Chapter 7

Establishment and Management of Modern Orchards

Saeed Ahmad and Malik Mohsin Abbas*

Abstract

The aim of this chapter is to describe the modern techniques that should be considered by the farmers for the establishment of modern orchards. Information about the selection of site, land preparation and climatic requirements of plants has been given for the consideration of growers. Moreover, layout system, method of plantation, planting distance of different plants, selection of plants, digging and refilling of pits have been described. Modern concepts such as high density plantation in fruit plants and its components along with limitation and management strategies are also components of this chapter. Detailed information about management practices such as training, pruning, fruit thinning, and nutrition of plants, weed management, insect pest management and protection of orchard plants against adverse weather. This chapter will provide the expert advice to students and growers for establishment of new modern orchard and for maintaining the already established orchards.

Keywords: Bubbler, clean cultivation, high density, layout system, mulching, pruning, scion, stock, planting geometry, stubs, thinning, zero tillage.

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7.1. Introduction

Fruits are nature’s gift for human beings. These contain essential vitamins, sugars, minerals, fiber and antioxidants that help to protect the human body from chronic diseases. Fruits are a part of healthy diet and help to boost immune system and decrease the incidence of diseases, skin disorders, and chronic illness as well as delay ageing (Bal 2007; Chattopadhyay 2008). Therefore, consumption of fruit is considered essential for health. More than three dozen fruits are being grown in Pakistan, from high hills of Khyber Pakhtunkhwa and Baluchistan to plains of Punjab and Sindh. The fruit consumption per capita is very low in Pakistan due to low production and high prices of fruits. The yield of fruit crops is three fold less as compared to other advanced fruit growing countries. Therefore, it is very important to increase the area under fruit crop as well as to improve productivity of existing orchards by employing modern techniques. Establishment of fruit orchard is a long-term investment and any fault or carelessness at early stages can affect the productivity and net returns over a long period. Therefore, expertise and knowledge about planting and post planting care is mandatory for successful fruit production (Bal 2007). The fruits plants are still cultivated on traditional lines in Pakistan. Therefore, the aim of this chapter is to provide the guidelines about the latest techniques for establishment of modern orchards.

7.2. Site Selection and Preparation

The fruit plants should be planted in the fruit growing tracks. Site should be selected on the bases of two major factors; the topography and the soil. Topography refers to the contour of the land, its elevation and physical feature of the area. Soil serves as a home for the roots of plants and provides all necessary nutrients to the plants (Bal 2007). Proper climate, market, transport facility, availability of trained labour and inputs, are also important factors, which should be considered before the decision to establish orchards. Every fruit cannot be grown successfully in all types of climate and soil. Proper combination of climate and soil is very important. The selection of suitable kind of fruit for particular region is the basic requirement for establishment of orchard (Bal 2007).

After the selection of site, preparation of the land needs some preliminary operations. These operations depend on the condition of site selected for growing plants. Land already under cultivation and well maintained needs nothing and plants can be transplanted directly after layout. Uncultivated and new site should be surveyed and analyzed to check the level of the land, to plan the irrigation system, and to examine the fertility status of the land. Existing vegetation should be removed and stumps should be uprooted properly to avoid regeneration of plants and to reduce the hurdles during movement of machinery. It is very impotent that land should be cleaned properly before the layout (Hernandez et al. 2005). A deep cultivation and laser leveling (Fig. 7.1) is required for virgin land (Zhang et al. 2002). Irrigation system should be planned and permanent water channels and paths should be prepared. Before plantation of orchards, growing of green manuring crops is also recommended to enrich the soil and improve its physical condition.
7.2.1. Climate

It refers to the meteorological conditions of a region. Temperature is the most important factor which affects the success and failure of the fruit crop. Different fruit needs different range of temperature. Apple, pear, plum and peach can be grown successfully in cool climate (7.5-12.5°C) and these trees shed their leaves in specific period and produce new leaves and flowers after rest period. Mango, banana, papaya and pineapple require long growing season and high temperature (18.5-23°C) without frost and snow fall. The response of fruit growth varies with the modification of temperature (Adama et al. 2001). Atmospheric humidity requirements differ from plants to plants, such as banana and papaya require high humidity but the mango and ber require less humidity. Fruits requiring high humidity cannot survive in arid zones (Sukhvibul et al. 2005). High humidity also favours the bacterial and fungal diseases. Amount and distribution of rainfall in the region should also be considered before the decision to grow the fruit crops. Heavy rainfall and water logging conditions are not good for fruit crops. Rainfall at flowering/blossoming affects the pollination by washing the stigmatic fluid and pollen from the stigma (Bose et al. 2001). Rainfall
just before harvesting is also considered not good for postharvest life of fruit because it increases the softness (banana and dates) and infection of fruit fly. If the orchard is designed with close plantation, the infestation of the diseases increases, for example guava planted at close distance in humid regions mostly remains victim of anthracnose disease. In citrus, the problem of fruit drop becomes severe at high humidity. On the other hand, most of fruit crops cannot grow properly in the region where rainfalls are very low, so need additional irrigation water to fulfill the plants requirements. Hot, high velocity winds and hail-storm are also harmful for fruit plants (Rouse and Sherman 1989).

7.3. Selection of Scion and Rootstock

Scion and root-stock selection are the key components for successful and healthy orchard establishment. For scion selection, care should be taken that it is removed from selected progeny trees (true to type) having good health, vigorous growth and heavy bearing (Tylus et al. 1986). The scion should be prepared carefully before the performance of actual grafting work. Previous season’s mature and healthy shoots having more terminal buds should be selected for successful plant growth. The grafting shoot is defoliated 7-10 days before the removal from the parent plant, leaving the small petioles intact. If scion wood is not to be utilized immediately, it can be stored for a short time. For transportation, scion sticks should be tied in small lots with proper labels for identification. Sealing of both ends of scion wood with melted wax prevent the excessive evaporation. Then put these tied sticks in sphagnum moss media, envelop in polythene bags, pack in appropriate box and store in a cool place (Wocior 2008).

Rootstock for grafting is prepared by raising the seedlings of desired species. The stock usually influences the tree size and vigour. For growing of rootstock, seeds should be taken from freshly harvested fruits which are free from any kind of infection. The rootstock should be well prepared before the start of grafting/budding operations. Remove the leaves and thorns from stock where grafting/budding work is to be performed. The selected stock should be healthy, uniform and having the diameter of pencil thickness (Fig. 7.2). The actively growing stock should be used so that bark will separate readily from the wood. If plants are not raised by the orchardist, then it is very important that plants should be purchased from the certified fruit nurseries.

