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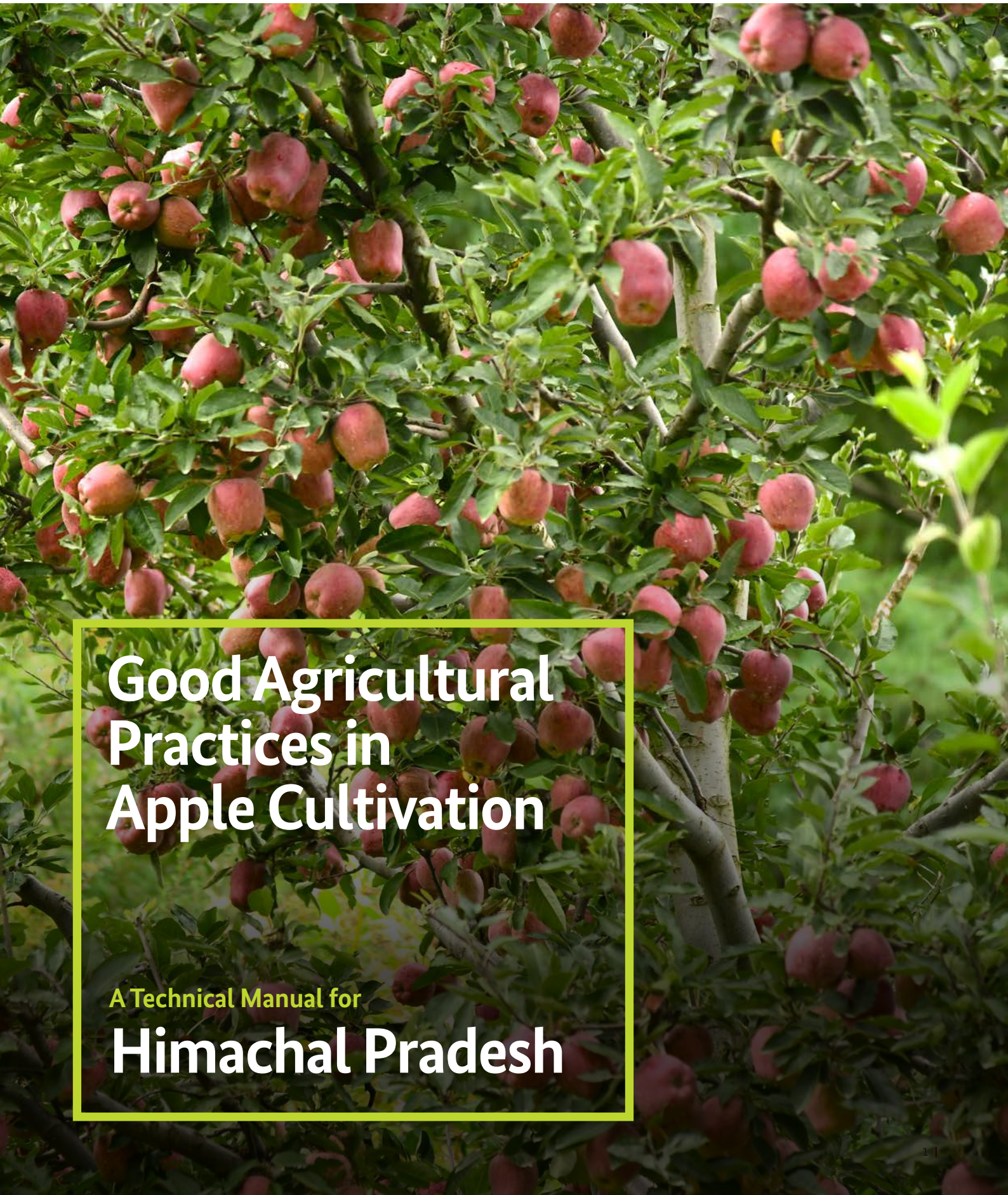

# Good Agricultural Practices in Apple Cultivation

## A Technical Manual for Himachal Pradesh

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

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Bengaluru, October 2024

# GOOD AGRICULTURAL PRACTICES IN APPLE CULTIVATION

## A Technical Manual for Himachal Pradesh

# Foreword from GIZ

**The global programme "Green Innovation Centres for the Agriculture and Food Sector (GIC)", commissioned by the German Federal Ministry of Economic Development and Cooperation (BMZ), is being implemented in India by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, in cooperation with the Ministry of Agriculture & Farmers Welfare (MoA&FW).**

The project has been working on the integrated development of the tomato, potato and apple value chains, focusing on identifying and scaling innovations that enhance the productivity and income of smallholder farmers and small-scale farming enterprises, promoting good agricultural practices and supporting FPO development. In this way, the project lays the groundwork that allows farmers to adopt agroecological practices and contribute to the transformation towards sustainable and climate-resilient food systems.

Apple farmers are confronted with multi-dimensional problems, such as climate change and a decrease in chilling hours, post-harvest losses, lack of alternatives to chemical inputs, and decline in pollinator populations. These challenges keep productivity low which negatively influences the farmers' income. To address this, the project has introduced many innovations such as manuals on good agricultural practices with scientific backstopping, pollination as an ecosystem service, solar-powered cold storage and solar dryers, trainings in food processing, and efficient irrigation techniques. Overall, the project has adopted sustainable agriculture practices to protect the soil and environment.

In Himachal Pradesh, the GIC project has been working in the apple value chain in Shimla and Kullu districts. The project is being implemented in close cooperation with the Department of Horticulture (DoH) Himachal Pradesh, Dr. Y S Parmar University of Horticulture and Forestry, (UHF) Nauni, and the Krishi Vigyana Kendra, and other implementing and private partners. The project has successfully demonstrated several innovations to achieve the key objectives.

GIC India promotes 'innovation bundles', which combine individual interventions to tackle multi-dimensional economic, social, and environmental challenges. Innovation bundles build evidence and promote proven solutions for upscaling through regional and national strategies and policies.

The project has worked towards disseminating the promoted good agricultural practices by training master trainers. These technical manuals on various aspects of apple production are useful tools for expanding the project's efforts. This document is prepared with the involvement of UHF and the DoH Shimla. I sincerely thank these organisations for contributing their learnings and hope that this technical manual will help to scale up sustainable agricultural practices in apple cultivation in Himachal Pradesh.

**Ms. Regina Sanchez Sosa**
Project Director
Green Innovation Centres for the Agriculture and Food Sector – India

# Message from Department of Horticulture, Himachal Pradesh

**Since 2016, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) India, under the project Green Innovation Centres for the Agriculture and Food Sector (GIC) India has been focusing on the apple value chain in the Kullu and Shimla districts of Himachal Pradesh.**

With an ever-growing demand for sustainable agricultural practices and the need to enhance the livelihoods of farmers, this project stands as a beacon of innovation and collaboration. The Memorandum of Understanding signed between our department and GIZ underscores our commitment to fostering agriculture innovation and promoting holistic development in the horticulture sector. Through this partnership, we aim to leverage climate -smart technologies and best practices, and knowledge exchange to empower apple farmers and uplift the entire apple value chain.

The joint goal of the Himachal Pradesh State Department of Horticulture (DoH) and GIZ is to create scalable models, processes, technologies, and knowledge management systems that can be effectively implemented by the DoH. Our aim is to enhance the income and productivity of smallholder farmers while ensuring the sustainability of the apple industry. Through innovative approaches and scalable solutions, we seek to address the challenges posed by climate change and foster resilience. By collaborating closely with stakeholders, leveraging expertise, and embracing a spirit of innovation, we are committed to realizing these goals and making a meaningful impact on the livelihoods of apple farmers in Shimla and Kullu districts.

The manual, which compiles sustainable farming practices for apple crop, will undoubtedly help all extension functionaries and farmers as a practical knowledge source. It is the result of combined efforts by GIZ India, the Department of Horticulture, and scientists from the Dr. Y S Parmar University of Horticulture and Forestry, Solan and will help make apple farming more sustainable and profitable.

As we embark on this journey, I extend my heartfelt gratitude to all the partners, stakeholders, and collaborators who have contributed their expertise, resources, and unwavering support to make this project a reality. Together, we can cultivate a greener, more prosperous future for the apple growers of the state of Himachal Pradesh, while ensuring environmental sustainability and socio-economic progress.

**Mr C. Paulrasu, IAS**
Principal Secretary, Horticulture
Government of Himachal Pradesh

# Message from Dr YS Parmar University of Horticulture & Forestry

**Apple fruit is the oldest, commercially the most important, and high value temperate horticultural crop of Himachal Pradesh. With its unique climatic conditions, the state has been blessed with some of the finest varieties of apples in India. However, to ensure the sustainability and profitability of apple farming in face of multiple challenges including climate change, it is imperative to adopt climate-smart practices and technologies.**

Through the Green Innovation Centers for the Agriculture and Food Sector (GIC) project implemented by GIZ India, we aim to empower apple farmers with the necessary skills and knowledge to enhance their productivity, quality, and marketability. We want to create a conducive environment for the growth of the apple industry, benefiting not only the farmers but also the entire community.

It is with great pleasure that I introduce the collaborative efforts of the GIC project and Dr. Y.S. Parmar University of Horticulture and Forestry (UHF), which aim to promote Good Agricultural Practices (GAP) in the region and provide essential knowledge through these manuals.

In this context, the research accomplishments and Good Agricultural Practices of apple cultivation practices have been compiled in the form of manuals. They serve as a comprehensive guide, covering various aspects of apple cultivation, from orchard management to post-harvest handling. These manuals are designed to be accessible and practical, catering to the needs of all kinds of farmers. I am sure this manual will help different stakeholders of the farming community to improve their knowledge, resulting in better income and sustainable horticulture development.

These manuals aim to enhance the skills of farmers, officials, and members of Farmers Producer Organizations (FPOs), creating a cadre of trainers equipped to disseminate knowledge and best practices within their communities. These barefoot trainers will sustain the capacity building process by providing farmers with the necessary skills in apple cultivation practices and creating a multiplier effect.

I am confident that through these collaborative efforts, we will foster a culture of continuous learning and improvement within the apple farming community. Together, we can create a sustainable and prosperous future for apple farming in Himachal Pradesh.

My best wishes and congratulations to whole team.

**Dr. Rajeshwar Chandel**
Vice-Chancellor,
Dr. Y S Parmar University of Horticulture and Forestry,
Solan, Himachal Pradesh

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# List of Abbreviations

| | |
|---|---|
| BMZ | Federal Ministry for Economic Cooperation and Development, gemrany |
| DoH | Department of Horticulture, Himachal Pradesh |
| FYM | Farm Yard Manure |
| GIC | Green Innovation Centres for the Agriculture and Food Sector |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit gmbh |
| IPM | Integrated Diseases and Insect-pest management |
| MoA&FW | Ministry of Agriculture & Farmers Welfare, Government of India |
| UHF | Dr. YS Parmar University of Horticulture and Forestry, Nauni |

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# INTRODUCTION

# Apple (Malus domestica) belongs to the genus Malus in the Rose (Rosaceae) family.

Apple trees are generally small when cultivated, with a height between 2 and 4.5 meters. If left untrimmed, a tree grown with standard rootstock can reach a height of 9 meters (30 feet) with an equally large crown diameter. The bark is usually brown and scaly. The simple leaves are roughly oval and usually have serrated margins. Apple flowers are showy with five white petals, often tinged with pink, and numerous stamens. Bees and other insects pollinate the flowers, and most varieties require cross-pollination for fertilisation.

