting with spacing 3x2 or 3x3 m which is subjected to lateral branch bending by strings and leader growth restriction to 2-2.5m considering the prevailing winter climatic condition. Similarly, modified leader form with specialized limb bending techniques has been found suitable for high density apple plantation in Uttarakhand with spacing of 2.5 x 2.5 under terrace plantation considering the climatic conditions.

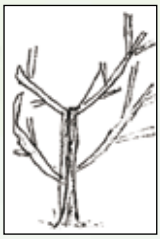
Canopy management leads to development of designer trees which are easily accessible, well exposed to sunlight and capable to produce high quality crops at an early age. In apple various type of training systems are in practices which are as follows:

Central leader training system

Central leader training system is the system to train main central branch with series of well spaced lateral branches and it grow tall with strong crotch angle. This system of training is suitable in areas having high snowfall with apprehension of breaking or tearing of branches.

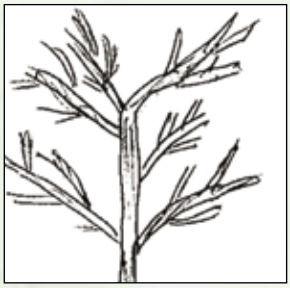
The main disadvantages are that with increase in age shading occurs and tree does not receive adequate light.

Open centre leader



This system is more suitable in area where limitation of adequate solar radiation, the central leader is headback after one metre above ground level and the scaffold limbs are allow to develop 0.40-0.50m above the ground level. The centre remains open; sufficient fruiting takes place in the inner canopy horizon. The disadvantages are that tree framework is weak, the crotches are also weak, so, there is apprehension of limb breakage in case of heavy snow fall.

Modified central leader

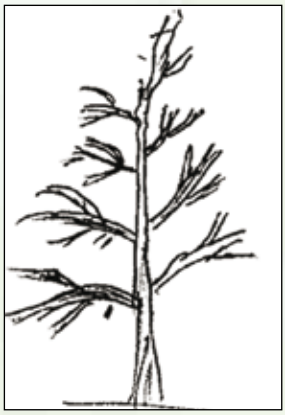


This system combines the advantages of both open centre and central leader system. In this case, the central leader is cut back slightly and not allowed to become dominant. The laterals are then selected to form the main scaffold limbs. As soon as the appropriate numbers of laterals develops, the central leader is cut to a side lateral and the dominance of the central leader is discontinued. This system allows well spread branch with strong crotch angle leads to

enhance availability of light inner side of the tree. The fruit size and quality is good due to adequate air and sunlight availability in this training system.

The plant architectural engineering offers good scope for high quality apple production through intensive orcharding and use of modern scientific concept of plant architectural engineering. The experimental findings at CITH reflect that the apple productivity can be increased up to 30-40 tones per hectare by the scientific interventions and modern concept of plant architecture engineering. With the advent of dwarfing rootstock, efforts have been made to standardize the efficient training system which are as follows:

Spindle bush

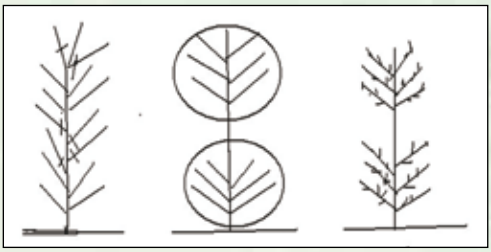


It is the modified form of Central Leader system, the tree allow to develop small, conical and only 2.0m height with 1.5m diameter. Horizontal scaffolds are promoted at 0.4 m above the ground level with little pruning for giving proper crotch angle and the horizontal bending of laterals. These spindles bush system start early fruiting. The total 15-20 number of scaffold branches are taken all around the tree at 15-20 cm interval. The lower branches are trained at 45-600 angle and should keep larger than the upper branches finally tree looks like conical in shape. This training system performed well at Central Institute of Temperature Horticulture, Srinagar.

Dwarf pyramid

This system of training is commercially adopted in the England. It is low-headed compact, central leader tree mostly suitable on dwarfing and semi-dwarf rootstock. The lowest branch arise from 0.30-0.40m from the ground level and successive branches radiating at intervals of 15-20 cm along the main leader, gradually diminishing in length from bottom to top forming a pyramidal shape. It allows 20-30 primary branches distributed well in all directions. The height of the tree is just 2m with 1.5 m canopy spread. Trees trained in this system starts early flowering and fruiting and is suitable for establishment of orchard in high density planting system.

Head and spread

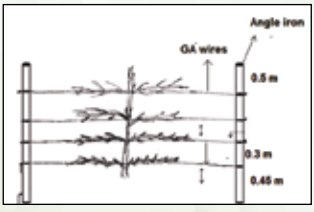


This training system is also known as two tier training system and has been proved very effective in Indian condition. In this training system, the first tiers (4-5 scaffolds)

are allowed to develop at 45-60cm above the ground level. The second tier system (5-6 scaffolds) develops after 60 cm of first tier system. The fruiting takes place in the inner periphery of canopy due to good exposure to the sunlight to develop excellent fruit colour. Experimental findings revealed that Starkrimson and Mollies Delicious cultivars on head and spread plant architecture system on M-9 root stocks resulted better yield after 8-9 years of planting. The fruit is also graded 80-90 percent of 'A' grade at CITH, Srinagar, J&K.

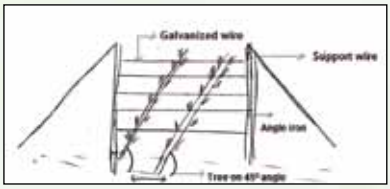
Espalier plant architecture

This training system initiated at Central Institute of Temperate Horticulture, Srinagar and has proved best on dwarfing and semi dwarf rootstock even on non-spur variety. It is also called multitier training system. In this system, the trellis is fixed at 1.5 m high with 4 -5 wire system. Trees are planted at 1.5× 3.0 meters apart in rows and plant to plant. This system of training accommodate nearly 2222 plants / ha. One year old grafted plant with strong central leader is used for planting. After planting , the heading back of plant at 45-60 cm above the ground level and allow to develop 10 scaffold branches (5 on each side)can be selected. As the lateral branches extend, these are fastened along the wire. Only winter pruning is done to shape the structure, which consists thinning out of unnecessary laterals and weak spurs. The winter pruning is very crucial to give the shape of the tree. The side laterals are cut back leaving 10-15 buds. This system performed better in respect to fruit yield and quality at CITH, Srinagar.