One of the major reasons for low production of fruit crops in Pakistan is the supply of poor quality planting material. Growers do not care about the nursery history records and buy the nursery plants from any nursery which supply the plants on low rates. Therefore, nursery plants should be purchased from the well reputed nurseries. The detail of certified fruit plant nursery is given in Chapter 6.
7.4. Layout Systems

After the selection of site, indication of actual places for fruit plants in the field at proper plant to plant and line to line distance is referred as layout. The layout plan is the first step in the establishment of successful fruit orchard. It should be prepared carefully with the consultation of Horticultural experts because, cultivation, management practices, health of plants, yield and quality of fruit, all is dependent on the system of layout (Goswmi et al. 2014). A good layout system is that in which maximum number of plants per unit area can be planted at proper plant to plant distance, where plants can get sufficient space for their development and should be convenient for orchard operation and give good aesthetic appearance. Any mistake or carelessness at this time can cause the losses throughout the life of orchard and that mistake cannot be corrected later. There are many orchard planting systems, which are used on the basis of agro-climatic conditions. In Pakistan, especially in Punjab, mostly square and rectangular systems are used at commercial orchards.
7.4.1. Square System

It is the most common, easy and popular method of laying out for fruit orchards on flat ground. Plants are planted at equal plants to plant and row to row distances. The plants are set at right angle to each other, every unit of four plants forming a square. The system is easy to layout and facilitates the intercultural practices in two directions, after plantation of orchard. In this system, aeration and light penetration must be ensured. Majority of the orchards of Punjab have been planted according to this system (Fig. 7.3).

**Fig. 7.3** Layout plan (above) and guava orchard (below) planted in square system.

7.4.2. Rectangular System

The plot is divided into rectangles instead of squares. It is because the row to row distance is kept more than plant to plant distance and plants are planted at the corners of the rectangles. In this system, more plants are planted and one-way cultivation is feasible. This system is also used for high density plantation but more management practices especially pruning is needed to allow the plants to grow normally. This system is helpful to maintain the light penetration and air circulation in the high
density trend as the line are stretched from North to South. The grapes, falsa, and pomegranate are usually planted under this system (Fig. 7.4).

**Fig. 7.4** Layout plan (above) and marking of points (below) for plantation of grapes in rectangular system.

### 7.4.3. Hexagonal System

In this system, the trees are planted in the corners of the equilateral triangles. Six trees thus form a hexagon with another tree in the center. This system is complicated and harder to understand for growers but 15 percent more plants can be accommodated than the square system. Three-way cultivation is possible in this
system. This system is recommended for that area where land is costly and very fertile with ample provision of irrigation water.

7.4.4. Quincunx System

This system is exactly like the square system, with the exception that after laying out the garden according to the square system one additional plant (known as filler) is planted in the center of each square. Quick bearing plants can be planted to get the early return and these plants are uprooted at later stages.

7.4.5. Contour System

This system is usually practiced in hilly areas with high slopes. In hilly areas, fruit plants have to be set on terraces. According to lay out it is similar to square/rectangular system. The trees are planted in lines following the contour of the soil with only a slight slope.

7.4.6. Triangular or Alternate System

The layout is completed according the rectangular system and one extra tree is planted at the intersection of the diagonals of each rectangle. In this system 50-60% more plants can be accommodated, as compared to rectangular system. However, this system is not considered good for permanent and long term, because plants become very large at later stages.

7.5. Planting Distance

After the decision of layout system, 2nd most important decision is how much plant to plant and row to row distance will be used for the establishment of orchard. Planting distance depends on various factors such as, climate, soil, choice of varieties, growth habit of tree, rootstock used, and nature of irrigation and pruning system to be followed. Suitable spacing among the plants in orchard is very important for growth and bearing life of plants. A guideline for plant to plant and line to line distance is given in Table 7.1.

7.6. Digging and Refilling of Pits

Pits (90 cm× 90 cm × 90 cm) must be dug at least one month before the actual plantation. These pits must remain empty for two weeks for exposure to direct sunlight or these pits can be covered with polyethylene for one week (Fig. 7.5). The covering of pits with polyethylene increases the temperature inside the pit very high. The direct sunlight and high temperature is useful to kill the soil born pathogen and plants remain safe in future. Moreover, the spray of fungicide and insecticide in these pits is also recommended to protect the root system of newly planted plants from termites and different species of fungi. The pits must be filled with equal part of top (upper) soil, silt and well rotten farmyard manure. After filling the pits, irrigation is
applied and when water is absorbed properly (not wet and dry), the soil should be leveled again and plants are planted in the centers of the pits.

**Table 7.1** Spacing guideline for the establishment of new fruit orchards.

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Planting distance (meter)</th>
<th>Plants/ha (Square system)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tropical Fruits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banana (i) Tall varieties</td>
<td>2.7 × 3.0</td>
<td>1210</td>
</tr>
<tr>
<td>Banana (ii) Dwarf varieties</td>
<td>1.8 × 1.8</td>
<td>3052</td>
</tr>
<tr>
<td>Cashewnut</td>
<td>7-8</td>
<td>202-140</td>
</tr>
<tr>
<td>Custard apple</td>
<td>5</td>
<td>390</td>
</tr>
<tr>
<td>Guava</td>
<td>5-7</td>
<td>350-330</td>
</tr>
<tr>
<td>Jaman</td>
<td>10-12</td>
<td>105-75</td>
</tr>
<tr>
<td>Mango</td>
<td>8-10</td>
<td>130-120</td>
</tr>
<tr>
<td>Papaya</td>
<td>1.5</td>
<td>4400</td>
</tr>
<tr>
<td>Pineapple</td>
<td>30 × 60 × 90 cm</td>
<td>43500</td>
</tr>
<tr>
<td>Sapota</td>
<td>7-9</td>
<td>120-180</td>
</tr>
<tr>
<td><strong>Sub-Tropical Fruits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avocado</td>
<td>10</td>
<td>105</td>
</tr>
<tr>
<td>Ber</td>
<td>7-9</td>
<td>180-120</td>
</tr>
<tr>
<td>Citrus, pomegranate</td>
<td>5-7</td>
<td>285-275</td>
</tr>
<tr>
<td>Date palm</td>
<td>6-7</td>
<td>275-202</td>
</tr>
<tr>
<td>Falsa</td>
<td>1.5</td>
<td>4400</td>
</tr>
<tr>
<td>Grapes (i) Head system</td>
<td>2 × 1.5</td>
<td>3300</td>
</tr>
<tr>
<td>Grapes (ii) Kniffin system</td>
<td>3 × 3</td>
<td>1100</td>
</tr>
<tr>
<td>Grapes (iii) Bower system</td>
<td>3 × 6</td>
<td>550</td>
</tr>
<tr>
<td>Litchi</td>
<td>7-9</td>
<td>180-120</td>
</tr>
<tr>
<td>Loquat</td>
<td>6-7</td>
<td>535-525</td>
</tr>
<tr>
<td>Pomegranate</td>
<td>5-7</td>
<td>285-275</td>
</tr>
<tr>
<td><strong>Temperate Fruits</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>3-7.5</td>
<td>1100-180</td>
</tr>
<tr>
<td>Cherry</td>
<td>9-12</td>
<td>123-75</td>
</tr>
<tr>
<td>Peach</td>
<td>6-7</td>
<td>535-525</td>
</tr>
<tr>
<td>Pear</td>
<td>7.5</td>
<td>180</td>
</tr>
<tr>
<td>Plum, apricot</td>
<td>5-7</td>
<td>285-275</td>
</tr>
<tr>
<td>Walnut</td>
<td>7-9</td>
<td>180-120</td>
</tr>
</tbody>
</table>
7.7. Actual Plantation and Care