The apple fruit is a pome (fleshy) fruit in which the ripened ovary and surrounding tissue become fleshy and edible. When harvested, apples are usually roundish, 5–10 cm (2–4 inches) in diameter, and some shade of red, green, or yellow; they vary in size, shape, and acidity depending on the variety of which there are thousands.

In India, the total area under apple cultivation in 2020-21 was 3,12,620 Ha, with a total production of 22,75,840 MT. The average productivity was 7.28 MT/Ha. Jammu and Kashmir is the most important apple-producing state, followed by Himachal Pradesh and Uttarakhand. Both the area under cultivation and the total production are on an increasing trend. India ranks fifth in terms of production amongst apple-producing countries in the world. In 2020-21, India exported 30,680 MT of apples worth Rs. 106.65 Crores, which has more than doubled in 4 years between 2017 and 2021.

The apple is a temperate fruit crop. However, the apple-growing areas in India do not fall in the temperate zone. However, the prevailing temperate climate of the region is due to the Himalayan ranges and high altitudes. The average summer temperature for apples should be around 21-24 degrees Celsius during active growth. Apple succeeds best in areas where the trees experience uninterrupted rest in winter and abundant sunshine for good colour development. It can be grown at an altitude of 1500- 2700 m above sea level. Well-distributed rainfall of 1000-1250 mm throughout the growing season is most favourable for apple trees' optimum growth and fruitfulness.

Himachal Pradesh is called India's fruit basket, with a total area of 2,34,780 Ha under fruit cultivation and a production of 6,24,490 MT in 2020-21. Apple accounts for 1,14,650 Ha area with a total production of 4,81,060 MT in 2020-21. Apple contributes about Rs. 5000-6000 crores to the state economy, contributing more than 80% of the total fruit production in Himachal Pradesh. Shimla and Kullu districts constitute approximately 65% of the total area under cultivation in apples and rank the highest and second highest among all districts in the state in production, respectively.

Apple production is susceptible to climate change, which will cause an increase in temperature and variability in precipitation. The excessive use of chemical fertilisers and pesticides has decimated the populations of most pollinators (bees, butterflies, and insects); poor pollination has, in turn, compromised apple production. Any negative impact on apple production due to climate change will impact the horticultural economy, which provides livelihoods and income for lakhs of families and other value chain actors from production to consumption.

# About Green Innovation Centres for the Agriculture and Food Sector - India

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is a public-benefit federal enterprise of the German Government. In its projects, GIZ works with partners in national governments as well as actors from the private sector, civil society and research institutions. GIZ's main commissioning party is Germany's Federal Ministry for Economic Cooperation and Development (BMZ). Other commissioners include the European Union, the UN, the private sector, and governments of third countries.

The global programme "Green Innovation Centres for the Agriculture and Food Sector (GIC)" is funded through the Special Initiative "Transformation of Agricultural and Food Systems" of the BMZ. Since 2016, the project is implemented in India by GIZ in cooperation with the Ministry of Agriculture & Farmers Welfare (MoA&FW). In Himachal Pradesh, the project works in collaboration with the Department of Horticulture, Himachal Pradesh.

Working in the Rohru and Chirgaon regions of Shimla district and the Naggar and Kullu regions of Kullu district, the GIC project identified, tested, and introduced various innovations in a participatory manner involving the farmers.

GIC India, in partnership with the Department of Horticulture, Himachal Pradesh (DoH) and Dr. YS Parmar University of Horticulture and Forestry, Nauni (UHF), has created manuals and implemented trainings in Good Agriculture Practices in apple cultivation in Himachal Pradesh. These Good Agriculture Practices cover canopy management, pollination management, nutrition management, and integrated pest management. Further, Training of Trainers will be conducted to create a local pool of trainers who will further disseminate these practices.

This manual is meant to introduce and give a snapshot of the Good Agricultural Practices that have been promoted on which farmers and trainers have been trained in Shimla and Kullu districts. These manuals and trainings will enhance the farmers' skills and knowledge in nutrition and soil health management in apple orchards. The manual seeks to convey an interactive, well-designed and facilitative approach to learning for the target group of farmers.

# Acknowledgements

Various institutions and individuals have contributed to the technical content of these manuals, which are acknowledged below.

- Scientists from Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan
- Ms Kavita Bhardwaj and Mr Umesh Kumar, Agriculture Experts, GIZ India
- Experts from the Kompetenzzentrum Obstbau Bodensee, Germany
- Senior consultants - Dr Joginder Singh Chandel, Retired Head of Fruit Science, Dr YS Parmar UHF Nauni and Dr Shamshar Singh Rana, Retired Associate Director, RHRTS Nurpur UHF Nauni

# CANOPY MANAGEMENT

# 01

Canopy management is a crucial practice in apple orchards, involving training and pruning of the tree's above-ground parts. Young trees are pruned to achieve the desired shape and framework while bearing trees are pruned to regulate vegetative growth, flowering, and fruitfulness for quality fruit yields. Regular practice helps fruit growers develop intuitive skills for good pruning, requiring knowledge of plant physiology and growth behaviour. Working with nature is essential for steering the tree in the desired form and producing abundant fruit. Proper canopy management increases the penetration of light that reduces incidence of pests and diseases and also allows easier access to fruits for disease and infection control. This reduces use of chemical pesticides, thereby promoting agroecology.

This manual aims to provide an understanding of the basics of training and pruning apple trees and the techniques used in this process.

# 1.1 Reasons for Pruning Fruit Trees

Professional fruit growing requires fruit crops that enable regular and sustained high financial returns from natural yields and good prices. These crops must also be cultivated as efficiently as possible in terms of labour input and costs. The shape of the tree canopy is, therefore, particularly important in converting as much productive sunlight as possible into good fruit. A good, productive canopy is the result of a series of steps.

The orchardist's central task is training fruit trees from planting to full yield and caring for the tree canopy. This guide explains the rules and practical applications of pruning apple trees in various situations.

The main reasons for pruning fruit trees are as follows:

- Promotion of health and longevity
- Yield increase
- Shaping and size control
- Removal of water sprouts and suckers
- Safety and accessibility

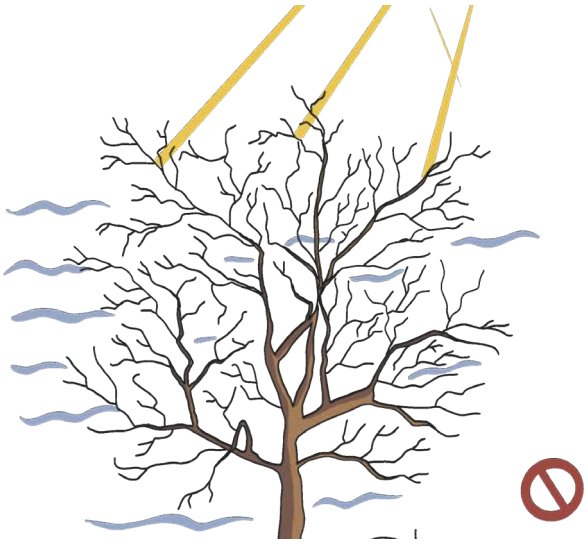


Figure 1.1: An unpruned apple tree is equivalent to lower vitality, no sunlight inside, more fungal diseases, and thereby lower yields, poor fruit quality, and poor accessibility

# 1.2 Basic rules of growth in fruit trees

## 1.2.1 Structure and development of canopy

Canopies consist of a main axis (trunk and trunk extension) and lateral axes of the first, second, third and higher order. The main axis and all lateral axes carry the fruit wood. Lignified shoots of fruit trees from previous years are summarised under the term old growth. Young shoots, the new growth, emerge from the buds of the old growth every year.

**Branch angle:** The shoots which develop on a leader or maiden whip form a certain angle with the leader. When the angle is narrow, it is called a narrow crotch-angled shoot. The narrow-angled shoots, if developed into scaffold branches, are weak in strength and split very easily with crop load and should be removed (Fig. 1.2). Another reason for their removal is that they grow very vigorously. Therefore, pruners should keep in mind that they should retain only wide-angled scaffolds and remove all other narrow crotch-angled branches.

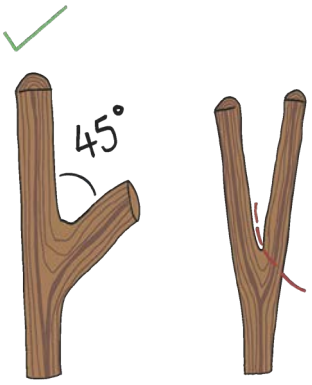



Fig. 1.2: Wide-angled scaffolds and narrow crotch-angled branches

## 1.2.2 Basic pruning rules

**Heading or thinning:** When pruning fruit trees, smaller or larger sections can be completely thinned out (thinning) or only cut back (heading).

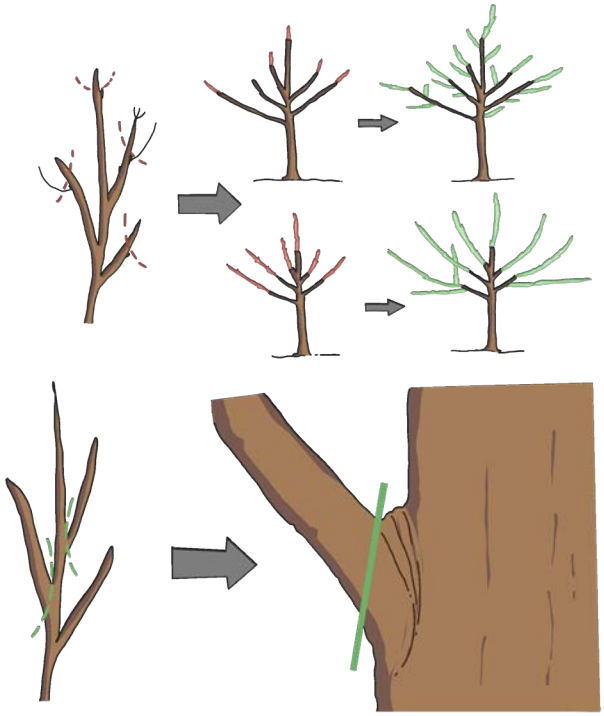


Figure 1.3: Heading and thinning


Figure 1.4: Reaction of a shoot to pruning

Thinning involves completely separating branches or twigs at their point of attachment. The existing growth relationships of the remaining branches in the overall system are largely retained.

After pruning, the tree will sprout again. The more a tree is pruned back in winter, the more it will sprout again in spring. Pruning too hard can lead to excessive new growth.

The reactions of individual shoots to varying degrees of pruning are summarised in pruning rules:

- The strength of the new shoots depends on the pruning intensity and the time of pruning
- The more pruning is carried out, the more vigorously the new top shoot will develop. However, this no longer applies if you prune back to the dormant eye zone.
- If pruned back hard, few strong shoots will develop from the remaining shoot.
  Consequence: Pruning measures here serve the tree structure.
- The total growth of shoots increases with increasing pruning intensity.
  Consequence: Heavy pruning has a growth-stimulating effect on the tree. Too much growth is bad, as the tree has to be pruned again. The tree becomes “restless“.
- Short pruning causes short shoots with flower buds to develop on the longer remaining shoot.
  Consequence: Pruning measures here serve to promote flowering.
- The number of buds that do not sprout is reduced by severe pruning.
- The more a shoot is pruned back, the fewer flower buds it will produce the following year.