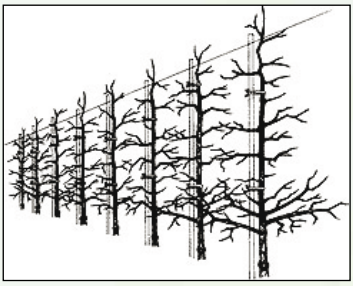
Cordon plant architecture

This training system is mainly used in gardens for cataloguing of varieties. Strong 2– 3 year old trees are used for plantings. The trees are planted at an angle of 45 degree. This system requires support for the plants; for which 5 wire trellises are erected at 1.5m height iron angle posts. The top wire is few inch below the top of the post. The first trellis is stretched at 45cm from ground level and others were fixed at 30cm interval. In cordon system, the trees are planted at 45o angle which results in movement of auxin to the basal portions of the tree thus lateral buds become productive.




Vertical axis or single axis plant architecture

This is modification of central leader training system. In this system trees are trained and maintained in a narrow leader to maximize light interception in side the canopy. The central leader is allowed to grow up to 10-12 feet height. Trees are supported by bamboo stick or iron poles are used to held the plant straight. This system is suitable on dwarfing root stock planted at 0.75x1.5m spacing. The first scaffold branches are allowed to grow at 0.45- 0.50m height from ground level by heading back the main trunk. The fruiting is promoted mainly on main trunk as well as primary branches of the tree. The fruiting starts 2-3 years after planting on standard and spur type varieties and resulted in 5-8 kg fruits per tree in Granny Smith and Coe-Red Fuji varieties. To support the plants, two wire trellis fixed on 15 feet iron angles at a distance of 8m. The first wire erected at 4 feet and subsequent wire on 8 feet height. The individual trees are fastened along with the two wires system.



Pruning Techniques

Pruning is judicious removal of plant parts with objective to develop balance between vegetative and reproductive growth. In young plant, pruning in initial stage is done to develop strong frame work so that it bear optimum fruit load. Severe pruning of bearing plant results in excessive vegetative growth and develop imbalance between vegetative growth and representative growth. Pruning helps in light interception and ease in reaching of the spray solution on individual leaf uniformly.

12. High density orcharding

High density orcharding is a horticultural skill to accommodate maximum number of plants per unit area. In today's context high density planting has become of prime importance due to increasing population and nutritional consciousness which has resulted in high demand of quality fruits. The increasing demand for fruit has offered scope of orchard engineering. High density planting can be developed through the use of dwarfing and semi-dwarfing root-stock; dwarf scion varieties, growth retardants and specialized horticultural techniques. The high density planting system accommodate more number of plants/ha (1x1m=10000plants;1x2m=5000plants;2x2m=2500 plants; 3x3m=1111plants; 4x4m=625plants; 5x5m=400 and 6x6m=277plants) depending upon the rootstock and varieties.

High density plating in apple

13. Intercropping

During pre bearing stage of apple orchard, intercropping with several suitable vegetable crops are recommended for realizing some farm income through

Apple + Peas

Apple + Methi

sustainable utilization of interspaces and available resources. The following crops are recommended as intercrop in apple orchard. Intercropping with legumes increase nitrogen use efficiency of apple crop and thus increases the yield of apple directly. Since intercrop gets ready during the season when apple crop is not ready thus provides the source of income during offseason period. Also crops like lentil, methi, red clover etc does not compete for water and nutrients with apple because their critical stages for irrigation and nutrient use are different than for apple. Intercrop increases cropping intensity and benefit: cost ratio.

14. Organic farming

The commodities grown through use of synthetic materials are not attracting the world market, because of health and other environmental problems. Consequently the demand for organically produced products is increasing which emphasis the use of biological materials in combination with agronomic methods for sustainable production by avoiding the use of synthetic materials. This is regarded as the best solution to restore our natural resources and to safe guard our environment and biodiversity. Major components of organic farming include maintenance and enhancement of soil fertility through biological means, addition of organic manure, use of soil micro organisms and utilization of biomass and crop residues, management of pests and diseases through use of botanicals, biological control agents, cultivation of inter crops, use of crops rotations, use of Vesicular Arbuscular Mycorrhyza (VAM) and Trichoderma etc. and other methods of biological control of pests and diseases.

Since the global trade in organic farming has crossed 30 billion US$ and India could be a bigger beneficiary of this boom. Through APEDA and other accredited agencies products worth several crore rupees were exported which included walnuts, mango, banana pulp etc. But there is a tremendous potential to include apple which can fetch premium price of 100 to 200 percent more than conventionally produced. The rainfed natural farming and use very low chemicals inputs in raising apples in India provide great scope and can be considered under organic farming regime for earning higher income and export promotion. In certain high altitude areas of J & K, H.P. and Uttarakhand apples are grown with minimum application of synthetic chemicals. This advantage of natural farming need to be propagated and popularized in the region for taking advantages of international markets for which Identification of potential varieties of apple for organic farming, guidelines for organic product/processing as per IFOAM and NPOP and development of package of practices involving various components needs to be worked for promoting organic culture. Taking advantage of topography and natural farming, Uttarakhand has taken a lead and promoting organic farming in a large way by introducing various schemes and subsidies. The other hill states too having greater advantage can exploit the opportunity on scientific line to take advantage of export market.

15. Plant Health Management

Pests and diseases in apple are causing heavy losses to an extent of about 30-40 % besides impairing their quality and therefore there effective management is most essential component for increasing production and productivity of quality apples. Most of the varieties in the country have been introduced from developed nations over the past few decades. These varieties have been mainly attacked by some of the important insects like sanjose scale, aphids, woolly aphid, peach leaf curling aphids, stem and root borer, shot hole borer, tent cater pillar, codling moth and European red mite and diseases like scab, powdery mildew, leaf spot, brown rot, gummosis, canker etc. Their, management through integrated approach has become priority for producing residue free fruits and their value added products. Involving cultural, biological, and chemical control measures.

Disease management approaches

Cultural and preventive approach: Proper disinfection of rootstocks and scions before planting, quarantine, sanitation and planting of only certified planting material; destruction of infected plant parts and pruned wood and rouging of infected seedlings; soil treatment and solarization; collection and destruction of fallen leaves; regular pruning and covering the cut ends with protective paints; no damage to twigs and spurs and proper support to fruit loaded limbs and removal of alternate hosts is essential to reduce inoculum development and further spread.