The commercial orchards should be planted in localities where such crops have already established themselves as commercial enterprises. Fruit trees should be planted where they will receive full sunlight for about 6 or more hours per day during the growing season. The fruit orchard needs special care and attention during the first 4-6 years for their healthy growth and maximum production. The establishment of good orchard requires proper and timely application of irrigation, weed control, hoeing, training and keeping them free of any type of pests and diseases. Evergreen fruit plants should be planted as early as possible after their removal from the nursery. After removal from the nursery, plants should be planted carefully in the center of already dug pit by keeping the rows straight on all sides. Care must be taken that the earthen ball should not break during planting. Press the soil firmly around the earthen ball in hole until plant is properly held in its position and always put top soil or upper soil layer around the earthen ball. However, bare rooted plants need more care to ensure that roots are properly spaced and no air pockets are left in the soil. For the support of plants, plastic pipes are recommended because the wooden sticks are more susceptible to termites (Fig. 7.6).
In orchard, young plants (4-6 years) are more susceptible to frost injury. Therefore, it is necessary to adopt timely measures and precautions against frost injury. If there is a chance of frost in the orchard, irrigate the field instantly as it reduces the risks of frost damage. Smudging is another technique in which dry matter is burnt at various sites in the orchard to reduce the damage due to frost. Shortly, orchard grower should be ready every time to protect his valuable trees from the threat of frost injury. In those localities where weather is hot, especially during summer, protection measures should be adopted against sun-burn. This damage can be minimized by planting the fast-growing plants such as Jantar and Arhar around the corners of orchards. Another protective measure to reduce the risk of sunburn injury is to white wash the trunk of young fruit trees. Windbreaks are also considered an effective strategy to protect the orchards against the attacks of storms and other plagues. Moreover, such types of orchards have less evaporation and exhibit less waterloss through transpiration.
7.8. **High Density Orchards**

Planting density is the single most important factor which determines the yield of an orchard for the first five years (Ram 1993). High density planting (HDP) is a modern system of fruit trees cultivation involving dense fruit trees plantation, permitting small or dwarf trees with modified canopies for better light interception and distribution, and comfort of mechanical field tasks. In these system pests, diseases, weeds and tree canopy managements are mostly carried out by machines (Goswami et al. 1993). Agronomic practices such as irrigation and fertigation in orchards are automatically controlled. Such type of tree planting system produces precocious cropping, high and regular yields of good quality fruits, and low labour requirement to meet the ever rising cost of production (Fig. 7.7).

**Fig. 7.7** A view of peach (above) and citrus (below) orchard under high density plantation.
Currently, the ongoing failure in the accessibility of cultivated land, increasing energy and land costs together with the rising demand of horticultural produce, have given thrust to the concept of HDP of horticultural crops (Goswami et al. 1993). Furthermore, it is of main concern to the growers with small land holdings. HDP is one of the important systems to achieve more production per unit area both in terms of short duration and perennial horticultural crops. HDP is a very intensive form of fruit production which has significance for food and nutritional security to fulfill the needs of fast increasing population.

### 7.8.1. Key Points to Adopt HDP

The HDP can be with one species (mono-species) or with different species (multi-species) of crops. The mono-species HDP basically comprise the planting of small tree densely, limiting their vegetative growth by using dwarfing rootstocks, bio-regulators or other horticultural techniques such as pruning/training. In the multi-species HDP, sunlight is intercepted at different levels by canopies of various species, based on their light transmission features, and shade tolerance. Beside, complication of their root systems, at various depths of soil, confirms the effective uptake of mineral nutrients and water (Goswami et al. 1993; Ram 1993).

The HDP system is comprised of five important components *i.e.* (i) Dwarf scion varieties, (ii) dwarf rootstocks and inter-stocks, (iii) training and pruning, (iv) use of chemicals/PGRs, and (v) appropriate tree management practices. All these constituents are connected in HDP that help to attain the desired goals (Goswami et al. 1993; Ram 1993).

HDP has certain definite advantages as well as limitations as compared to the conventional low density plantation. Under HDP system, per plant yield is low as compared to low density plantation. However, in HDP, the total yield per unit area of land is much more than low density planting. The establishment of high density orchards appears to be the most suitable method and need of time to overcome the problems of less productivity, long gestation period, and ensures early earnings and exportable quality fruits (Goswami et al. 1993; Ram 1993). Some important features of HDP are as under:

- HDP enables the better utilization of sun-rays and increase productivity per unit land area.
- HDP orchards are precocious, easily controllable and fetch more profit per unit area.
- HDP orchards have better amenability to modern input saving horticultural techniques such as drip irrigation, mechanical harvesting, etc.
- In HDP, usage of dwarffing trees and handling of unnecessary vegetative growth stretches higher productivity and harvest index as well as early financial incomes.
- HDP system is quite suitable for mechanization in various horticultural practices such as pruning/training, plant protection and harvesting, which can decrease the labour cost.
At higher productive stage, tall trees need heavy machinery and equipment for performing spray of pesticides and crop harvesting because the external canopy of tree is the main fruiting zone, which extends outwards with the enlargement of tree.

7.8.2. Constraints in HDP

- For various fruit crops, farmers have very poor accessibility of planting materials used for HDP such as, dwarfing fruit scion and rootstocks varieties.
- For HDP fruit crops, standardized production technology is lacking.
- High initial cost of establishment for high density orchards as compared to old-style planting systems.
- In HDP, there is no chance of intercropping and mixed cropping system.
- Due to overcrowding, if canopies are not managed properly, there can be problem of light penetration and aeration, which ultimately results in higher insect-pests and disease infestation.
- This system requires scientific approach and modern technologies for its management (training, pruning, irrigation etc.) as compared to conventional planting at wider spacing.

7.8.3. Components of HDP

The HDP system has four major components which are as follows:

**Planting density**

Even though a small canopy with a high number of well-illuminated leaves is efficient in photosynthesis but it is very poor in light interception, which leads to low potential yield per ha (Goswami et al. 2014; Sansavini and Corelli-Grappadelli 1997). The light interception could be enhanced by increasing the density of trees. An optimal tree density is the level which is needed to facilitate the better light distribution and interception leading to higher rate of photosynthesis and ultimately increased the yield per ha. An optimal light interception is a feature of plant form, planting density, tree arrangement and leaf response to light for photosynthesis. The optimum light interception can be defined as “a level of light intercepted by an orchard system above or below which, the economic yield will be reduced” (Goswami et al. 2014; Ram 1993).

**Planting geometry**

The planting system is a combination of tree arrangement and plant form. In HDP orchards, tree arrangement must have adequate passages for the movement of farm machinery. The way in which trees are arranged also regulates the distribution pattern and interception level of light. In litchi, single hedge row and double hedge row system and/or square system with 4-5 m apart, having enough space for passage, is being practiced in developed countries for HDP (Goswami et al. 2014; Ram 1993).
Pruning system

High density orchard trees show slightly higher growth in terms of height from 8th year to onwards as compared to normal density because of more pressure from side plants for solar radiation. Once the trees have filled their allotted spaces, crowding may occur and canopies of adjacent trees begin to overlap. This may lead to excessive shading and reduction in photosynthesis by covered leaves within the tree canopy resulting in poor yields (Sansavini and Corelli-Grappadelli 1997). In high density orchards, this situation should not arise and therefore, the frame development and formative pruning should be trailed from initial stage. Once the tree is mature, excessive growth can be frequently removed by pruning to provide a short term or instant advantage. The chief objective of pruning in HDP is to develop the plants in such forms that they can get proper light, are small in size and easily manageable, especially in terms of mechanization (Goswami et al. 1993; Ram 1993).