## 1.2.3 Influence of the position and strength of a shoot within the tree structure on its growth

The vigour of the shoots depends on their position in the tree canopy. The following growth rules must be observed.

- Side shoots with the same length and thickness

have the same attachment angle and are set at the same height in the canopy, developing equally strongly. Consequence: When pruning, pay attention to the "sap balance", i.e. the cuts are made at the same height.

- If one of the comparable shoots is thicker and the other thinner, the thicker one will grow more vigorously.
  Consequence: In this situation, balanced growth is achieved by tying the thicker shoot downwards and the weaker one upwards.
- Long shoots grow more vigorously than short ones.
  Consequence: equally strong development occurs if the long shoot is pruned and the short one is not.
- Of otherwise comparable shoots, steep shoots grow more strongly than flat shoots.
  Consequence: If steep shoots are formed horizontally, growth is equalised
- If comparable shoots or branches attach to the main axis or trunk at different heights, the higher ones will grow more vigorously.
  Consequence: If you cut them all back to the level of the lower-lying one - "on the sap balance" - or shape them accordingly, they will grow evenly.
- Pruned extension shoots do not grow as strongly in the vicinity of unpruned competitor shoots as when all shoots in the tree are pruned evenly.

Using the sap balance with the left stronger branch and right weaker branch:
The right branch cut slightly higher than the left branch results in equal growth vigour; in the following year, they are treated equally to avoid further uneven growth.

## 1.2.4 Influence of Pruning Intensity on the Tree as a Whole

Intensive pruning leads to strong new growth and tends to inhibit flower formation. The proportion of old growth with productive fruit wood is lower. Young trees produce later, and yield trees are more prone to alternation.

When pruning, pay attention to the number and position of the flower buds on the branches. If the majority of the flower buds are removed during pruning, this will result in weak flowering, few fruits and an entry into future alternation.

## 1.2.5 Possibilities of Weakening Growth Through Suitable Pruning

Pruning can be used to weaken growth for canopy, height limitation and growth control. There is a choice of certain forms of pruning, the time of pruning and the shaping of parts of the canopy.

- Pruning to strong buds results in a strong growth impulse; pruning to weak buds results in relatively weak new growth.
- Pruning back to a flower bud (pruning to flower bud) always has the effect of weakening growth.
  Consequence: Be careful when pruning shoots that serve the tree's structure, such as the central stem-forming central shoot. Pruning to leaf bud stimulates growth; pruning to flower bud slows growth when the final height is reached.
- When pruning a two-year-old branch just above the annual shoot limit (bark ridge), only a few dormant eyes remain on the one-year-old stump. Weak new shoots with flower buds can form from these.
- Pruning back fruitcake shoots to the dormant eyes at the former fruit set points produces weak shoots (fruitcake pruning).

## 1.2.6 Alternative Shoot Treatment: Shaping Instead of Pruning

In addition to pruning, the direction of growth of scaffold branches, fruiting branches, and fruiting wood can also be directed by tying, stapling, weighting or spreading. This work requires more time but can help preserve shoots from pruning that are fundamentally interesting for the structure of the tree in favour of rapid canopy development. This allows the yield capacity to develop more quickly.

The best time to bend young shoots is when the shoot is still elastic and can be easily shaped but

has already reached its final length. This can be recognised by a developed terminal bud. This time is usually around the end of July.

If the young tree has plenty of shoots that grow too upright, the growth of the side shoots can be curbed by placing these shoots in a flat position. This is done by tying or spreading them out with a stick or weighing them down with weights.

If strong, steeply growing shoots or older branches are trained horizontally, their vigour is slowed down, and flower formation is encouraged. If only some shoots or branches are treated accordingly, they will grow weaker, while the shoots that have not been trained will grow stronger. Differently developed canopy sections can be harmonised in this way

## 1.2.7 Influence of the pruning times

Pruning times are crucial in determining a tree's response to pruning and new shoots. The tree's temperature, tolerance to frost, and reaction to fungal infections also influence the time of pruning. Apples and pears can be pruned during pre-winter or even during winter, but only if the temperature is warmer than -4 degrees Celsius.

### Dormant Pruning

The majority of apple pruning is done during the dormant season for the following reasons:

a. The branches and their direction of growth can be seen easily at that time
b. There is less danger of pulling the bark away from and around pruning wounds
c. Other orchard operations are less pressing
d. Dormant season pruning has less dwarfing effect than summer pruning.

The optimal pruning time depends on the size of the orchard and labour availability. Early winter pruning can be hazardous due to extremely cold temperatures, so it's better to wait until late winter. In sub-zero temperatures, pruning should be done in the latter part of the dormant season before bud bursts

### Summer pruning

The practice of summer pruning during the growing season is not common in India, but it is an integral part of pruning and is done to refine the basic structure of trees formed by winter pruning. The two goals of summer pruning are:

- Reducing and limiting tree height
- To reduce extension growth and induce early fruit bud formation on the life of lateral shoot.

Summer pruning then significantly restricts growth. It is used on vigorously growing trees to slow their growth and increase their fertility. Due to the length of the growing season, a distinction must be made between different times for summer pruning

### Early summer pruning

The best time for summer pruning in India's (HP) climatic conditions is mid-July to mid-August when the shoots' tips terminate in buds. This pruning is confined to one-year-old shoots or laterals emerging from primary scaffolds. Shoots 5-6 inches long and terminating in flower buds are not pruned. Summer pruning promotes spur development and a better fruiting system in older branches.

### Late summer pruning

Late summer pruning takes place during the ripening period of the fruit and can also take place after the harvest as an anticipated winter pruning. Fruit-bearing shoots are often pruned just behind the fruit. Shoot growth should be as complete as possible for this. Essentially, shoots that shade the fruit are removed. It is hoped that this will primarily improve the colour and flavour of the fruit and increase its stability during storage. However, excessive intervention in the leaf mass can result in reduced fruit sugar and acid content and moderate fruit colour.

# 1.3 Cultivation Systems and Different Tree Shapes

Successful fruit growing begins with choosing a suitable cultivation system for the respective crops according to the climatic, regional and personal

situation of the producer on his farm. The aim is to optimise the productive part of the usually limited area for fruit production.

Different types of tree fruit have their own cultivation requirements, resulting in different cultivation systems.

The selection of a suitable cultivation system depends on various factors:

- Growth vigour of trees of different fruit species and available tree material with weak-growing rootstocks,
- Aspects of the labour economy with regional wage relations. With low wages, additional manual labour can be done that is no longer economically viable with high wages.
- Possibilities for mechanisation in the given topographical site conditions. Intensive crops are easier to cultivate with machinery on flat land.
- Necessity and technical possibilities of weather protection against hail or excessive sun or measures against blossom frost
- Necessity, frequency and technical possibilities for plant protection
- Available acreage - with little acreage, the goal of achieving maximum yields with high intensity and labour input will dominate
- Prices and costs of the means of production in relation to income.

## 1.3.1 Indian Standard Tree Canopy

Due to hilly terrain and sloppy lands in India, the standard tree has been the most common form grown on seedling rootstock and planted far apart in low density. Such trees are less precautious and take many years to reach full production. For the standard apple tree, the modified central leader system of training is the most suitable and easiest to manage. It consists of a central trunk around which scaffold branches of the desired number and spacing can be arranged. Generally, 10-12 primary scaffold branches are developed on the central leader, and then the leader is modified about 3-4 meters above the ground. The following procedure may be adopted to develop the apple tree for the modified leader system of training.

**Pruning at planting:** Almost all nursery apple plants are sold in India as one-year-old whips without any feathers. After planting in the orchard, these whip

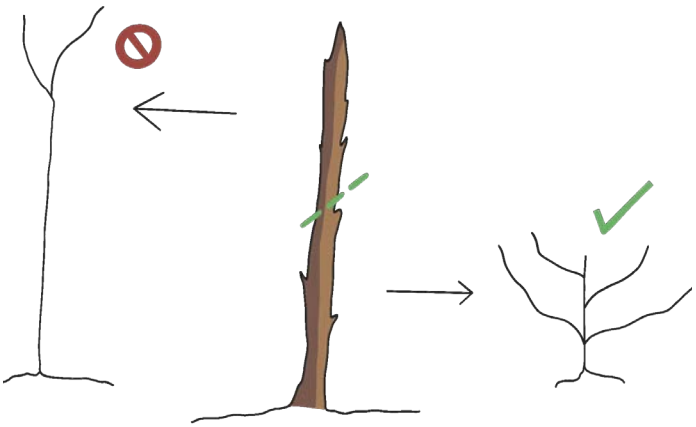


Figure 1.5: Pruning at planting stage

plants are headed back to a certain height to control apical dominance and encourage the development of side scaffolds. The principle is the same whether it is proposed to grow a bush tree, a tall tree, or trees growing on different systems. For the bush tree, the whip is cut at a height of 60- 70 cm and for tall trees, it is pruned at 90 to 120 cm height.

**Scaffold branches:** The basic objective of training of young trees is to build up a framework of primary and secondary branches. The braches which originate from central leader of tree are called primary branches and those arise from primary branches are

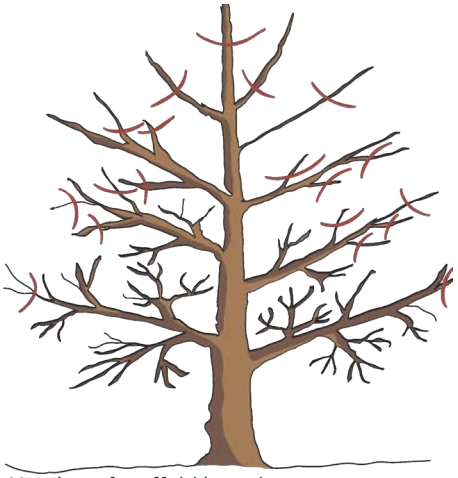
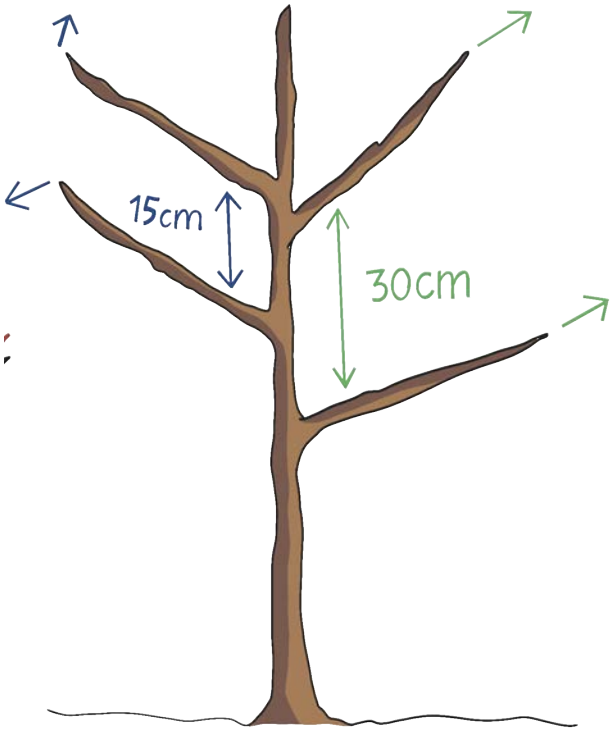


Figure 1.6: Number of scaffold branches

In standard tree, all the systems rely on at least 12-15 scaffold branches and should have more primary branches. The secondary branches are located on the lower primary branches.