Chemical/biological measures: Integrated spray schedule with recommended fungicides and pesticides which can vary depending upon area and availability of pesticides should be followed when any particular disease appears and posses economic loss. Dodine should be sprayed separately. Other pesticides, chemicals, nutrients or growth regulators should not mixed with the recommended fungicides. For control of scab, premature leaf fall and powdery mildew diseases integrated spray schedule with dodine, carbendazim, hexaconazole, mancozeb, captan and copper oxychloride are suggested depending upon the situation. Canker caused by *Bopyosphaeria spp.* could be successfully controlled through the use of Chaubattia paste (Red Lead: Copper carbonate: Linseed oil, 1:1:1.25) on pruned portions in November-December followed by spray with 0.1% bayleton or 0.1% carbendazim during growing season. To avoid degenerative disorders like apple mosaic, the disease free budwood or grafts be procurred only from government nurseries or registered nurseries. Biological agents *Athelia sp.* and *Chaetomium globosum* supplement with urea treatment on pseudothecial density significantly reduced scab pathogen.

Important pest and disease management approaches

Pest /disease	Symptoms	Control measure
San jose scale  *(Quadraspidiotus perniciosus)*	Both nymph and adult suck the sap from all the parts of tree and fruits. Infested tree show a general decrease In vigour, growth, and productivity .the affected fruits present pink coloured areas around the scales	Selected healthy plant form nursery and treat with chlorpyriphos 0.05% before planting. Spray the dormant miscible spray oil (2% of HP spray oil E , Servo oil, IPOL , Levon-30 or Wonder TSO)Applicationof chlorpyriphos(0.04%) during May.
Wooly apple aphid *(Eriosoma lanigerum)* 	It lives in colonies on both the root and aerial parts of the plants and damage caused by sucking dap from twigs, branches and roots which results in formation of galls or knots around sucking site.	Soil should be thoroughly treated with carbofuran @ 4-5g/m^2 or phorate @ 2-3g/ m^2. Before planting, the plants selected from nursery treated with chloropyriphos (0.05%). The roots and aerial parts sprayed with methyl demeton (0.05%) during December - January. Use of tolerant rootstocks like M-21, M-25 and MM series and M baccata var. Himaliaca
Tent caterpillar *(Malacosoma indicum Walker)*	The caterpillars spin tent like silken nests at forking of twigs for hiding in during day. During night, they feed on foliage and under sever infestation the entire plant may be defoliated	Place an open vessel containing kenosiniged water below the tree so that caterpillars which have fallen may also be killed readily under severe infestation, profenofos (0.05%) or quinalphos (0.05%) should be sprayed which may be repeated after 15 days, if required.
Apple root-borer *(Dorysthenes hugeli Redt.)*	The grub either bore or girdles the roots and feed on internal tissues which are severed from the bore. As a result of feeding, roots are severed from the base. The tree if young, die away while older ones become weak and fall down due to strong wind.	The tree basin should be sprayed with 0.05% chlorpyriphos in July for controlling the grubs. Dig out the basin of infested tree during December – January for collection and mechanical destruction of grub.

Defoliating and fruit eating beetles *(Anomala spp; Holotrichia spp.)*	The beetles defoliate trees from June-Aug; which come out of the soil at dusk and feed on leaves during night and then, get back into the soil in morning for hiding.	Shaking of trees after dusk or during night to collect and destroy beetles, during ploughing, of orchard so as to expose the white grubs to adverse conditions. When infestation is high, spraying of Chlorpyriphos (0.03%) or Quinalphos (0.05%)
Apple scab 	This disease is prevalent in every pocket of the apple growing area especially on Delicious group of cultivars. Velvety –brown to olive – green , turning to mousy–grey lesions occur on leaves and fruits.	Follow recommended spray schedule of 7-8 sprays of non-systemic and systemic fungicides in the growing season like Mancozeb/ Dodine/ Hexacanozole/ Captan/ Botertanol/ Flusilazole/Penconazole/ Triadimefon /Carbendazim etc with a single pre leaf fall application of 55 urea. Such a spray programme is commonly employed in Jammu and Kashmir, Uttrakhand and Himachal Pradesh. **After infection** Newly available EBI (Esterol Biosynthesis Inhibitors) fungicides (Bitertanol, Fusilazole, Penoconozole, Fernarimol, Myclobutanil, Hexaconazole) can be applied within 96 hours of the start of the infection and can be used in case of availability of prediction system. **Pre- symptom spray strategy** Due to paucity of resources or non favourable weather, spray of a fungicide (Carbendazim, Thiophanate Methyl, Dodine, Guazatine or EBI fungicide) can be carried out late of the incubation period , but 2-3 days prior to symptom expression . **Post symptom (eradication)** Carbendazim and Thiophanate Methyl are the best eradicant fungicides and need to be

Root rot *(Dematophora necatrix)* 	The disease is favored by high soil moisture and temperature of 20-25 oC and is most common in heavy soils. The disease usually appears in apple nurseries just after onset of rains. The infected plants show wilting symptoms and get dried.	Spray of 20 ppm aureofungin (17 g/100 litres of water) on the tree and on the root system during dormancy, improvement of soil aeration and drainage, Carbendazim 50 WP (0.1%) has been advocated for drenching ailing trees.
Powdery mildew *(Podosphaera leucetricha* ELL. And Er. Salm.) 	This occurs commonly in nursery plants. It causes stunting of vegetative terminals with narrowing of leaves. In bearing trees of cultivars Jonathan, Versifield, Benoni, Winter Delicious and Golden Delicious, reduction in tree vigour and flower-bud formation occurs. Blossoms abort and fruit russeting occurs particularly in Jonathan.	Removal of infected terminals in less susceptible cultivars like Delicious, and reduce the level of primary inoculums for the next season 3-4 sprays of fungicides like Carbendazim 0.05% , thiophanate–methyl (0.05%), dinocap (0.05-0.10%), wettable sulphur (0.30-0.50%), triademefon (0.05%), bitertanol (0.025-0.10%) and fenarimol (0.040%) from the pink bud stage (7-14 days interval) can keep disease under check.
Cankers 	The initial symptoms of the disease are visible as water soaked spots at cuts or in damaged portion of branches or twigs. The bark of infected branches becomes papery and it is sloughed out. Infected branches and twigs get dried.	Avoid mechanical injuries to trees and protect pruning – wounds with a choubattia paste. Cankers should be scarified and treated with a fungicidal paste, Chaubattia paint, Santor 'A' or copper oxychloride paint.
Apple mosaic virus 	AMV is one of the oldest known and most wide spread apple viruses. The tree infected with apple mosaic virus develop pale to bright cream spot on the leaves. Golden Delicious', Jonathan and 'Ambri' are severely affected.	In order to avoid spread of disease indexing of root stock and scion required to be done properly. Infected trees be uprooted and burn.
Pre-mature leaf fall in apple *(Marssonina coronaria)*	Formation of brown to dark brown spots of variable size on mature leaves in summer and drop off prematurely.	Protective sprays of mancozeb (0.3%), propineb (0.3%), dodine (0,075%), carbendazin(0.05%), dithianon and ziram (0.3%) .