The height of tree, circumference and main stem girth in high density plants can be reduced by adopting the practices of regular back pruning or dehorning of branches after the harvesting of crop during 11th to 15th year, along with light pruning of fruited shoots every year. Dehorning is a process of removal of some selected branches from their place of origin on limb to control the vigour, light and air circulation. Good light distribution inside the tree canopy increases the number of well illuminated leaves. This condition induces a high rate of canopy photosynthesis that leads to higher yield per tree (Sansavini and Corelli-Grappadelli 1997). Small and compact canopy plant form is preferred for HDP, which can be attained by continuous pruning and dehorning techniques (Williamson and Coston 1990).

Mechanization

In HDP systems, another key component is automation which contributes to higher production efficacy. Important farm operations that can be automated are irrigation and fertigation. In fact, irrigation and fertigation practices have been identified as the key factors for the success of high density orchards. Fruit plants should not be kept under stress after the pruning operation; therefore, guaranteed irrigation joined with fertigation is crucial after pruning and during fruit development in high density fruit orchards.

7.9. Management Practices

The trees canopy management is one of the chief component for getting higher yield and good quality produce. Fruit trees produce fruit regardless of human intervention. Fruits house the seeds needed for trees to reproduce. However, for human consumption, it is important to manage fruit tree canopies to optimize the balance between vegetative growth and fruit production, and to keep fruit picking manageable. An unmanaged tree canopy will produce fruits up to height of 25–30 feet in the air, which is very difficult to manage and harvest. Canopy management will help to develop a strong tree framework that will support heavy crop loads, while increasing the fruit production and improving fruit quality on the long-term basis.
7.9.1. Pruning

Pruning can be defined as ‘The management of trees framework or fruiting wood or removal of any excess or undesirable plant parts (shoots, roots, twigs, limbs etc.) so as to allow the remaining parts to grow normally or according to the need of pruner’. Pruning is one of the most critical approaches for the development of a successful orchard. Pruning has a lot of beneficial effects as removal of un-productive wood, diseased, dried, broken and criss-cross branches (Sansavini and Corelli-Grappadelli 1997). It also diverts the flow of photosynthates to those plant parts which are capable of bearing fruits. Like training, pruning also allows more air and light penetration into the interior of the tree canopy. It controls the tree size and regulates the fruit crop. The pruning time influences the vigour of the new tree growth, whether it is vigorous or moderate (Fig. 7.8).

![Fig. 7.8 Pruning of guava (left) and peach (right) orchard.](image)

7.9.2. Training

Training is the positioning of tree limbs in such a specific way to manage the growth, rather than their removal. It can also be defined as ‘the development of young trees framework strong enough to bear heavy fruiting without any harm to branches’. For the development of good tree framework, 2-4 evenly spaced main limbs should be selected to provide balance, symmetry and greater strength. Training is advantageous as more light and air enter into the plant canopy to facilitate the proper colouration and development of superior quality fruits. It also protects the trees from wind damage. It is the best source for equal distribution of fruit bearing shoots on the main limbs of trees. It is also helpful for ease in cultural and harvesting operations in the orchard (Williamson and Coston 1990). Training of evergreen trees is different from deciduous trees and is discussed as under.
Ever green orchards

The term evergreen refers to “a group of plants that retain their foliage during winter”. Most of the evergreens have a strong central branch leader system, which requires little pruning except to control the plant height, increase the branching density, or to clip into special shapes. Appropriate identification of growth habits are necessary before pruning to save the natural shape and beauty of any plant. Evergreens trees can be grouped on the basis of whether they have whorled branches or random-branching patterns. New growth extends from buds that were developed from the previous year growth on the tips of twigs. However, a few random-branched species are capable of producing new growth on both old and new wood branch portions.

Prune all evergreens trees before the start of new growth in the spring or during the semi-dormant period during mid-summer. During the pruning operation, general branching pattern should be followed to maintain the natural shape of tree. Remove the dead, diseased, or broken branches anytime. Clipping should be practiced in late spring or early summer when new growth begins. This allows cuts to heal and new buds to form for next year. In most of the cases, selective pruning (one branch at a time) is better as compared to shearing/clipping. Shearing creates a formal and geometric shape that gives a natural look but becomes more difficult to maintain as the plant size increases. Irregularly, an evergreen plant may lose its leader system. Sometimes a new leader develops from a dormant (latent) bud, or one of the topmost branches will dominate and become the new leader. If no leader develops naturally, tie one of the upper most branches straight and train it to become the new leader. Curtail the surrounded lateral branches to reduce the inner branch competition.

Deciduous orchards

Generally, most of the deciduous fruit trees are pruned during winter when the plants are dormant. In winter, the framework of plant is clearer. It is easier to find diseased, damaged and criss-cross branches/wood that is obstructing the air flow through the plant canopy. These all parts need to be removed as they provide a harbour for diseases and insect-pests (Williamson and Coston 1990). Winter pruning will stimulate the vegetative growth. During the growing period, in good seasons, the tree stores carbohydrates in its trunk and roots to allow the plant survival during winter without presence of leaves. Such trees will have enough stored food to keep the summer trees alive. If there is heavy pruning in the winter, there is an overflow of stored food and profuse growth will occur in the following spring. This can be necessary to re-invigorate and produce new wood on old or weaker plants, but should not be practiced if you desire to limit the tree’s size (Sansavini and Corelli-Grappadelli 1997). After winter pruning, the plant grows more vigorously, producing vegetative wood rather than flowering and fruiting wood. Climate has a significant role at the time of winter pruning. Young trees are more susceptible to damage in hard winters. Therefore, pruning should not be practiced in late winter, early spring or after the danger of frost has passed to minimise damage in frost prone areas (Rieger and Myers 1997; Williamson and Coston 1990; Sansavini and Corelli-Grappadelli 1997).
7.9.3. Fruit Thinning

Many fruit tree species bear plenty of flowers which produce excessive fruit that the tree is unable to support. Too many fruits per tree can result in small fruit size and poor quality, breakage of limbs, exhaustion of tree reserves, and reduction in cold hardiness (Westwood 1993). In some fruit crops, heavy fruiting can partly or entirely obstruct the flower bud initiation. The growers have recognized these as major problem for fruit production and tree longevity, and adopted fruit thinning practice usually by hand. The term fruit thinning is defined as “the removal of little portion of fruit crop from the tree before its full maturity in order to increase the size and quality of the remaining fruit” (Osborne and Robinson 2008). Due to fruit thinning, more carbohydrates and photosynthates accumulate in the remaining fruits, and so improve the final fruit size, colour, eating and keeping quality, and ultimately increases the marketability of the produce. Fruit thinning during on-year is also helpful to overcome the biennial bearing of fruit trees, e.g. Mango (Ziaf et al. 2004) and citrus (Ouma 2012). Moreover, fruit thinning also reduces the limb breakage of heavy bearing tree (Westwood 1993; Osborne and Robinson 2008). Fruit thinning can be done using anyone or the combination of following methods.