Figure 1.7: Distance between scaffold branches

The main considerations about the distances between scaffold branches are to maintain sufficient distance to admit sunlight and to ensure that the branches, when grown and enlarge, do not clash with each other.




secondary branches. The secondary branches are subsequently furnishing with spurs or laterals on which fruit is borne (Plate 4). The spurs and laterals are periodically renewed in a bearing tree.

**Zone of development:** AAll the shoots should be in the direction of their zone of development. If the shoot is directed to the zone of development of another branch, it should be removed, spread or tied in a better position. If the branch or shoot is too close, overlaps or crosses another, one of them should be removed during early stages.

**Wide angled branches:** All the training systems rely on wide-angled laterals for forming the primary branches. A wide crotch angle is developed either by tying down the branch or by using tree spreaders. Narrow-crotch angled branches should be removed by giving a cut on a cone with the bud facing downwards. A new branch grows, pointing downwards.

**Vertical shoots:** All vertical shoots on the central leader and primary scaffolds should be removed. Similarly, all strong growing secondary branches and laterals from primary branches should be removed as they compete with the central leader or dominate the tree. A strong growing branch can create an imbalance in the tree and suppress the growth of the central leader, which ultimately affects tree canopy development and reduces cropping capability.

**Heading back:** Branch leaders are headed back in all systems, with the extent of this removal based on the leader's growth. Vigorous growth requires 20-25% new growth removal, while poor growth requires 40-50% of the same. In some high-density training systems, the leader is not headed back to control the branch's vigour.

Heading cuts should only be practised on leaders, with other laterals removed or shortened for fruit buds. The severe shortening of laterals is followed by a renewal system of pruning to encourage new vegetative growth

### Summer training

The following summer, most of the buds on the main branch will sprout. To develop a clean stem up to 60 cm from the ground, the sprouted buds are pinched off soon after their appearance. Three or four well-spaced sprouted buds projecting in opposite directions are retained, with the lowest one 60 cm above the ground. During summer pruning, branches below 60 cm from ground level should be removed, and a spreader is used when the shoot length is 10-15 cm to make a wide crotch angle.

### First dormant (winter) pruning

If summer pruning is not done, then 3-4 well-spaced primary branches having wider crotch angles are selected during dormant pruning. The selected branches should be spaced 10-15 cm apart in a spiral fashion. All branches lower than 60 cm from ground level, along with other undesirable branches, are also pruned off. The selected branches are headed back by ¼ of their growth to a bud projecting to the outer direction. The central leader is also headed back to 30-45 cm above the last branch.

### Second dormant pruning

During the second dormant pruning, 2-3 well-spaced new primary branches are selected on the leader in a similar manner as chosen in the first year. The primary branches are allowed to grow as leaders, and secondary branches are not allowed to develop as leaders on these primary branches. Still, side shoots are allowed to develop on primary branches.

The growth of these side laterals is controlled by summer pruning, and spurs are developed on them. In rare cases, two secondary branches which are growing outward direction should be selected on lower primary branches. The selected primary and secondary branches are headed back by $^{1/3}$ to $^{1/4}$ of their growth. The secondary branches selected as laterals should be spreading horizontally, whereas upright or down-ward growing branches should be removed.

### Further training pruning

The third-year training consists of thinning out unwanted branches and heading back to desirable side branches. The central leader should be headed back to a bud or weak shoot, which will develop as a side branch. By the fourth year, training should be completed.

# 1.4 Formation and Care Work

## 1.4.1 Pruning and training young trees after planting

Sparsely branched trees are only planted in exceptional cases and require special treatment. If non-branched or poorly branched trees still need to be used, they can be pruned back to the desired trunk height using a knip-tree method. To prune, remove excessively thick side shoots and competitors to the centre axis, and cut on cones with buds pointing downwards to encourage new shoot growth without competing with the centre shoot. If there are more than eight to ten long side shoots, remove the excess, especially those too steep. Cut back to 60% of their original length to stimulate growth towards the trunk and prevent early bald patches.

During vegetation, remove all newly emerging side shoots from 30 cm below the tip to promote tip growth. Any blossoms or apples should also be removed, as they are of poor quality and have a negative impact on tip growth. If these apples remain hanging and grow larger, the centre shoot may snap or break off, requiring a new dominant centre shoot to be built up. In subsequent years, the tip should be consistently removed and tied to a wire framework or stake

After pruning the tip, new side branches develop near the tip, sometimes bearing apples from the first flowers. These should be removed up to 30 cm below the tip, as they weaken growth.

Figure 1.8: Pruning of tip growth in young trees

## 1.4.2 Pruning of Stronger Growing Rootstocks

With stronger growing rootstocks (MM 111, MM 106, M25) in semi-intensive cultivation, later base branches of good quality are only pruned when they touch a neighbouring tree. In this case, the apples should pull the base branches downwards. Otherwise, base branches that are cut back too short will grow upwards, and several shoots will develop from the front buds. If pruning is necessary, prune the bud downwards.

The tip should be encouraged to achieve a dominant function, allowing the center to go up for a few years. If the stem extensions are moderately strong and long, they will produce short side shoots with a flower bud. If they are very long and relatively thick, their upper, vigorous side shoots are broken out to prevent the tree from developing too much in length and thickness.

The juvenile stage is predominantly vegetative, with more long shoots and few short shoots. As fruiting progresses, the long shoots become less important, and the short shoots take up a greater proportion of the total number of shoots in the tree canopies. Pruning should focus on the tree's structure during the youth phase, ensuring that the trees are not overloaded but maintain sufficient vigour and avoid early alternate. After five to six years, the first fruiting shoots have passed their zenith and begin to senesce, producing small, low-quality fruit, which is why they are removed. Now, the continuous rejuvenation of the fruit wood begins.

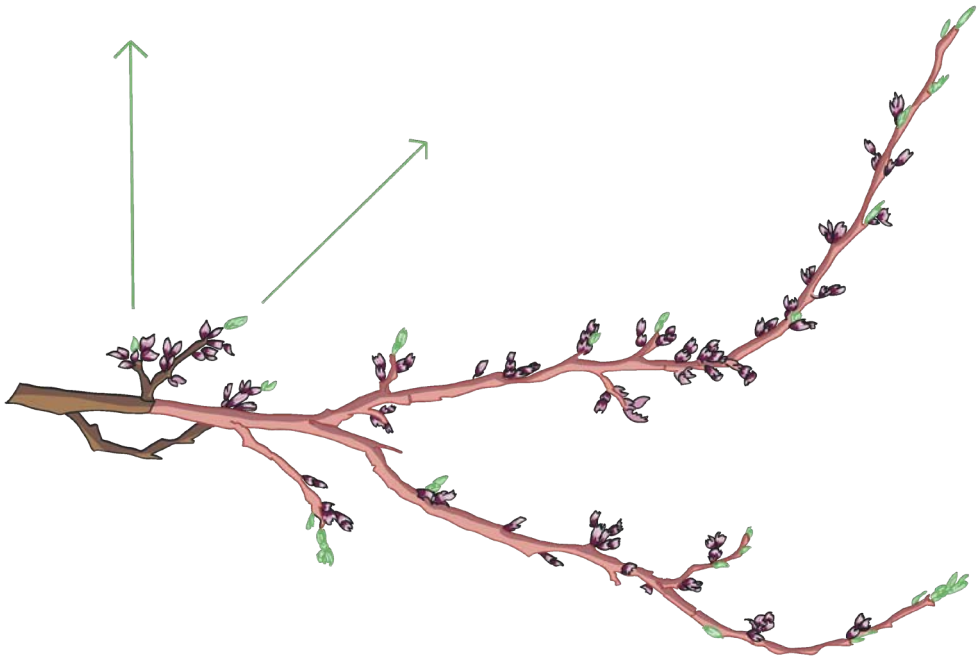


Figure 1.9: Removal of old overaged wood in trees

## 1.4.3 Maintenance Pruning and Fruit Wood Regeneration

Trees stop growing at their genetically determined height, which can be slowed down by grafting, fertilising sparingly, watering, and pruning moderately. Once the tree reaches its final height, it's crucial to limit it without causing extreme top growth. Slender spindles and super spindles can react to careless pruning, so pruning should be moderate after a height reduction. Excessively strong and overlapping fruiting branches should be removed in good time to avoid creating large trunk wounds. Those who tolerate strong fruiting branches can promote the development of vegetative and overgrown tree canopies.

### Fruitwood pruning

Young canopies form fruit wood at the beginning of their development, and pruning is not relevant at this stage. As the fruit wood's age and size increase, its vitality of the fruit wood and, thus, the quality of the fruit decreases, requiring rejuvenation and strengthening through pruning. This can be done in two variants: "long fruitwood pruning" and "short fruitwood pruning." The choice depends on the distance of the trees planted, the space given to the fruit wood, and whether it should be encouraged more or less.

**Long fruitwood pruning (thinning)** means that the branches are left long. This is preferably practised on trees with strong growth. These trees have a relatively large number of one-year-old long shoots. Their side buds should develop into flowering short shoots. Only then can and should the new growth above the two-year-old branch section be pruned to flower buds.

**Short fruitwood pruning (heading)** is particularly suitable for calm trees. Instead of replacing entire fruiting branches as in long pruning, weak fruiting wood is pruned by about half to the flower bud or removed completely. All unnecessary or excessively strong long shoots are cut away or cut short. Pruning stimulates growth.

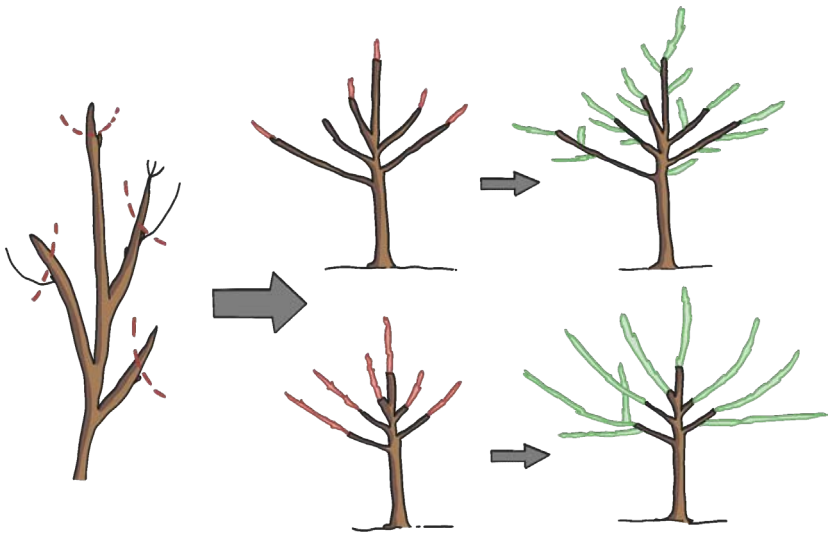


Figure 1.10: Heading and thinning in fruitwood

### 1.4.4 Keep the Tree in Vegetative Status

Heavy pruning can negatively impact growth stabilisation, as too many small cuts on short-fruiting wood can reduce yield and cause overgrowth.