16. Inclement weather conditions/ climate change and their management

- **Drought like situation and its management:** Droughts usually accompanied by high temperature, usually lead to foliage wilting and defoliation, bark splitting, poor bud development and sprouting, bloom shedding, poor fruit set due to improper fertilization and fruit drop at early stages and sun burning spots on fruits (atmospheric drought) and also leads to nutrient deficiencies on leaf and fruits due to reduced absorption and uptake of essential elements. Tree basin preparation to prevent loss of water by disturbing capillary action at the soil surface; mulching and weed management for moisture conservation and minimizing competition by weeding and drip irrigation system for irrigation at critical stages are very important in drought management and for harvesting higher productivity.
- **Hail storm damage:** This has been a major cause of concern for the apple industry in H. P and Uttarakhand. Availability of anti hail nets and anti hail guns to the orchardist in time may prevent the damage. High density planting systems are convenient for anti hail net use.
- **Foggy and cloudy weather:** This situation is detrimental for maturing fruits. Russeting and fly speck spots appear on the fruit skin making the fruits unmarketable. Such situation prevails in lower hills of Uttarkhand, H.P and J & K during monsoon. Planting of early genotypes and their early harvesting should be done before the damage starts.
- **Insufficient chilling in winter:** Due to warmer winters, chilling fulfillment to the apple trees is insufficient and as a result, proper bud break does not takes place. Low chilling cultivars like Schlomit, Anna and Micheal etc are good under such situations.
- **Water shortage at critical stages:** Over the years it has been observed that shortage of proper rainfall just after winter break causes loss of fruit drop and failure in proper fruit set and development. Snowfall has shifted its timing from peak winter to early spring i.e. March or April. Dry winter is not conducive for apple trees as soil moisture which is received due to winter snow is beneficial for better flowering and plant growth.
- **Weather forecasting:** Temperate climate shows a drastic annual variation which has become critical under changing trend of climate globally. Himalayan belts are also showing the impact by inadequate winter chilling, less winter snow and rain, faster rate of glacier melting, frequent drought like situations or heavy hail storms during bloom period and fruit maturity

time. Weather forecast models based on 20-30 years meteorological date specifically indicating the impact and intensity disease-insect infestation or resurgence can be effective in adopting preventive measures. Higher winter chilling, majority of which is met by January (1000 hrs) results in early flowering (Sharma et al., 2005) and lesser and inadequate winter chilling result into delayed and poor flowering. Temperature is important for effective pollination period. A temperature around 10-200 C with optimum around 15-180 C with low humidity (30%) during bloom is beneficial for higher fruit set. Pollinator activity is also better. Yield forecasting has also become important based on agro climatic specific weather-tree interaction principles. Drought like situation if prevail just after fruit set fruit drop is higher and fruit size is reduced. Insect population is dependent on temperature, humidity and duration of wetness for expressing there resurgence intensity. Disease prediction based on computer models for apple scab is important for timely advice to farmers to follow appropriate fungicide. Pre mature leaf fall and mite has also showed high degree of resurgence under changing climate in India. Different models have been proposed for epidemic development (Thakur and Xu, 2004) like Simple Lookup model(mill's table) based on weather factors to interpret risk of disease development(light, moderate and severe); Computer based disease warning systems like PODEM (apple powdery mildew warning system); ADEM(apple disease warning system); PEST-MAN(forecasting system for apple and pear diseases) and VENTEM(scab warning system) are very important under changing climate scenario as they have great impact on production, productivity and quality of apples.

17. Pre and post-harvest management

Despite this fact that India is the 2nd largest producer of fruits and vegetables in the world, but a huge quantity (30-40%) goes waste due to post harvest losses. Inadequate pre and post harvest treatment, short shelf life, lack of maturity indices, inadequate processing infrastructure, grading, packing, packaging, road and transport facilities etc. are the key factors causing huge losses. Proper post harvest handling and value addition therefore are essential for reducing these losses and increasing production, productivity and vis-à-vis the returns. Several modern technologies are invented for pre and post harvest management of temperate fruit crops have greater significance which include preharvest factors such as nutrition, rootstock and environmental factors and post harvest include harvesting, grading, pre-cooling, packaging, CA storage/cool chain, preparation of value added products and their disposal to terminal markets.

17.1 Crop regulation and pre-harvest management

Improving fruit set: To enhance flowering and fruit set, 3% Dormex (hydrogen cyanamide) 40 days before bud break in Royal Delicious apple was found effective. Application of Boric acid (1%) at the time of bloom can help in better pollen tube growth. Spray of Miraculan (0.75 ml/L water) or Paras (0.6 ml/L water) or Biozyme or Protozyme (2 ml/L water) at bud swell and petal fall stages has been recommended for better fruit set (Anoymous, 2003).

Thinning: Hand thinning of flower cluster after every 3-4 cluster or retaining only 2-3 fruitlets per cluster is practiced. At petal fall stage NAA 10ppm (1ml planofix/4.5L water) 7-15 days after petal fall or at fruit length around 15 mm is most effective. Carbaryl @0.075% (Sevine 50WP/L water) 7-10 days after petal fall and Ethephon(100-200ppm) at full bloom to petal fall is also effective.