Manual thinning: Hand thinning is the manual removal of fruit to regulate crop load and increase the fruit size before harvest. It is very easy, precise and less risky method but this needs more labour for thinning. It is very viable economically with significant increase in the profit. Higher value varieties, such as mandarin and oranges, are able to achieve the economic gain from hand thinning (Osborne and Robinson 2008). Hand thinning can be done with the help of an iron frame having the square with four legs of 0.125 m$^3$ long on each side (Fig. 7.9). Count of the frame depends on the tree canopy. In citrus, weak, blemished and unhealthy fruit are removed, leaving 9-10 fruit in each frame. Hand thinning is normally done after the natural fruit drop as early as possible, because it shows good results. Hand thinning in citrus fruits mostly starts in late June and early July when the fruit size is nearly 30-40 mm in diameter. It increases the net return by 20-40% (Ouma 2012).

Fig. 7.9 Method to count the number of fruit-set using frame.

Mechanical thinning: Mechanical thinning is an innovative approach for thinning fruit crops trained to any kind of spindle shaped trees, regardless of species, cultivar, temperature, and tree age. This technology is very beneficial to save the time of labour and is more economical (Westwood 1993). Mechanical thinning, alone or in
combination with either chemical or manual thinning, improves the fruit quality, particularly fruit size (by improving the source sink relationship and enlarging the photosynthates partitioned to the remaining fruits) and colouration (by allowing more light access to the tree inner canopy), sugar (taste), and sometimes firmness for better storability. The device saves labour costs, otherwise required for hand-thinning (Ouma 2012). Mechanical thinners include trunk shakers to remove the flowers or fruits and a drum shaker that has vibrating rods inserted into the plant canopy to remove the developing fruits. Mechanical thinning technology is low cost, require little skill, and cause less damage to residuals. However, it has some drawbacks such as, removal of some best fruit in stand and leaves some of the poor ones, which are more susceptible to wind and ice damage (Westwood 1993; Ouma 2012).

**Chemical thinning:** The processes involved in chemical fruit thinning appears to be complex and researchers continue to debate the effects of applied chemicals on the production of endogenous hormones, photosynthesis, carbon assimilation, phloem transport and many other physiological processes (Ouma 2012). Number of mechanisms has been proposed to explain the thinning action of applied chemicals and they are not equal for all the chemicals. Moreover, indication for action of chemicals used for thinning suggests several responses of leaf or fruit to the efficacy of different thinning chemicals (Ouma 2012). Application of naphthalene acetic acid (NAA) at the time of full bloom reduced the fruit set in apples. The thinning activity of ethephon (2-chloroethyl phosphonic acid), which releases ethylene on hydrolysis within the treated tissues, had been evaluated. But, one of the major problems with this chemical is the marked effect of temperature on the rate of release of ethylene in the exposed tissue or parts. High temperature following its application could result in severe over thinning (Walsh et al. 1979). Benzyl adenine (BA) is considered to be a mild thinning agent, and combinations of BA with NAA or carbaryl are often used for maximum effectiveness. Under certain conditions, BA alone can stimulate the fruit growth more than would be expected from it as a thinning agent. Chemicals that inhibit the process of photosynthesis can also serve as thinning agents in apples. Application of NAA inhibit the assimilation of carbon by as much as 25% for up to 48 h in ‘Delicious’ and ‘Empire’ apple leaves, and this inhibition continued for 2 weeks. Chemical fruit thinning is usually advantageous to save the labour cost and time. Chemical thinning could be practised earlier and at right time in the season to achieve the best results as compared to manual thinning (Ouma 2012). However, most of the chemical thinning agents could not achieve the satisfactory or reliable thinning results. It is because of little information available regarding the actual mechanism of such type of chemical thinners and their effectiveness in relation to environmental factors. Understanding the modes of action of these chemical thinning agents at molecular level will benefit the development of fruit thinning technologies and it will allow the initial screening of new potential thinning chemicals without extensive field trials (Ouma 2012).

7.9.4. **Nutrition**

There are seventeen essential nutrients which are required for plant growth and development: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, zinc, copper, boron, molybdenum, chlorine and
nickel. Of these seventeen elements, all except C, H, and O are derived from the soil (Singh et al. 2012). When the soil cannot supply the level of nutrient required for adequate growth, supplemental fertilizer applications become necessary. The nutritional needs of fruit crops are different from those of annuals. In perennial crops, there is a need to supply nutrients for current fruit production as well as for the vegetative parts, which persist for several years (Rosen and Bierman 2005).

Fruit trees require nutrients to live and thrive. When one or more of these nutrients are deficient in the soil, the tree will not reach its full landscape potential, will be more susceptible to diseases and insect-pests, and will have a shorter life span than a tree which has received proper fertilization. Plant nutrient management can influence the flowering, fruit setting, fruit size, the amount of vegetative growth, and other plant characteristics. The nutrients required by all plants, including trees, can be divided into two groups: macronutrients and micronutrients, based upon the quantity necessary for growth and development. Macronutrients are required by plants in larger quantities as compared to micronutrients (Chattopadhyay 2008).

The nutrition management in plants is the basic need to provide favourable conditions for the development of healthy trees which are able to produce higher yields with better fruit quality. Fruit trees are not long lived but have a spreading root system as compared to other field crops. Therefore, the nutrient requirement of fruit trees is much more different than other crops. A large number of factors like tree age, kind of rootstock, and scion varieties make it very difficult to formulate the exact nutrition program which would apply to all diverse conditions (Rosen and Bierman 2005; Chattopadhyay 2008).

Growers must learn to manage these nutrients for optimum plant growth and production and to minimize the adverse environmental effects. The most important is balance of nutrients, when one element is deficient, its absence can negatively affect the plant mechanisms and thereby obstruct the optimum uptake, utilization, or distribution of other minerals. On the other hand, an excess of any element may be toxic to trees, thus affecting the availability of other nutrients in the soil. Plant roots absorb most of their nutrients from the soil solution in an ionic form. Plant roots absorb larger molecules, but their rate of absorption is slow. Thus, a fertilizer, either organic or inorganic must first be broken down into its simplest forms that plants can utilize more efficiently (Neilsen and Terry 1996).