Figure 1.11: A hormonally generative tree produces more fruit (left), while a hormonally vegetative tree produces branches (right), resulting in poorer fruit quality and a shorter shelf life.

## 1.5 Practical Procedure for Pruning

Pruning mature apple trees aims to remove old and undesirable wood, maintain moderately vigorous conditions for efficient fruit production, and vary depending on tree, orchard, and year. The pruning requirements vary based on the cultivar, age, vigour, growth and fruiting habits, agro-climatic conditions, and cultural practices.

The sequence is as follows:

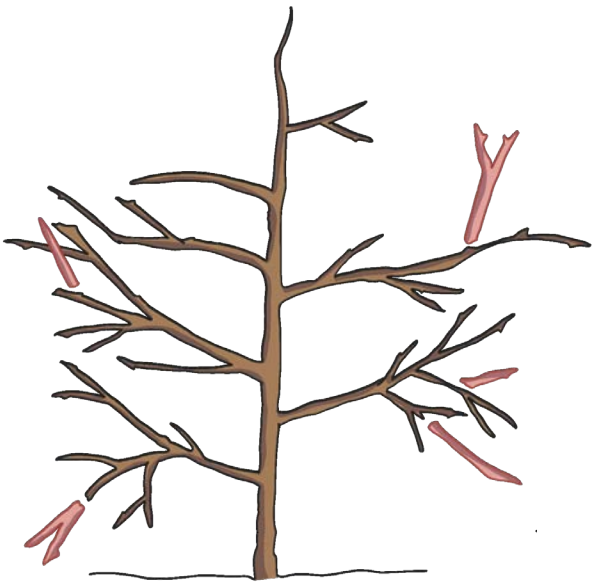


Figure 1.12: Remove diseased, dead, or broken branches as they don't yield fruit, disrupt structure, and are potential sources of harmful organisms.

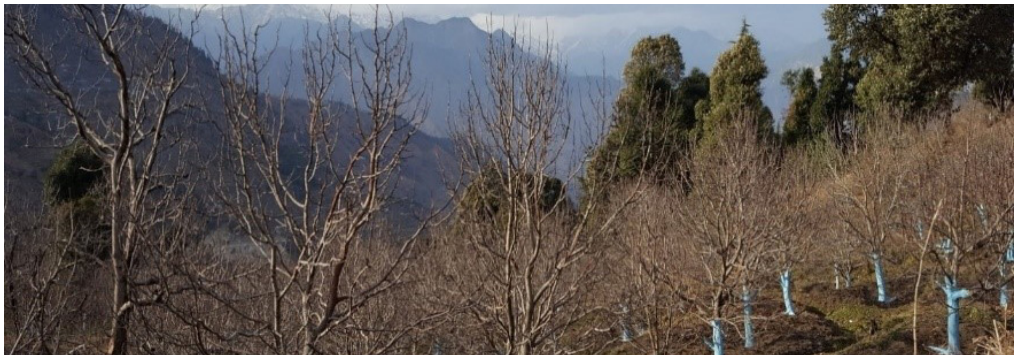


Figure 1.13: Removal of old, unproductive branches

**Removal of old, unproductive branches:** To improve tree interiors, remove densely packed branches, particularly those growing inwards or upwards at the base of bark ridges or cones, to allow light into the interior and promote future fruiting branches.

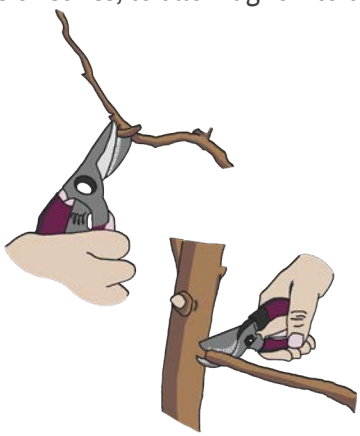


Figure 1.14: After large incisions, smaller areas are thinned, e.g. double overlapping or parallel branches are removed.

After large incisions, smaller areas are thinned, e.g. double overlapping or parallel branches are removed. Branches from the trunk are removed on cones, bud downwards, to allow new branches to form and bear fruit after two years. Branches that extend far out are shortened to flower buds. Downwardly falling branches are completely removed on branch rings, as they are unproductive and may produce poor quality fruits.

Figure 1.15: Vertical shoots (water shoots), especially in the head area, are removed if they were not cut in summer.

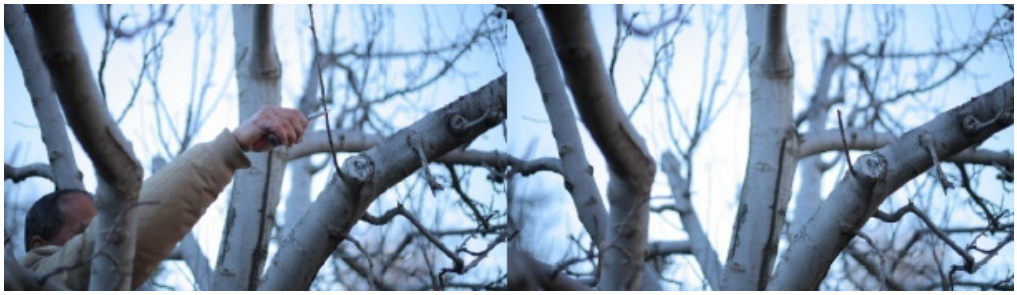


Figure 1.16: Shoots and root suckers at the base of the trunk are also removed.

Vertical shoots (water shoots), especially in the head area, are removed if they were not cut in summer. A few, not too strong shoots are left for future fruiting wood if

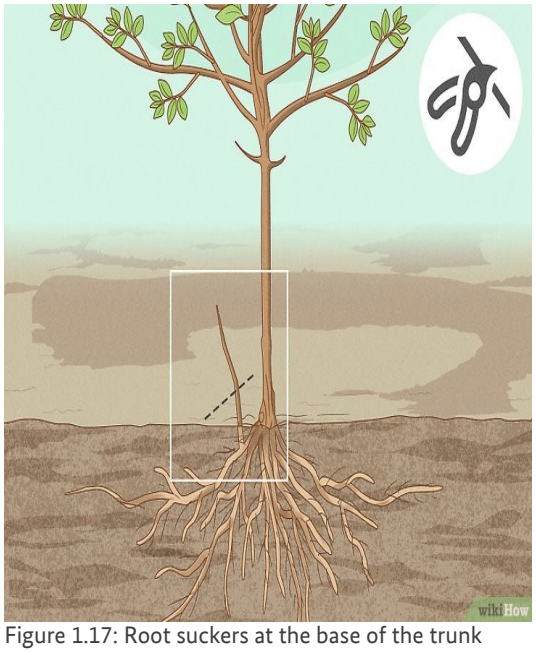


Figure 1.17: Root suckers at the base of the trunk should be removed

the area in question needs new branches. If fruiting is to be accelerated, the branch can be bent downwards.

Apple fruits are mostly borne on spurs, and fruits borne on healthy spurs on a new growth are far superior to those borne on weak, old and shaded spurs. With the age the spurs become weak and thus systematically renewed by removing old spurs

Retaining water sprouts on branches rejuvenates old trees by cutting them using stub cut (2-3 inches from base) and click pruning (6-9 inches from the base), resulting in new fruiting shoots and spurs for quality fruit production.


Figure 1.18: In general, fewer well-placed incisions are better than many small incisions.

For dense trees, large removals should be made, potentially over two years, as excessive removal stimulates growth. Winter pruning can be followed by soothing summer pruning, or large areas can be removed in summer.

The extent of pruning should depend on the need for new growth. No more than 20-30 % of the canopy volume should be removed. Otherwise the tree will respond with vigorous new growth.


Figure 1.19: Comparison of pruning a heavily overgrown tree before and after

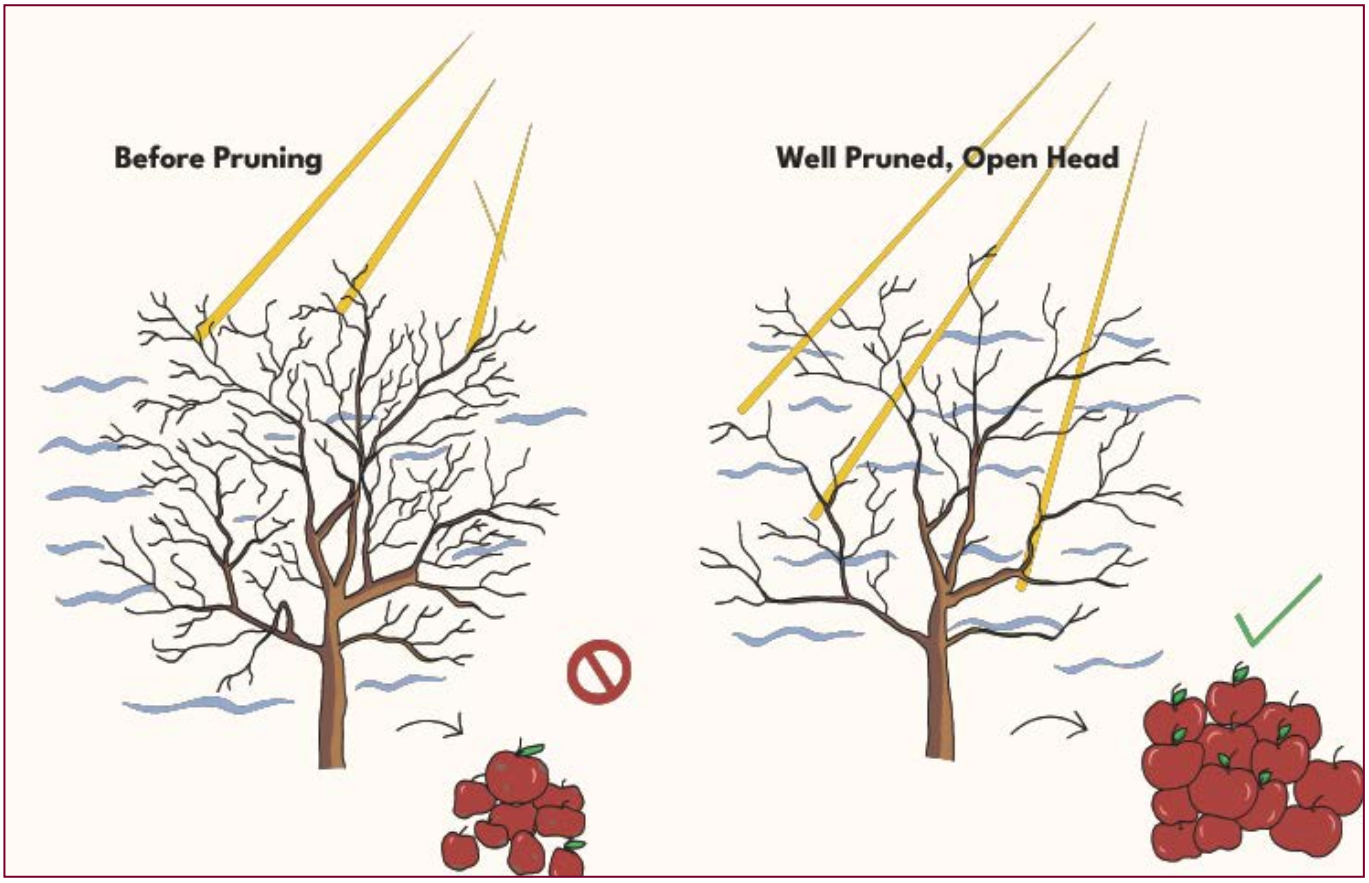
The pruning process aims to increase light to reduce incidence of pests and diseases which will reduce use of chemical control methods, remove overlapping branches, and establish a clear tip, avoiding stimulation of new shoots. However, the risk is lower in summer than the same pruning carried out in winter.