Fruit drop: Most of the fruit varieties have been noticed to have the following three waves of fruit drop namely 1. Early drop due to inclement weather like hail storm and drought, improper and poor pollination and fertilization. 2. June drop due to moisture stress and competition for growth and food and 3. Pre-harvest drop due to physiological imbalance or any disorder which causes to economic loss. The application of 10 ppm NAA (Planofix 1ml/4.5L water) a week before the expected fruit drop or 20-25 days before harvest can check the fruit drop effectively.

Fruit colour and maturity: In Delicious varieties and all the red colured improved strains of apple, colour development is generally poor and due to rise in temperature early in the season growth of the fruit takes place faster but conversion of starch into sugars and other necessary physico-chemical changes essential for quality produce does not takes place properly in marginal areas below 1828.8 m elevation above mean sea level which fetch poor market price. On the other hand, fruits at higher altitude areas get sufficient maturity duration accompanied by day time strong solar radiation and cooler night which favours better colour and quality. Application of 250-500ppm 2-chloroethyl phosphonic acid (Ethrel, CEPA or Ethephon) about 20 days before harvest improves colour of fruit substantially but impairs shelf-life.

Extension of shelf-life of fruits: Apple grown in upper belts can be stored for 90 days under ambient conditions whereas apples in lower belts can be stored for 60 days. The influence of post-harvest infiltration of calcium chloride on keeping quality of Red Delicious apples has also been investigated under various storage conditions. In Himachal Pradesh also pre-harvest three sprays of 0.5% calcium chloride of right from first or second week of July at two weeks interval and addition of carbendazim(0.05%) with calcium chloride solution controls bitter pit, extends shelf life and also reduces blue mould incidence. Post-harvest dip (4%) been recommended for improving shelf-life of apples.

Maturity indices & harvesting: Maturity indices/harvesting stage determine the quality of fruits and its shelf life. Maturity standards have been calculated and standardized based on days to harvest from full bloom and TSS in apple. Royal Delicious, Red Gold, Rich a Red, Red Delicious and McIntosh are ready to harvest after 120-135 days from the date of full bloom with T.S.S. ranging from 12-14 oB (Table-1).

Table-1: Maturity Indices for Commercial Cultivars of Apple for H.P.

Cultivars	DAFB	Firmness (kg)	TSS (^{0}B)
Starkrimson	103 + 3	8.2 + 0.20	12.5-13.5
Royal Del	120 + 5	8.2 + 0.40	12.0-13.5
Rich-a-red	128 + 3	8.6 + 0.25	12.0-13.0
Red Delicious	134 + 5	8.4 + 0.40	10.0-14.0
McIntosh	135 + 4	6.8 + 0.25	11.5-13.5
Golden Del	148 + 6	8.4 + 0.40	12.0-14.5
Grany Smith	180 + 5	8.7 + 0.30	11.5-13.0

Codex and quality standards: before import export of apple under codex standards, declaration and phytosanitary certifications are required and have to be followed strictly under international marketing. The apple shipment must be free from insect-pests and diseases like Mediterranean fruit fly *(Ceratitis capitata)*, codling moth *(Cydia pomonella)*, light brown apple moth (*Epiphyas postvittana)*, scarlet mealy bug (*Pseudococcus calceolariae*), comstock mealy bug (Pseudococcus comstocki) and apple maggot (Rhagoletis pomonella) and fire blight (Erwinia amylovora). Apart from this pest free area status as per International standard specifically for apple maggot and Mediterranean fruit fly should be certified along with cold treatment at 0 °C or 0.55 oC or below for 10 days before shipment or 1.1 °C for 12 days in transit refrigeration. Another main factor is pesticide residue regulations which should comply with the national standards as per the Prevention of Food Adulteration Act (Table-2).

Table-2: Maximum residue levels (MRL) of chemical or pesticide for apple

Chemical(ppm)	India	Codex	USA	EU
Ethephon	NS	5.0	5.0	3.0
Benomyl	5.0	5.0	7.0	2.0
Endosulfan	2.0	1.0	2.0	0.3
Dodine	5.0	5.0	5.0	1.0
Malathion	4.0	2.0	8.0	0.5
Captan	15.0	25.0	25.0	3.0

Source: Deodhar *et al.*, 2006

17.2 Post harvest management:

Grading: Grading of fruits before packaging is an important post harvest operation as it determines price of the fruit. Fruits are generally graded for size and quality. In India fruits are generally graded manually but mechanical grading should be preferred as it enhances efficiency. Automatic and mechanical graders which are common in western countries are rare in India need to be introduced and popularized. Four apple grades are recommended (Table-3) as proposed by UNDP for domestic and international market viz., extra large (80 mm diameter), large (75 mm), medium (70mm) and small (65 mm), while Chadha and Awasthi (2005) proposed ***India No.1:*** Apple which are mature but not overripe, clean well formed and free from decay, breakdown, diseases, broken skin, visible water core, injury caused by russetting, sun burn, spray burn, hail etc. ***India No. 2:*** Fairly well formed. ***India Utility:*** Mature, clean and free from decay; ***India Processing Peeler:*** Apples which are not smaller than 6.25 cm diameter fairly well formed, not seriously sun burn, damaged by bruising and hail or other indentation and **India processing juice:** free from decay, injury and damage from other factors.

Table-3: Apple grades generally followed in India

Grade	Minimum fruit diameter (± 2.5 mm)	Conventional method of measurement
Super large	85	4 finger and thumbs
Extra large	80	Over 4 fingers
Large	75	3-4 fingers
Medium	70	2-3 fingers
Small	65	1-2 fingers
Extra small	60	0-1 finger
Pittoo	55	No space

Anonymous, 1992 and Lal, 1982

The present grading need to be replaced in future as proposed below to meet the codex standards as per FAO/ WHO for competes in the international market (Table-4).

Table-4: Proposed grades as per codex standards

Size code	Diameter (mm)	Weight (g)
A or 1	>80	>240
B or 2	71-80	191-240
C or 3	66-70	151-190
D or 4	61-65	121-150

Pre-cooling: The rate of precooling of any commodities depends upon the difference in the temperature between the crop and cooling medium; nature of cooling medium; thermal conductivity of produce; velocity of cooling medium and the rate of heat transfer from produce to the cooling medium. There are several methods of precooling used commercially, the selection of most suitable method depends on the crop, storage life required and economics. The various methods of preecooling are top icing, room cooling, forced air cooling, hydro cooling and vacuum cooling. Common field practices for apple cooling are, picking fruits early in the morning, evaporative cooling, watering and forcing air by fans over fruits. Forced air cooling or hydrocooling conditions of -1 to 0 0C as preferable temperature, RH 90-95%, freezing temperature around -1.7^{0}C suitable for maximum of 8 month storage.