Furthermore, proper nutrition is one the most imperative factors affecting the anticipated productivity of the modern orchards. In the current scenario, nutrient deficiency in the soils has now become a prevalent phenomenon, which clues to the decreased yield and quality of fruits. Average yield/production of the Pakistani orchards is alarmingly low, i.e., merely 9 tones ha⁻¹ as compared with fruit yield in developed countries. Nutrient deficiency may be attributed to calcareousness, low organic matter and the high soil pH. Soil and climatic conditions are very useful to predict the nutrient deficiency; but, are not adequate to make significant recommendations (Neilsen and Terry 1996; Rosen and Bierman 2005; Chattopadhyay 2008). Soil and plant analysis, for inspecting nutrient deficiencies, play key roles in the successful nutrient management of the orchards. Soil variables are important characteristic that show recurrent spatial variability in orchards.
Observation regarding the change of orchards’ nutrition from place to place and from every corner of the fruit cultivation area is not considered possible due to the laborious soil testing, sampling, analysis and the un-usual statistical methods. Therefore, application of the updated modern systems such as geographic information system (GIS), is now becoming unavoidable for the efficient site specific nutrition management (Vitharana et al. 2008; Jin et al. 2012).

GIS has now become extensively used tool for the quantification of the spatial variability, for the estimation of prevailing soil characteristics and bioavailable nutritional aspects, leading to assess values of un-sampled orchard locations. Unbalanced fertilizer application in fruit orchards of Pakistan leads to either over or under fertilization and consequently causes significant yield losses. However, yield losses can be decreased by the site-specific nutrition management programmes. This site specific nutrition management is however, possible only through modern hi-tech GIS in modern fruit orchards. Therefore, GIS is now becoming essential to check the current nutrition status and to apply timely as well as balanced fertilizers in modern fruit orchards (Moral et al. 2011).

**Organic nutrient management**

Organic fertilizers are made up of larger molecules and substances that take more time to be broken down into usable form by the plant. In recent years, the quick and considerable response to fruit production due to mineral fertilizers concealed the use of organic manures; the insufficient supply of the latter sources impaired such modification. However, these fertilizers are energy intensive, costly and moreover, extensive use of such fertilizers with low doses of organic manures deteriorates the soil fertility and plant health as well by reducing the organic matter content and beneficial soil micro flora. The integrated nutrient management provides a vital component for improving the soil fertility and plant health for optimum crop production. These routes are operated using FYM and bio-fertilizers along with different inorganic fertilizers. The usage of bio-fertilizers for crop production is gaining momentum as they are environment friendly than inorganic fertilizers. Regular nutrient application using suitable fertilizers, or alternative use of nutrients enriched with organic manures and bio-fertilizers in integrated nutrient management results in quality fruit production. Bio-fertilization increased the shoot height by improving the hormonal status of the plant. Integrated application of chemical fertilizers, organic and biological nutrient sources in an effective way, would not only reduce usage of chemical fertilizers but will also influence the vigour of the plant as well as reduce the environmental risks.

Organic fertilizers not only supply various nutrients for crop production, including micronutrients, but they are also a good source of organic matter production. Organic matter improves the soil structure or tilth, increases the water-holding capacity of coarse-textured sandy soils, improves the drainage of fine-textured clay soils, slowly releases the nutrients, reduces wind and water erosion, and promotes growth of earthworms and other beneficial soil microorganisms. Low application rates of manures and compost can lead to nutrient deficiency and low yields. On the other hand, higher rates of such fertilizers result in nitrate leaching, phosphorus runoff, accelerated eutrophication of lakes, and excessive vegetative growth. Thus,
understanding how to manage manures or compost as organic fertilizers is important for any farming operation with livestock that depend on manure as key source of nutrients, as well as for vegetable growers who have an access to cheaper supply of manure, compost, or other sources of organic nutrients.

Integration of organic fertilizers is a common practice to improve the yield of many fruit crops. It also limits the chemical interference and finally reduces the adverse effect on the environment. Due to the high cost of inorganic fertilizers and poor purchasing capacity, organic fertilizers have been used for their eco-friendly and beneficial effect on environment and fruit crop production. Good quality organic manures such as, vermicomposting, bio-fertilizers and green manures are the most valuable source of organic matter applied to the soil. All these types of organic matter are very useful to the plants and soil. FYM consists of decomposed mixture of cattle dung and remnants of straw and plant stalks fed to the cattle. Green manuring is also a good source of organic fertilizer. Green manuring is practiced by ploughing or turning the green plant tissues into the soil for improving physical structure as well as fertility level of soil. Some green manure crops accumulate high levels of phosphorus and are thought to increase the availability of phosphorus to subsequent crops by returning it to the soil in organic form. For further detail, see chapter 9.

7.9.5. Irrigation

The artificial application of water to the land or soil is known as irrigation. It is used in growing of crops/orchards, maintenance of landscapes and re-vegetation of disturbed soils in dry areas during periods of poor rainfall. Moreover, irrigation also has some other uses in crop production, i.e. protecting plants from frost and prevents soil compactness (Williamson and Coston 1990). To optimize irrigation schedule, the variables of weather, water availability, and plant stress must be considered. These variables may change throughout the irrigation season, increasing the complexity in determining when irrigation should occur and the amount of water to apply. To determine how much water to apply, the irrigation needs of the plant must be calculated (Williamson and Coston 1990). This amount is weather driven and is influenced by the humidity, temperature, and day length time. The demand for water by tree is equal to rate of evapo-transpiration (ET). ET accounts for the loss of water through soil surface, loss of water through leaves and through stomata that allow the gas exchange required for photosynthesis. In Asia, all orchards have not access to sufficient irrigation, though, adequate watering during the early years can help in tree establishment. The time and volume of water applied varies with tree size, soil, weather and time of year. Maximum water use in year four in summer would be 160 liters per tree. Irrigate orchards two to three times a week in sands and one to two times a week in heavy clays is recommended for good crop production (Bal 2007). Different irrigation systems can be used in orchard as per availability of capital and volume of water for irrigation. These irrigation systems are discussed below.

Surface irrigation

In surface irrigation, water is introduced into furrows or borders from the top of the orchard surface soil. This method is more suitable for sloppy lands where furrows are made alongside the contours. The furrow length is determined by soil
permeability, which varies from 10-20 ft. However, the length is shorter on sand and sandy loam soils as compared to clay and clay loams. During down-slope water application, some of the water infiltrates into the soil. Through surface irrigation, water is applied excessively, so that excess water infiltrates into soil or flows outward across the orchard. When water reaches the lowest part of the orchard or end of the orchard, water is shut off or the end of the orchard is blocked with berms to keep the water in the orchard. Shutting the water off before it reaches the end of the orchard is more common when border and furrow irrigation is used. In furrow irrigation, the orchard is often accompanied by 10 to 15% of the applied water lost as runoff. This irrigation system is more valuable in free flooding and least in furrow irrigation. In this method, frequent hoeing is necessary to restore the soil tilth. There are several types of surface irrigation, for example, flooding, basin, and modified basin system.