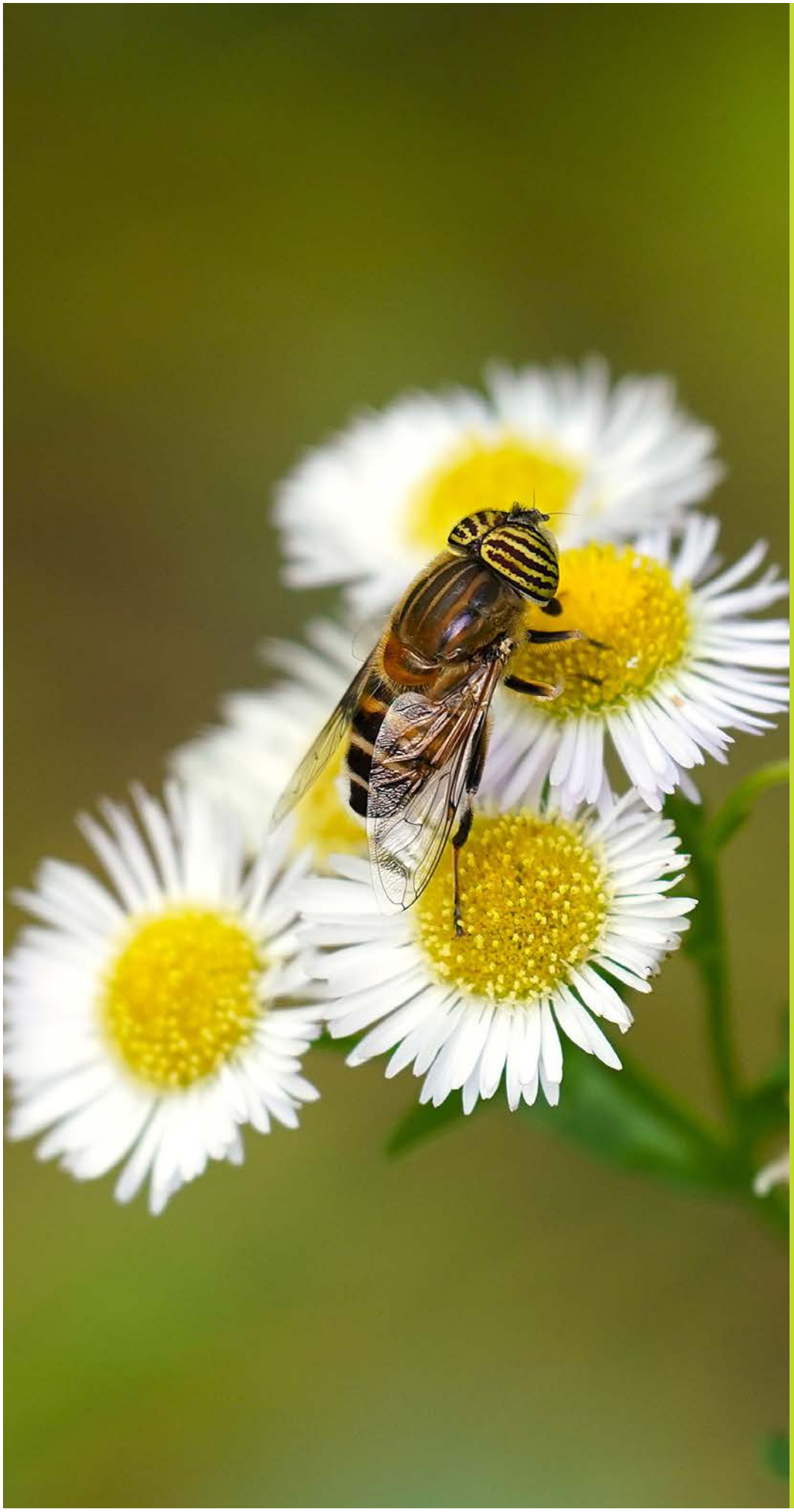
### Elimination of competitors

Figure 1.20: A strong side branch (more than 50% of the thickness of the trunk) should be removed on bud downwards.

Figure 1.21: Pruning a strong branch halfway up from the previous year provokes the sprouting of several buds below the pruning cut. The branches growing vertically inwards must now be removed (without cones) so that further growth is directed outwards. The pruning could have favoured the outward-facing buds.

The final rule is to approach pruning with confidence and courage, as following these rules will lead to successful pruning and a better understanding of the appropriate pruning techniques. Avoid excessive “snipping around” to avoid over-wake the tree.


Before Pruning
Well Pruned, Open Head



# POLLINATION MANAGEMENT

# 02

# 2.1 Pollination

**Pollination** is the transfer of pollen grains from the male anther of a flower to the female stigma, with the goal of creating offspring for the next generation. Plants use seeds to produce offspring, which contain genetic information to produce a new plant. Flowers are the tools that plants use to make their seeds. They rely on vectors like wind, water, birds, insects, butterflies, bats, and other animals to transfer pollen. These animals or insects that transfer pollen from plant to plant are called "**pollinators**".

Successful fruit production in apple orchards relies on a good fertilisation process and fruit set.
Key factors include:

- Larger fruit size (e.g., small fruit can get price Rs 40/Kg while large fruit size gets Rs. 80/Kg)
- Avoid june drop (20% more fruit)
- Uniform shape
- Proper fruit set
- Better fruit quality

Insufficient fertilisation in apple orchards can lead to poor fruit development or early fruit drop. A fully fertilised apple contains ten seeds, but a minimum of 6-7 seeds per apple is essential for optimal fruit development.

A successful fruit set requires pollination and successful fertilisation with a fusion of the male and female germ cells. Pollination is part of the fertilisation process and involves the transport of the male pollen from one flower's anthers contacting it with the female stigma of the other flower, forming a fusion of the two cells.

# 2.2 Pollination in Apple Orchards

Apple orchards require pollination for optimal yield and higher production, as all apple varieties are self-infertile and require fertilisation from another variety, similar to most temperate fruits.

Some critical problems in apple orchards regarding pollination:

- Inappropriate ratio of pollinator varieties in orchards.
- Limited availability of beehives at the time of pollination.
- Unfavourable weather conditions during the pollination stage.
- Use of chemicals that affect the pollination of insects.
- Lack of awareness of different methods of pollination in orchards.

# 2.3 Factor Responsible for Better Pollination

## 2.3.1 Effective Pollination Period

The Effective Pollination Period (EPP) is the timeframe after flowering that can lead to a successful fruit set, typically three to five days for apples. To achieve this, bee colonies should be present in orchards at the start of flowering, as delayed pollination only transports pollen to flowers and fails in fertilization.

## 2.3.2 Influence of Weather

The growth of pollen tubes and the ageing process of ovules are both temperature sensitive. The optimal fruit set is achieved in a moderate temperature range with an extended flowering period, ensuring longer pollination.High temperatures cause ovules to age rapidly, impeding the growth of pollen tubes. Meanwhile, at temperatures around 5 to 10°C, the growth of pollen tubes halts, yet the ageing process of ovules persists. Prolonged cool spells also hinder fruit set due to ongoing ovule ageing.

## 2.3.3 Aspects of Fertilisation Process

After describing pollination, the aspects of fertilisation following pollination and its physiological basis must be considered for the ultimate success of a good fruit set and apple harvest.

### 2.3.4 Flower Quality

The capability of an apple blossom to be fertilised depends on its quality. This can be determined by the previous year's cultivation and weather conditions. Frost temperatures below -2 degrees Celsius during flowering can destroy blossom organs, preventing fertilisation.

Flower quality is difficult to assess, but fewer than 10-15 stamens and five pistils indicate insufficient supply in the previous year. If the flower clusters also have few flowers and only small transitional petals, this usually also indicates an impairment of the flower's quality. The king flower is usually the best-supplied of all the flowers in the flower cluster.

Severe leaf damage (spider mites, hail, etc.), heavy fruit set/yield, or late harvest can lead to low carbohydrate reserves, resulting in small, weak flowers with shorter stems and low vigor in spring because the plant would lack the reserves to ensure optimum flower bud quality.

### 2.3.5 Chilling Requirements

Chilling hours are the number of hours between 0°C (32°F) and 7.2°C (45°F) during the dormant period. The accumulation of these hours over the winter months is essential for the apple tree's physiological processes and the subsequent bloom and fruiting. Insufficient chilling can lead to delayed or uneven bud break, reduced flowering, and poor fruit set.

## 2.4 About the Pollination– The Transport by Insects

Apple trees rely on insects for pollinating its flowers, a pivotal process in fruit production. Apple blossoms require a robust insect population for effective pollination, as wind alone is insufficient due to the weight of the pollen.

The animals known for effective flower pollination include wild bees, butterflies, hummingbirds, moths, certain flies and wasps, nectar-feeding bats, and honeybees, which are the key pollinators, as they overwinter as a colony, allowing a large workforce to be active during spring flowering.

To protect bees and other beneficial insects, avoiding insecticide application during blossoming or post-blossoming and adhering to bee protection regulations when using plant protection products is essential. Regular checks of beehives for deceased insects are also crucial for their well-being.

Bees prefer flowers with higher sugar content, leading to lower fruit set. Apples typically have a 21% nectar sugar concentration, so it's advisable to avoid nearby competing crops with attractive flowers, such as rapeseeds or mustard for insects during the flowering period.

Figure 2.1: Wild Bee Hotel

If natural habitats are lacking, insect hotels can support the population of wild bees. Wild bees fly even at low temperatures. However, due to the small number of individuals, they do not have the efficiency of honeybee colonies.

# 2.5 Consequences of Self-sterility for the Optimisation of Fertilisation

## 2.5.1 Pollinizing Varieties (Pollinizers)

Pollen from the same variety do not guarantee successful fertilization, so it's crucial to ensure flowers are pollinated by pollen from different varieties. Studies by the Central Institute for Subtropical Horticulture have shown that the compatibility of varieties planted in India varies based on fruit set after pollination, with Royal Delicious pollen leading to low fruit set and low fertilisation of other varieties. Traditional orchards in Himachal Pradesh have a low pollinizing variety ratio, resulting in a lack of abundant pollens during blossom periods. UHF recommends a 33% pollinizing variety ratio in apple orchards. To increase this ratio, various methods can be used. When planning new orchards, land layout should ensure an optimum ratio of pollinizing varieties, with various ways of laying out orchards.