Packaging: Generally consumption of fresh temperate fruits are usually away from the production site. Careful management of the distribution system will ensure retention of its quality and maximum returns. Packaging is an another important component essential to protect the fruits. With fresh fruits often there are two level of packaging, the first is the pack in which produce is offered to the consumer and the second is the pack that contains the consumer pack and used to transport apple to the retail market or to store for long time.

Wooden box packing: Generally two types of wooden boxes are preferred, one is of 45.7 x 30.5 cm internal dimension with height of and 25.4 to 30.5 cm to accommodate 18-20 kg apple and other is of 41.5 x 18.5 x 16.5 cm dimension to accommodate 10 kg apple. Tray packed wooden boxes has also been found better where apples are packed in deep cup pulp board tray in boxes. Use of inside polyethylene lining (100 gauge) with 0.5% ventilating area and ethylene absorbents (ethysorb/green keeper/purafil) prevents fruit shriveling or weight loss.

Corrugated fiber board carton: Made of non woody raw materials like bagasse or paddy husk. These cartons are very convenient for long distance transportation and protect fruits from weight loss and any bruises. CFB boxes are light weight, easy to handle and packing and moreover requires no extra padding. To protect from rain damage, corrugated plastic cartons or laminated cartons are also useful. CFB weighs around 1.25 kg with very negligible bruising loss (3.5%) over wooden boxes with 4.0 kg in weight and loss as high as 32%. Moreover no wrapping materials are required and printing of information about attributes of packaged apples is also possible. CFB is internationally acceptable packaging material and the arrangement of different grades can be made in CFB as indicated in Table-5.

Plastic crates: Collapsible or non collapsible plastic crates are also in use for apple collection from harvesting site to packing house or for stacking in cold storage and for local market transport.

Table-5: Arrangement of different grades of apple in CFB

Grade	No of fruit layers	No. of fruits/ layer	No. of fruits/ box	No. of trays
Super large	4	18	72	5
Extra large	4	20	80	5
Large	5	20	100	6
Medium	5	25	125	6
Small	5	30	150	6
Extra small	5	35	175	6

Source: Anonymous (2003)

Wrapping material: Individual fruits are wrapped after quality grading for packing in the boxes. Wrapping materials may be newspaper, tissue paper, polyethylene liner/bags, wax coating and paper mounted trays. Policies about waxing of apple is not clear in India though in 2003 India proposed to ban waxed fruits and vegetables. However USA and Australia generally use waxed apples for export. USA mostly uses carnauba wax, beewax and shellac. China and New Zealand export unwaxed apples. Considering the advantages of wax coating this could be a good post harvest practice for extending shelf life of apple.

Storage of temperate fruits: India has varied agro climatic conditions. Consequently, a large variety of fruits are available round the year. To increase further availability of particular fruits in off season it is necessary to store the fruits in suitable type of storage system. Proper storage of fruits at low temperature ensures regular distribution and minimizes imports during off season. There are different systems of storage such as low temperature storage, evaporative cooler, zero energy cool chamber, controlled atmosphere storage, hypobaric storage etc.

Low temperature storage: Temperature and relative humidity are the two most important considerations for storage of any horticultural commodities. Temperature below the optimum range for a given commodity will cause chilling injury, whereas the temperature above will result in reduced shelf life. There is also recommended relative humidity range for different perishable commodities. Relative humidity below the optimum range will result in unacceptable moisture loss and relative humidity above optimum may cause excess growth of microorganism and sometime cracking of fruits. The recommended temperature and relative humidity for apple is -1.1 to 0.0 OC and 85-90%, respectively for 4-8 months storage life. For apple varieties which are sensitive to chilling, storage temperature may be kept at 3-5 OC. Relative humidity may be as high as 90-95%.

Controlled or modified atmospheric storage system (CA/ MA): It is a modern storage technology where higher CO2 and lower O2 level are maintained. The

principle of Modified atmosphere does not differ from the principle of CA storage except that the control of gas concentration is less precise in MA storage. In general CO2 concentration is maintained between 2-5 % whereas O2 is at about 3 % at temperature 3.3 or 0 or -1.1OC depending upon the cultivars sensitivity to low temperature storage. The effects of decreased oxygen and increased carbon dioxide levels are to reduce respiration rate, delay ripening of climacteric fruit, prolonged shelf life, delayed breakdown of chlorophyll, reduce rate of production of ethylene, some time production of undesirable flavour, development of physiological disorder such as Brown Heart, Core Flush, tissue breakdown in apple. All these factors must be taken into consideration with CA storage.

Postharvest Disorders, Diseases and Their Control

The wastage o apple during storage is often very serious. It may be brought by various diseases causing pathogens

Physiological Disorders

- **Shrivel.** Golden Delicious apples are particularly susceptible to water loss. Weight loss can be as high as 3 to 6%. Rapid cooling, storage of fruit with plastic bin liners, and well-designed refrigeration equipment reduces water loss.
- **Bruising.** Can be excessive, especially for Golden Delicious where bruises are more visible. Gentle handling is important.
- **Bitter Pit.** Sunken brown spots on the skin, especially at the calyx end is related to low calcium concentrations in the apple. Best controlled by calcium sprays prior to harvest and calcium dips prior to cold storage. Apply field sprays under rapid drying conditions to avoid russeting. Reduced incidence with controlled atmosphere storage is found.
- **Superficial Scald.** It is the browning of the skin which develops in cold storage. Susceptibility of Golden Delicious to this disorder is low. Controlled atmosphere storage delays onset.
- **Controlled Atmosphere Damage.** Oxygen levels below 1% and CO2 above 15% induces off-flavors due to fermentative metabolism. Other symptoms of CO2 injury include partially sunken brown lesions on skin or internal browning and cavities.

Pathological Disorders

Moldy Core. Caused by several fungi including Alternaria sp., *Fusarium* sp., *Aspergillus* and *Penicillium*. Golden Delicious apples are particularly susceptible because of the open or deep sinus cavity. Drenching can increase the incidence of moldy core.