**Drip and bubbler irrigation**

Drip irrigation is the most effective method of irrigating the orchards. It saves time as well as conserves precious supply of clean water (Selim et al. 2009). In drip irrigation, water is directly delivered to the plant root zone through drip pipes and emitters, where it leaches slowly drop by drop into the soil (Fig. 7.10). In this method, no water is lost through surface runoff or evaporation, and soil particles have plenty of opportunity to absorb and hold water for plants. This system of irrigation is found 90% or more efficient than other irrigation systems (Selim et al. 2009). Due to this reason, it is the preferred method of irrigation in desert regions. It has other benefits which make it useful almost anywhere (Vories et al. 2009; Ahmed et al. 2012). It is easy to design, easy to install, and can reduce the problems of disease associated with high levels of moisture in some plants, but it may be expensive for small land holding farmers. There are two key factors which lead to higher drip irrigation efficiency, (a) water percolates in the soil before it can evaporate or run-off, and (b) water is applied on those points where it is required rather than sprayed everywhere. Plants watered with drip irrigation grow rapidly and are more productive, because they use water as they need and water stress does not slow their growth process. Plants irrigated with drip system do not wet their foliage as from sprinkler system, so they escape from several foliage diseases. In bubbler irrigation system, emitters are placed above the soil and irrigation water is applied through thin spray close to the soil (Fig. 7.11). Fertilizers can also be added in the irrigation water, which facilitates its equal distribution to all plants.
Fig. 7.10  Drip irrigation system in apple orchard.

Fig. 7.11  Bubbler irrigation system in peach orchard.
Sprinkler irrigation

Globally, the supply of water is becoming reduced with the passage of time; the usage of sprinkler irrigation is gaining more importance for the development of agriculture and forest sector (Fig. 7.12). Adaptable and powerful sprinkler irrigation technique can be used economically under various topographic conditions, because it requires least developed land, the main advantage over all other systems. Irrigation through sprinkler is valuable for sandy soils or any other soil, where surface irrigation may be ineffective or costly or where erosion may be chiefly risky. This system of irrigation enables lower rate of water application for germination of seeds, delaying of fruiting bud and crop harvesting in hot weather.

In this system of irrigation, the mixed application of fertilizers and pesticides is probable; hence the efficiency of this system is more than surface type of irrigation system as it saves the labour cost. However, this system has certain demerits such as (i) initially it is very costly, (ii) continuous and higher energy is needed for operation, (iii) the distribution and efficiency of water is poor under high windy conditions and high temperature, (vi) water is lost through evaporation, (vii) spray on plant foliage may cause washing of chemicals and generates more risk of pests and diseases, and (viii) deposition of salts on leaf surface if available water is saline. Irrigation through sprinkler would enable the farmers to achieve higher crop productivity with least possible water supply from the reservoir.

Fig. 7.12 Sprinkler irrigation installed at sub-mountainous area of Khushab.
7.9.6. Weed Management

Weeds are plants growing where they are not wanted, and usually interfere with the production of fruit crops. These weeds compete with trees for water, nutrients, sunlight, and act as natural habitat of insect pests and diseases (Mayberry et al. 1995). In orchards, most of the weeds are perennial, having underground roots or stems, which produce abundance of seeds and remain viable in the soil for very long period. Weeds mainly distributed through wind, water, air and via animal manures etc. Eradication of weeds from orchard is necessary as these compete with the water and nutrients in fruits trees (Wagner-Riddle et al. 1996). Various types of weeds such as bathu, pohli, piazi, pit para etc. are commonly known as winter season weeds. On the other hand, motha, kahi and barhu commonly grow in rainy seasons. The presence of weeds in orchards usually reduces the fruit production. Weeds can be controlled through many ways such as mechanically, competitively, biologically and chemically. However, combination of one or more of such methods gives more effective results as compared to any single one to eradicate the weeds.

Mulching

Mulching is a soil management technique in which different types of raw materials, like hay, straw, grass, dry leaves, wood shavings, weed scrapings, paper or polyethylene, is placed on the soil surface between the rows of fruit plants (Fukuda 1994). The application of mulches also affects the soil organic matter content, activity of soil born microorganisms, availability of nutrients, soil compaction and erosion (Engel et al. 2001). Mulches improve water holding capacity of the soil. The main purpose of mulching is to conserve the soil moisture, temperature regulation, weeds control and production of high quality fruit (Himmelsbach 1992; Stojanowska 1994). Moreover, weeds are controlled without disturbing the soil surface, which minimizes the waterloss by evaporation. However, organic mulches are susceptible to fire outbreak and also facilitate the hibernation of rodents. Polythene mulching is also beneficial to control insect-pests in some crops, e.g. inflorescence midge in mango.

Zero tillage

Generally, the zero tillage is a farm based operation that reduces the costs while maintaining the yield and protecting the environment. Zero tilling or no-tillage farming is a way of raising crops without any mechanical or manual disturbance of the soil surface. In this system, weeds are eradicated by using herbicides, orchard soil is left bare without cultivation, thus there is no water penetration under the soil surface and no growth of weeds. This system obviously reduces the cost of cultivation and harvesting operations. The adoption of zero tillage technology has advantages such as reduction in the sowing cost, increased fertilizer and water use efficiency (WUE), reduced soil erosion (Hernandez et al. 2005) and ease in farm operations. The most powerful benefit of zero tillage is improvement in biological fertility of soil. However, this system has some drawbacks such as quick soil dryness, and more frequent irrigations are required.
Clean cultivation

The clean cultivation is the operation in which orchard land is always kept free from any kind of grasses or vegetation. This system is helpful to control the weeds and improves the soil moisture retention; soil aeration makes the soil more fertile by increasing the nutrient availability. Continuous application of clean cultivation without addition of organic matter or any kind of legume crop results in the depletion of soil nutrients. Conventional clean cultivation is highly productive when practiced within the timeframe of a single growing season. Clean cultivation for extensive periods accelerates the soil erosion, loss of organic matter and deterioration of soil physical properties.

7.10. Use of Plant Growth Regulators

Plant growth regulators (PGRs) are the organically produced compounds, other than nutrients, which in minute quantity promote, inhibit, or modify the plant growth mechanisms. PGRs are important constituent of good and quality fruit production. These PGRs can be used to reduce the excessive vegetative growth, to modify tree shape or to initiate the fruiting. Auxins, gibberellins (GA), cytokinins, abscisic acid (ABA), and ethylene, are the most important PGRs that are produced naturally in the fruits (Escalada and Archbold 2009). The first three PGRs are used to increase the strength of fruit tissues while last two are known to promote the ageing and senescence processes in fruits. The jasmonates are also naturally occurring PGRs and known to regulate the numerous aspects of plant growth and development and responses to biotic and abiotic stresses. GA and 2, 4-D is the most extensively and commercially used PGRs in fruit crops. Both of these chemicals have pre and postharvest applications. The pre-harvest application of 2, 4-D delays and reduces the abscission of fully mature fruits and increased the fruit size in citrus fruits. Ethylene causes a slight enhancement of GA₃ metabolism in orange fruits (Choi et al. 2002). Ethylene accelerates the senescence of fruits and chemicals have been developed to mitigate its effect. Plant bio-regulators, such as 1-methylecyclopropene (1-MCP) and Aminoethoxyvinylglycine (AVG), have an inhibitory activity against ethylene production. 1-MCP is an ethylene inhibitor that apparently binds to the cellular ethylene receptor proteins and effectively inhibits the ethylene responses by making plant tissue insensitive to ethylene. 1-MCP is a non-toxic and odourless plant growth chemical (McArtney and Obermiller 2008). In ‘Shamouti’ oranges, 1-MCP effectively inhibits the negative effect of ethylene and delays the process of degreening. However, it is shown to be unsuccessful against ethylene effects such as enhancing the chilling injury and increasing of decay.