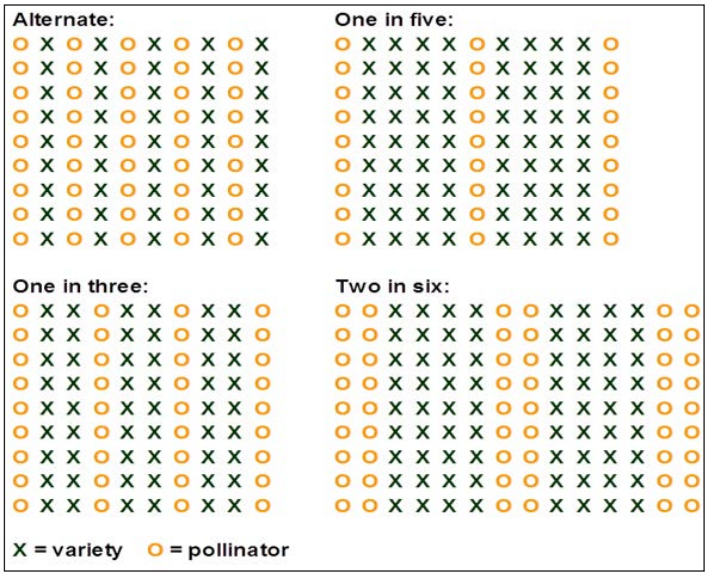



Figure 2.2: Various Ways of layout for main and pollinizing varieties

Figure 2.3: Ornamental apple "Evereste"

## 2.5.2 Maintaining Pollinizer Variety Ratio by Grafting

An alternative to dedicated pollinator trees or mixed variety plantings involves grafting a branch of a pollinator variety onto the main tree. Each tree then possesses its own pollinator within its domain, but this method also occupies productive space.

Grafting and top-working trees with suitable pollinizer cultivars in orchards is a method that involves selecting appropriate pollinizer varieties based on the conditions of the orchards and grafting their scions onto side branches of trees. This method helps increase pollen numbers in the orchards after two to three years.

Figure 2.4: Grafting pollinizer varieties

Figure 2.5: Grafted pollinizer variety in bloom

## 2.5.3 Flower Bouquet Method

Figure 2.6: A plastic bag with branch of a pollinising variety tied to an apple tree

An alternative to using live trees or grafted pollinator branches is to place cut branches of a pollinator variety in a bottle or plastic bag filled with water and tie them within the tree for improved pollination. However, this method requires additional work and is uncertain due to the rapid aging of flowers and the uncertainty of the source of the flowers, as well as the potential for a loss of pollinator branches.

## 2.5.4 Pollen Dispensers

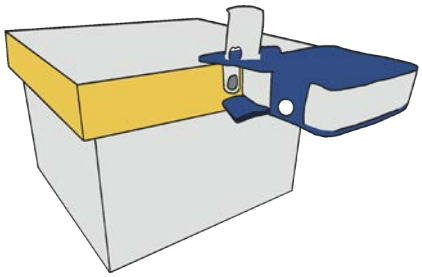


Figure 2.7: Pollen dispenser

Hive pollen dispensers are devices placed at the hive's entrance and that force outgoing foragers to walk through the pollen, facilitating pollen adhesion. They are effective in pollinizer-deficient orchards when flowering does not synchronize.

### Fixation and use of pollen dispenser

The pollen dispenser is installed at the hive entrance of an Apis mellifera strong colony. Two grams of dehisced pollen should be mixed with powdered and dried another husk in a 1:1 ratio. The mixture should be kept in a pollen dispenser daily from 9 to 11 am continuously for five days.

## 2.5.5 Management of Honeybee Population in Orchards

Honeybees are the most dominant pollinators in apple orchards. They can be easily managed. For orchards with a 25-33% pollinizer population, 3-4 strong colonies per hectare are recommended. Place honeybee colonies in apple orchards at 5-10% bloom. The colonies should have a strength of 6-8 bee frames, with 3-4 frames of broods and a prolific queen. Beekeepers must establish favourable conditions: strategically placing beehives in sheltered areas to shield the bees from harsh weather and potential threats.

Bees thrive in temperatures above 18 oC, with a guideline stating 75 bees should leave the entrance every minute from a hive with 20,000 or more adult bees. However, honeybee activity is affected by environmental factors such as airflow, clouds, previous night's temperature, and how long the hive has been in its present location. Cool weather, rain, or winds can also hinder bees' movement.

**Water Requirements:**

Bees require water for nectar diluting and feeding to larvae in hives, and if there is no water source near orchards, they will fly long distances to find it. If water is available within 100 meters, bees spend less time searching for water and more time for pollination. Therefore, creating favorable conditions for bees is sensible and beneficial, and fruit growers should provide clean and fresh water sources near the apiary.

## 2.5.6 Movement of Honeybee Colonies

Every bee transport is a stressful situation for the colony. It would be ideal to transport the colony at night, as this is when all the bees are in the hive. When transporting bees, several important aspects must be considered to ensure the health and safety of the bees:

- **Ventilation and temperature:** bees need sufficient ventilation during transport to ensure good air circulation. Care must be taken to ensure that the grid floor is open, and the entrance hole is only closed with a grid and not a wedge. Temperature control is also important, as too high or too low temperatures can harm the bees.
- **Securing the hives:** Hives must be stable and securely fastened during transport to prevent them from shifting or being damaged during the journey.
- **Avoidance of stress and vibrations:** Smooth transport without strong vibrations is essential to minimise stress for the bees. Strong vibrations or shocks can make the bees restless and lead to injuries. Bees tend to become fuzzy under stress. This causes the temperature to rise, and the bees die when they become sticky with wax and honey

Figure 2.8 and 2.9: Bees pollinating apple flowers

that is becoming liquid.

- **Protection from foreign substances:** To maintain the well-being of the bees, hives should be protected from the entry of foreign bodies, dust, or other potentially harmful substances.
- **Transport time:** The transport time should be kept as short as possible to minimise stress for the bees. Long transport times can lead to exhaustion and an increased mortality rate.

## 2.6 Fertilisation Success and Further Development of the Fruit Set

Fruit set refers to the percentage of flowers that develop into fruit, typically between 10-30%, depending on factors like year, variety, flowering density, and weather. Fruit growers aim for an average annual yield, but excessive fruit sets can be detrimental as trees may alternate and produce insufficient fruit. The quality of flower buds influences fruit set and development, with high-quality flowers preferring fruit. Urea spraying during harvest and leaf fall can delay leaf fall and improve tree nitrogen status, as a large proportion of the nitrogen goes into the tree's reserves. After generally successful fertilisation, the ultimate aim is to achieve a good but not excessive fruit yield. The fruit grower can hardly positively influence the further development of the fruit set after fertilisation. Hormones can be used in the early stages of development to reduce harmful excessive fruit set.

## 2.7 Possible Causes for Lack of Fertilisation

If no or only a few fruits are formed despite abundant flowering, this can have various causes:

- The planted variety is self-infertile, and the tree is very far away from the tree with the pollinator variety, or there is no suitable variety for fertilisation at all.
- The planted variety is self-infertile, and the second tree, which is suitable as a pollinator variety, blooms with a time delay so that one variety is no longer ready for fertilisation when the other blooms.
- There are too few bee colonies in the crops.
- There are no natural insects, such as wild bees, bumblebees, etc., in the neighbourhood.
- There is no bee flight when the fruit tree is in bloom because it is too wet and/or too cold.
- A cold snap or night frost causes the blossoms to freeze.
- Although all the conditions for a bee flight are present, the bees find a more attractive food supply (e.g. in a nearby mustard field) and avoid the fruit blossoms.

## 2.8 Importance of Wild Insect Pollinators

Pollinators and pollination are crucial for terrestrial ecosystems, including those dominated by agriculture. Pollination is essential for crop productivity, with approximately 70% of tropical crop species relying on insects for pollination and yields. India, the world's second-largest producer of fruits and vegetables, estimates the economic value of pollination's contribution at $726 million, while in Himachal Pradesh, it is estimated at $365 million.

Artificial methods of pollination have only partially reduced plants' dependence on pollinators. Pollination by insects, primarily bees, remains an essential step in the production of many crops, including melons, squash, apples, berries, and almonds. Other beneficial insects such as wild bees, butterflies or moths provide the rest of the pollination. Pollination services are more effective and stable when there is high pollinator diversity and abundance, leading to higher crop production. Naturally occurring wild bees, bumblebees, and other insects sometimes forage at lower temperatures, unlike honeybees that tend to stay in the hive below 12 degrees Celsius. Ideally, these different species complement each other.

There are over 20,000 bee species on Earth, including 199 found in Himachal Pradesh. Important wild bees for pollination in apple orchards include bumblebees, leafcutter bees, mining bees, and mason bees. Actions must be taken to protect natural areas surrounding orchards, reduce pesticide use, and promote in-farm bee habitats to ensure wild pollinators continue to visit. A reduction in wild pollinator diversity is harmful not only to cultivated crops but also to wild plants. Farms close to forest areas have a higher number of wild pollinators. Therefore, it is important to conserve forest areas.

## 2.9 Protecting Bees and Wild Insects

The simplest and cheapest pollination measure is the protection of bees and other pollinators in orchards, as these insects play an essential role in pollinating fruit trees. Here are some measures to protect bees when protecting plants in orchards:

- Choosing bee-friendly pesticides: Fruit growers should use bee-friendly pesticides, avoiding applications during flowering, to minimize their harm to bees.
- Avoidance of overdosing: Fruit growers should dose their pesticides according to specified instructions. Excessive doses are not effective, damage bees and are expensive.
- Timed applications: Fruit growers should apply plant protection products outside flowering periods to reduce direct exposure to bees, as they are not active at night.
- Avoid unintentional treatments of other flowering plants in the crops under or between the trees or in neighbouring areas. Insecticides harmful to bees applied to these flowers will damage wild insect populations. Beekeepers will avoid the places where their honeybees will be harmed.
- Remove the flowers in the endangered areas. Fruit growers mow the flowers in the crops to be treated before applying toxic pesticides.
- Optimisation of plant protection application techniques: Fruit growers must use plant protection techniques to apply plant protection products only to fruit trees and not to areas that do not require plant protection. For this purpose, the technology must be set for low drift and targeted application. The blower must not be set too high. This saves money and protects beneficial insects.
- Respect for the beehive of the bee colony: Fruit growers do not use products that are harmful to bees within a radius of at least 20 meters around a beehive.
- Monitoring and control: Fruit growers monitor the occurrence of pests and diseases in orchards. Plant protection applications are used not according to the routine but according to actual needs. This saves money, avoids residues on the fruit and protects the environment.
- Provision of bee flora in the orchards: Apart from apple blooms, ensure availability of other sources of flora for the bees, such as bramble, barberry, and dhain (shrubs), calendula, thistle, an clover (herbs), and pear, peach, and apricot (trees). Provision of floral sources is especially important in the lean winter season.