Blue Mold and Grey Mold. The two most important postharvest diseases of Golden Delicious apples are caused by *Penicillium expansum* and Botrytis *cinerea*. Both fungi are wound pathogens. Sanitation is critical to control of these diseases. Drenching can spread spores of *Penicillium* and Botrytis to wounds from harvest operations. Use of fungicides during drenching may reduce decay.

Bitter pit

Bitter pit of apples can be controlled by use of calcium nitrate sprays in the orchard. It is now known that apples have a critically low level of calcium and that other functional disorders are linked to calcium deficiency. Apples having more than 5 mg Ca/100 g are likely to be free from bitter pit. A balanced fertilizer program and the application of three or four calcium sprays at 1- to 2- week intervals before harvest are recommended practices for the control of bitter pit. Dipping the fruit in calcium chloride after harvest is sometimes effective, and that the addition of the scald inhibitor diphenylamine to the calcium chloride after harvest is sometimes effective, and that the addition of the scald inhibitor diphenylamine to the calcium chloride solution improved effectiveness. CA storage and waxing of apples also reduce the extent of bitter pit. Bitter pit is caused by an imbalance of Ca, Mg, and K rations.

Processing

Apples are processed into various products such as juice, concentrate, vinegar,, sauce, butter, preserve, candy, Jam, Jellies and canned products. Apples are also dried as rings, chops, or cubes. They are also used for making fermented beverages such as cider and wine. The waste from the apple processing industry, such as peel, core, or pomace, can be utilized for production of pectin and various edible products.

A. Juice

Apple juice is a popular drink and one of the important breakfast items. Apple juice contains a considerable proportion of the soluble components of the original apples such as sugars, acids and various other carbohydrates. Malic acid is the predominant acid in apple juice. Several distinct forms of apple juices available in the market include clarified apple blends with other juices/extracts.

1. Clarified Apple Juice

Preparation of clarified apple juice involves granting and pressing the apples, clarification with pectinol enzymes, filtration and packaging. Traditional packaging involves pasteurization at 80-88°C, then filling and hermetically sealing the juice in glass containers or metal cans. Recently, laminated flexible packages have also been introduced with this process. This aseptic process, with the product packed in laminated flexible containers, has been successfully introduced in many countries of the world.

2. Natural Apple juice

The characteristics of a natural apple juice are considered to be very close to the juice which comes directly from the press. Commercially, this is accomplished through the addition of ascorbic acid or through heating, the pressed juice to flocculate unstable compounds. Ascorbic acid helps in preserving the very light color of the juice by reserving the oxidation of juice constituents. The juice is then immediately pasteurized to inactivate the oxidizing enzymes occurring naturally in apple juice. Another process for making natural apple juice utilizes heat to flocculate the unstable compounds in the juice. In this process, the juice from the press is heated to 95-970C to induce flocculation, followed by cooling to l8-20°C until bottling. Plate or tubular heat exchangers are used. The juice is centrifuged to remove the flocculent and non soluble and heated to 88°C, a lower temperature than the initial heating and bottled. Thisjuice from both the processes is higher in viscosity the clarified apple juice. The product from the ascorbic acid process is bright cream to bright yellow in color, with a stable suspension of small solid particles and it may have a light sediment. The heat-treated product in slight in color and may have a slight haze.

3. Pulpy Apple Juice

Pulpy (crushed) apple juice has a light color and a high pulp content of fine cells. In its production, washed apples are coarsely ground and passed through a pulper with a fine screen. The pulped juice is then deaerated by passing it through a vacuum chamber, which helps in minimizing oxidation and then homogenized, pasteurized at 88°C and filled into containers. It is continuous process with very little time elapsing between the grinding of the apples and final sealing of the containers.

4. Apple Juice Blends

Apple juice and apple juice concentrates are used as the base for blended fruit juice and fruit juice drinks. Apple-cranberry and apple-pear are favorite blends. Combinations of apple and tropical fruits are available, as are blends with citrus juices. Several of these blends are sold as frozen concentrate as well s in single strength forms. Apple juice blends with citrus juice and ginger extract has been developed as an apple appetizer. Efforts to improve the nutritional qualities of apple juice by blending with either egg yolk or soya bean proteins have also been successfully made.

B. Concentrate

Apple juice and other fluid foods are concentrated in order to reduce their volume and weight, which results in lower costs of packaging, storage and transportation. The principal methods applicable to apple juice concentration include evaporation, reverse osmosis and freezing. ln preparation of apple juice concentrate, the clarified juice is concentrated to six fold and the concentrate

is back to fourfold (42° B) with fresh juice. However, concentrate prepared by stripping of the juice of volatile flavor constituents prior to concentration and hen adding back the volatile flavor constituents to the concentrated juice was reported to be superior in flavor and aroma. Prepared concentrates are frozen and stored at -18°C. The clear juice is passed through a filter press using diatomaceous earth as a filter aid to ensure complete removal of small particles. The filtered juice is pasteurized at 80-87°C for 30s in flash pasteurizers. The hot juice is filled into sterile bottles and sealed. The juice is also canned in lacquered enamel cans and sometimes it is also fortified with vitamin C.

C. Frozen products

For freezing, apple slices, after treating with 3% brine solution are subjected to vacuum to remove air, which is responsible for enzymatic browning. They are reimmersed in slat solution, washed and filled with sugar in a proportion of 4:1. Alternatively, apple slices are f'rozen by subjecting them to a high vacuum, treating with salt solution, blenching the brined slices in free-flowering steam,, cooling in water and packing in slipover cans. Slices can also be prepared for freezing by immersing them in 0.2% SO2 solution or in bisulfite solution containing citric acid for 1 min. the slices are kept under refrigeration for several hours to allow proper penetration of SO2 into the slices, which are then filled into slipover cans with sugar (5:l) and frozen at 6.0°C or below.

D. Dried Products

Apples can be preserved by drying. The peeled and cored apples are prepared as rings, segments, chops or cubes and treated with a weak solution of citric acid and a bisulfite dip. The latter provides SO2 which inhabits enzymatic browning. The sulfured slices are dried at 65-70°C for 6-8 h. Among different treatments a 2500-ppm SO2 dip of apple rings resulted in best dried product are packed in moisture-proof containers. A freeze-dried product based on apple and milk can be prepared by using 50% apple, 3.5%o each of sugar and lemon juice and milk in various proportions (O-43%). Apple slices of 2-3mm thick in size treated with 1% citric acid and 1% ascorbic acid and dried at 60-65°C for 6-8 hours in cabinet dryer give better peoduct (Sing et al., 2015).