7.11. Integrated Pest Management

Integrated pest management (IPM) is an inclusive method that integrates the practices for economic control of pests (Nelson 1994). It helps the community to control the insect-pests, diseases and weeds, economically, and improving human healthy by preventing the environmental pollution. It is called as integrated because
IPM directs the use of biology of pests, information about environment, and available technology to prevent unacceptable levels of pest damage through economical means by least damage to the people and environment. In IPM techniques, different types of methods are included such as pest-resistant varieties, pest scouting, forecasting of pests, cultural, physical, biological control, and judicious use of pesticides (Singh et al. 2001). The major objective of IPM is to control the pest population below the level of economic injury. In IPM programs, synthetic pesticides are used along with monitoring, biological control, and organic materials. In IPM, synthetic insecticides are applied at periods that curtail damage to useful organisms. The major goal of IPM strategies is to produce high quality fruits at low cost without causing any adverse effect on environment. Growers, who adopt IPM techniques, don’t try to eliminate the pests, but try to suppress the pest populations to such a level that would be economical. IPM entails the knowledge of pests and the coordination of all fruit production mechanisms (Smith et al. 1997). The IPM techniques are specific to the agro-ecological production conditions in any given area, and may include the usage of pesticides. Thus, only a few general principles can be applied and no absolute standards have been set for crop production. IPM seeks to reduce the pest populations to economically manageable levels through a combination of cultural control (e.g. crop rotation, inter-cropping), physical controls (hand picking of pests, use of pheromone traps), and less toxic chemical controls. This technique shields the environment from excessive or unnecessary application of pesticides (Whalon and Croft 1984). The excessive use of spray is slow poising for human body and has following problems:

**Resistance in pests against pesticides**

First spray of insecticide kills the insects but after some period these insecticides become ineffective and higher doses are required to kill these insects. It is because a genetic mutation is developed in pest and they become resistant to pesticide(s) (Daly et al. 1998).

**Killing of friendly insects**

There are so many species of insects, which are beneficial for growers, because these insects play important role in pollination and in pest control. These can also be killed by the spray of pesticide.

**Environmental pollution**

Most of pesticides are toxic and remains in the air and damage the living organism. Therefore, it is very important that awareness about the IPM should be developed among the growers so that they can reduce the pollution and keep them healthy by reducing the unnecessary use of pesticide. IPM program prescribes common sense strategies to reduce sources of food, water and shelter for pests in buildings, crops, and grounds. The control of pests by this method is economical and a safe for human.
7.12. Weather Station Installation in Modern Orchards

A modern orchard is that where precise and advanced management practices are followed and plants can be protected against the adverse climate by knowing the accurate advanced information about the local weather. Weather station provides information regarding the local weather. Installation of the weather stations is very imperative for the higher yield and fruit crop management in the modern orchards. Weather station should be installed in every modern fruit orchard. This is consisted of following components:

7.12.1. Soil Moisture Meter

Water is the basic necessity for plants but the excessive irrigation or moisture in the soil is more harmful for some fruit plants as compared to drought. Application of water when soil is wet and without need of the plants is known as over irrigation. Now, different soil moisture meters are available which are installed in the orchard at different places. They give the reading about the soil moisture and proper soil moisture can be managed at proper times. It is because the precise soil-moisture measurement is one of the fundamental components for the good irrigation management of modern fruit orchards.

7.12.2. Air Humidity Hygrometer

Relative humidity is the amount of water vapours present in air, and can also be defined as “the ratio of partial water pressure, to the equilibrium vapour pressure of water at a given temperature”. It is directly related to the rate of transpiration, which is considered a vital mechanism of fruit plant affecting the growth and use of minerals. The hygrometers are installed in the orchards to measure the moisture contents in the atmosphere so that some protection/precautionary measures can be adopted timely to protect the fruit trees.

7.12.3. Air Temperature Thermometer

This type of thermometer is mostly used in the orchards to measure the freezing and very high temperature. Both limits have a negative effect on orchards and farmers can manage it properly. The advanced weather forecasts help to protect the plants against the frost. Wind machines are installed to mix the warm air among the trees. Wind direction is very important consideration that should be determined before the installation of wind machines.

7.12.4. Precipitation/rain gauge

Rain, hail and condensation of water vapour in air in the form of fog or dew, all have huge impacts on the fruit crops. Fruit orchard precipitation sensors provide correct measurements of the effects of these phenomena on the orchard field.
7.12.5. Soil Temperature Sensor

Soil temperature can be a critical limiting factor for growth of the fruit tree and for development of different insect-pests. Many rootstocks of fruit plants are temperature sensitive and start root activity at different soil temperature while scion is still dormant. Therefore, fruit orchard with soil temperature sensor installed at weather station will enable the precise monitoring of pest and diseases as well as forecast the growth of fruit trees.

7.12.6. Leaf Wetness Sensor

Sensors in fruit orchards can even detect a small amount of water on the surface of the sensor. The leaf wetness of fruit orchards will determine the ability of different pathogens to cause any serious disease such as downy mildew of grapes or powdery mildew of mango.

7.12.7. Solar Radiation Pyrometer

Solar radiation is the actual energy source of fruit plants that can vary significantly over small stretches of orchard land. Weather station sensors have the ability to measure different aspects of the solar energy on the fruit orchard surface.

7.12.8. UV Radiation Sensor

UV-B radiation significantly influences many aspects of the fruit plant biology. So, sensors in locally installed weather stations in modern fruit orchards allow growers to monitor the important part of the solar radiations.

7.12.9. Characterization of Orchard Variability

Characterization of the fruit orchards variability is the most important step because other steps can be implemented successfully if variability is correctly known. For example, field variability in the form of orchard topography, elevation and orchard boundaries can be determined with proximal or satellite based remote sensors in GIS.

Orchard soil can vary for physical and chemical properties. Proximal soil sensor has the capabilities to provide true information with respect to high spatial or temporal resolutions in orchard soil variations. Moreover, the proximal soil sensors are considered more accurate as compared to the remote sensors.

Similarly, fruit crop variability, which is the variability in different aspects of the fruit trees such as, height, density, nutrient level and water stress, can also be accurately estimated by sensors.

Moreover, variability in the orchard weed density, nitrogen contents, pest and disease infestation and leaf chlorophyll contents, can be successfully determined by
the remote and proximal sensors with GIS. Two sensing systems are briefly described as under.

**Differential Global Positioning Systems (DGPS)**

Differential global positioning systems (DGPS) is a network of the satellites that is used for the location identification of data points of fruit trees and the soil attributes regarding the latitude, longitude and elevation with utmost precision. So, orchard inputs can be customized to the individual locations based on precise DGPS provided information.

**Geographic Information System (GIS)**

Geographic Information System (GIS) integrates complete system of hardware, software and collected data for the characterization, management, analysis and display of all forms of geographically referenced information of fruit orchards. A GIS is able to accept, organize, statistically analyses and display of diverse spatial data, which are digitally mentioned to a common coordinate system (Pickles 1995). When these different data sets are grouped and covered to combine the new data sets, which can be used for the further allocation decisions of the modern fruit orchards.

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