E. Cider

Alcoholic beverages from apples are generally called cider or wine, depending on the alcohol content in the final product. There are two types of apple ciders, dry and sweet ciders. The fruits are crushed or grated and juice is obtained by dehydraulic press, then sugar is added to the juice to raise the brix to 22°. In addition, 100 ppm of SO2 and a pure culture of wine yeast, Saccharomyces cerevisae strain ellipsoideus are added Joshi et,al (1990). After fermentation at 20-25°C, the cider is racked and filtered. Before bottling, the cider is made sparking clear. During the aging process, most of the suspended material settles down, leaving a major portion of the liquid clear. The fermented liquid is further clarified

by using bentonite, casein, gelatin or filtering through pulp filters. After aging and clarification, the cider is pasteurized to prevent spoilage. Must prepared by direct addition of pectinolltic enzyme to the must improved the fermentability and made available the minerals and increased the color appeal of the product.

F. Vinegar

Vinegar made from fermented apple juice by acetic acid fermentation is called apple cider vinegar or cider vinegar. Apples are grated and pressed to get juice. Even after this, the pomace contains a large percentage of juice, which is rather difficult to extract. To extract this residual juice, the pomace is ground finely and actively fermenting cider is added in order to promote yeast fermentation. The pomace is allowed to ferment for 2-3 days and then pressed. By this method, a larger yield of juice is obtained than by simple grinding and pressing. The juice extracted by this method is inferior quality and is used for production of cider vinegar. Apple juice is fermented with wine yeast. when fermentation is complete, the yeast and fruit pulp settle to form an impact mass at the bottom of the tank, from which fermented liquid is separated. The clear liquid is stored in vessels. The acetic acid fermentation is brought about by acetic acid bacteria (Acetobacter sp.). ascetic aid fermentation, the fermented liquid is adjusted to 7-8% alcohol content. Mother vinegar containing acetic acid bacteria is then added to hasten the process and inhibit the growth of undesirable microorganisms. The vinegar is prepared by the or leans slow process or the German quick process' once the process is complete, the fermented liquid is allowed to age to improve the flavor. Acetic acid may also react with alcohol.

G. Other Products

I. Apple Butter

Apple butter is similar to apple jam except that it is made from finely sieved apple pulp to which small quantities of species consisting of nutmeg, cinnamon, clove etc. are added. The pulp: sugar ratio is generally l:3/4. on account o fits mild, spicy taste and flavor, apple butter is popular among a large number or consumers.

2. Chutney

To make chutney, apple slices are cooked along with other ingredients (sugar, salt and species) until they become thick. The product is bottled hot.

3. Applesauce

Applesauce is made from peeled, cored and sliced apples which are cooked in steam and passed through a pulper. The pulp is mixed with sugar, spices and salt and heated under steam at about85°C. acetic acid is added to adjust the acidity in the product. The hot mixture is filled into glass bottles and then heat processed and cooled prior to storage.

4. Pickles

Pickles are made by adding apple, slices to a boiling mixture of vinegar, sugar and spices and continuing boiling for 5 min. The mass is then simmered until the pieces become soft. The product is then packed into jars. The vinegar and sugar mixture is rebioled to a syrupy consist ency and poured the slices and filled in the jar. If desired, spices are also added to the jars.

5. Jam and Jelly

In the production of apple jam, good-quality fruits are selected and washed in coldwater. The fruits are peeled and the skin and seeds are removed. The peeled fruits are cut into small pieces. The fruit pieces are cooled and crushed with a paddle and made into a fine pulp by sieving.To 1kg of pulp, an equal quantity of sugar and 2.5 g of citric acid are added and the mixture is mixed thoroughly. The mixture is cooked slowly with occasional stirring until it passes a sheeting or drop test. The final weight of jam is in the range of l'5 times the sugar added. The hot jam is filled into clean extract obtained by boiling unpeeled apple pieces in water for 25-30 min and filtering through muslin cloth'

6. Preserves

Apples for preserves are peeled without removing the stem, pricked with a fork and kept in 2-3% sodium chloride solution to prevent browning. This is transferred to 2% lime water and kept there for some time. Alum solution and a pinch of sodium bisulfite are added to bleach the color' Fruits are blanched for 2-3 min. an equal quantity of sugar is required for good-quality apple reserves. Apples are placed in layers of sugar (half quantity only) in a vessel and left undisturbed for 24h. During this period, sugar absorbs the water and syrup may be formed. The mass is heated to boiling for a few minutes and sugar is added to raise the total soluble solids to 59-60° B. A small quantity of citric acid is added and the mass is boiled for about 5-g min and then kept undisturbed for another 24 h. on the third day, the strength of the sugar syrup is raised to 70° Birx and the product is lowed to stand for a week.

H. Waster Utilization

I. Flavor Compounds

Peels and cores from apple canneries and apple driers can be utilized to produce vinegar and for jelly juice stock. Apple pomace obtained after extraction of juice can be used to produce natural flavoring compounds. These compounds can be obtained by extracting with liquid CO2 which is fractionated at two different temperatures to obtain a flavorless fraction and an intensely flavored fraction. This procedure gave a broader flavor spectrum than did those prepared by distillation. Apple processing waste can also be used as fuel source or animal feed.

2. Pectin

Pectin can be obtained from apple processing waste. To obtain pectin, the dried apple pomace is boiled in water for half an hour. Protopecting is hydrolyzed to pectin by heating and acid hydrolysis and extracted by the alcohol extraction method. The extract obtained is filtered, bottled and may be pasteurized as such or may be spray dried to 5% moisture and used after dispersion with water as an additive. Low-methoxyl pectin I sproiduced by treating a solution of pectin with pectin methyl esterase, which removes a methyl group from the ester until of galacturonic acid. Low-methoxyl pectin forms gels in the presence of a comparatively low concentration of soluble solids and high pH (6.5) if a calcium source is present.

3. Animal Feed

Apple pomace can be used as animal feed by feeding either as fresh or as dried pomace. However, pregnant cows fed with apple pomace supplemented with non-protein nitrogen have been found to give birth to dead or weak calves.

4. Citric Acid

Citric acid can be produced from apple pomace by growing Aspergillus niger under controlled conditions. More than 250 g of citric acid per kilogram of pomace solids can be produced.

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