- Communication and cooperation: Fruit growers should communicate with beekeepers and local beekeeping associations to coordinate the flowering phases of the fruit trees and the planned pesticide applications. Beekeepers can remove the bee colonies from the crops in good time during treatments or close the flight holes.
- Training and education: Fruit growers and workers in orchards are regularly informed about the correct handling of plant protection products and the protection of pollinators.
- Prohibition of particularly hazardous pesticides: Fruit growers must comply with legal regulations and refrain from using pesticides that are particularly hazardous to bees.

## BOX 1: Pesticides Harmful for Bees and Wild Pollinators

**Fruit growers can improve bee living conditions by using pesticides responsibly, creating bee protection strips near orchards, offering alternative food sources and habitats outside of fruit blossoms, and maintaining habitats for insects on unused land.**

**All preparations containing one of the following active substances fall into the category of plant protection products that are hazardous to bees:**

- **Abamectin**
- **a-Cypermethrin**
- **Bifenthrin**
- **Carbaryl**
- **Chlorpyriphos (Dursban)**
- **Chlorpyri-phos-methyl**
- **Chlothiadin**
- **Cyfluthrin**
- **Cypermethrin**
- **Deltamethrin**
- **Diazinon**
- **Dichlobenil**
- **Dichlorphos**
- **Dimethoate**
- **Diqua,**
- **Esfenvalerat**
- **Etofenprox**
- **Fenoxycarb**
- **Flufenoxuron**
- **Imidacloprid**
- **Indoxycarb**
- **Lambda cyhalothrin**
- **Malathion**
- **Methiocarb**
- **Methomyl**
- **Milbemectin**
- **Oxydemeton-methyl**
- **Parathion**
- **Phosmet**
- **Pyridaben**
- **Pyrimiphos-methyl**
- **Spinosad**
- **Spirodiclofen**
- **Teflubenzuron**
- **Thiamethoxam**
- **Triflumuron**

# Conserve Wild Pollinators fo

## Our Friends – The Pollinators

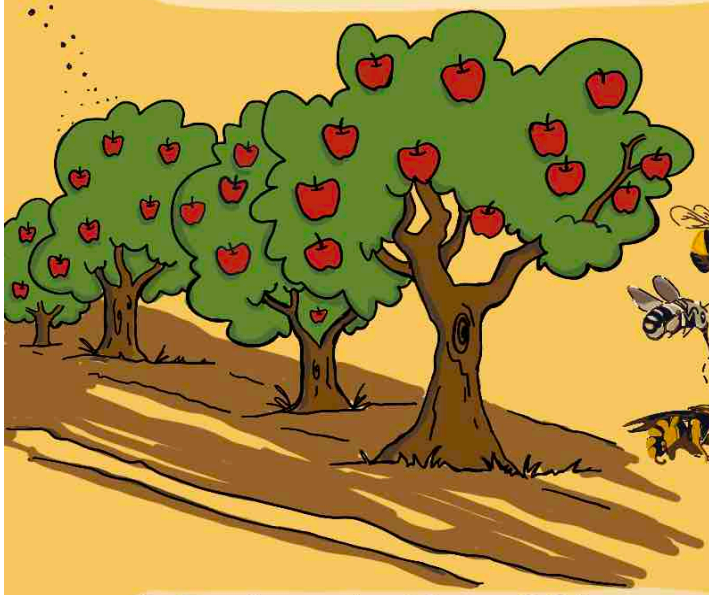
Pollinators provide essential ecosystem services that enable plants to produce fruits and seeds, enhance their vigour and growth, and allow mixing of gene pools for increased survival, and hybrid seed production.

**Annually, they provide pollination worth over Rs. 3000 crores in agriculture in Himachal Pradesh alone.**

## Contribution to World

There are **20,000 different kinds of be**
**pollinating more than 75% of all the sta**

- 90% of all the flowering plants of the world
- 73% Bees
- 19% Flies
- 6.5% Bats
- 5% Wasps and Beetles
- 4% Butterflies, Moths, and Birds



- Carpenter Bees
- Halicitid Bees
- Bumble Bees
- Anthophorid Bees
- Megachilid Bees
- Stingless Bees

## Who are the Wild

Pollination services are bette
pollinator diversity. Wild polli
bees are better pollinators th

## 1. Reduce the Use of Chemicals

Even common chemicals, used at the recommended dosage are lethal for honeybees.

- Avoid using chemicals during the flowering period.
- If urgent, use natural products, only when the bee activity is minimum.

## What Can W

## 3. Promote Habi

- Termite mounds, tree trunks,
crevices in walls, are some of
of wild bee pollinators. These
conserved.
- Provide mud hives in farms a
- Build bee hotels from a bundl
reeds or stems, or holes drilled

## 2. Bee Flora Propagation

Flowering plants provide pollen and nectar that serve as food for bees!

- Plant bee flora to be available round the year.
- Plant a bee garden.
- Raise awareness for propagation of bee floras.
- Diversify crops.

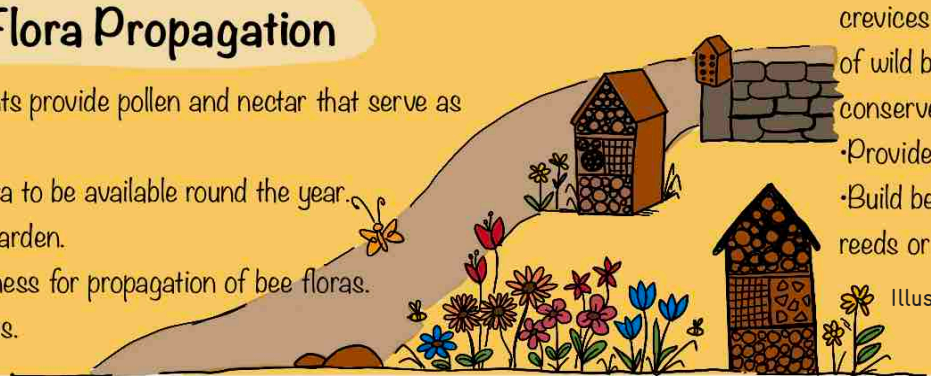


Illustration credits: Nitasha

# or Sustainable Horticulture !

## Crop Pollination

**ees on Earth,**
**aple crops** and for
d.

## Pollinators are struggling!

Without them, humans and ecosystems cannot survive. 40% of pollinator species are at risk of extinction! The problems they face are:

- Increase in monocultures
- Introduction of non-native plants, bees, and insects
- Climate change, land clearance and habitat fragmentation

Flies

Bats

Birds

## Pollinators?

er when there is high
nators, such as wild
an honey bees.

Butterflies

Wasps

Beetles



## We Do?

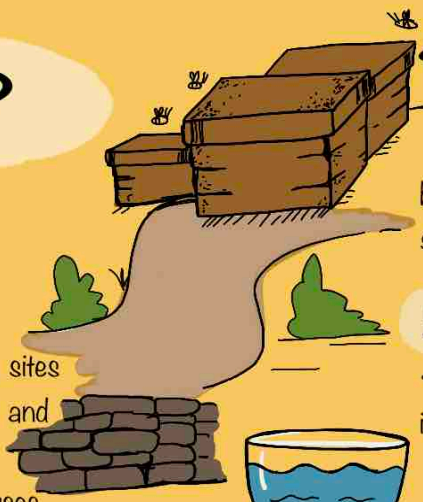
### 4. Support local Beekeepers and Organisations

by buying local honey of native bees and its byproducts such as soaps, lotions, and beeswax candles.

### tats

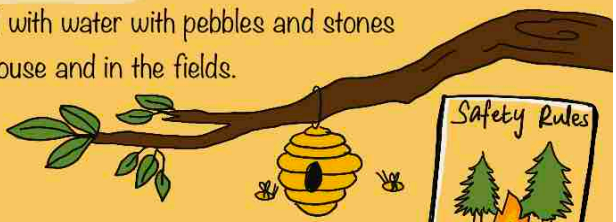
logs, cavities and
the natural nesting sites
should be promoted and

nd wall hives in houses.
e of bamboo canes, hollow
d in a wooden block.



### 5. Water Provision

·Keep a shallow bowl with water with pebbles and stones inside outside your house and in the fields.






### 6. Measures against Forest Fires

·Protect bee hives and habitats from fire hazards.

Nambiar © GIZ Green Innovations Centre

# NUTRITION AND SOIL HEALTH MANAGEMENT

# 03

# 3.1 Basic Requirements for Nutrition of Fruit Trees

Fruit trees require balanced fertilization to meet their nutrient requirements, as soils with high natural nutrient capacity cannot sustainably meet these requirements. Fertilizers are crucial for maximizing yields and are a significant cost factor.
Over-fertilization can drain profits, especially for expensive speciality fertilizers. Fertilizers cannot compensate for cultivation errors in fruit crops. To ensure optimal yields and tree growth, it is essential to identify the causes of insufficient yields and implement appropriate countermeasures. Injudicious use of fertilizers can lead to environmental problems, such as nitrate enrichment in surface and groundwater, and toxic effects on plants. Therefore, need-based plant nutrition is crucial. It is defined as **the supply and absorption of chemical compounds required for plant growth and metabolism**. Plant nutrition is the study of the chemical elements and compounds necessary for plant growth and reproduction, plant metabolism and their external supply.

Soil health is a critical component of farm management, and nutrition management takes into account maintenance of good soil health. Healthy soils lead to increased crop yields and productivity, thereby increasing income. However, they are also important because healthy soil ecosystems are habitat for beneficial microorganisms, earthworms, and other organisms that contribute to soil structure and nutrient cycling.

Healthy soils acts as a sponge with higher water retention capacity, effectively storing and releasing water. They can help prevent soil erosion and mitigate the impact of droughts and flooding. They are also important for practicing agroecological practices because they promote the overall vitality of crops and their ability to resist pests and diseases.

**Classification of nutrients:** Nutrients are essential elements that play a crucial role in plant growth and development. If only one of them is missing, fruit plants cannot develop normally.

There are seventeen essential elements for any plant, with carbon, hydrogen, and oxygen obtained from air and water, and the remaining fourteen from soil.

Other non-essential elements, such as calcium, magnesium, and iron, can also have beneficial effects on certain plants. Based on plant requirement, the elements are classified as:

- Macronutrients: C, H, O, N, P, K, Ca, Mg, S (Required by plants in large amounts)
- Primary macronutrient: N, P, K
- Secondary macronutrient: Ca, Mg, S
- Micronutrients: Fe, Mn, Cu, Zn, B, Mo, Cl and Ni (Required by plants in small amounts)
- Beneficial nutrients: Na, Si, Co and Rubidium (R)

As beneficial elements, they can minimise the toxic effects of other elements or
replace other nutrients for less specific functions.

# 3.2 Influences on Effectiveness of Fertilisation

Nutrient availability to fruit trees is influenced by various factors beyond pure nutrient quantities, and simply applying nutrients to the soil doesn't guarantee their benefit to the right recipient.

### Interactions of nutrients during intake

Nutrient uptake can be made more difficult (antagonism) or easier (synergism) by the ratio of nutrients to each other.

### Influence of the crops

Fruit trees store nutrients as reserves in their shoot and root system for years, which are then mobilized when

## BOX 2: Role of Solar-Powered Biofermenter in Soil Health Management


**Soil degradation has emerged as a concerning issue in face of intensive cultivation and monocultures. Degraded and eroded soils have an impact on farmer incomes, local ecology, and also decrease the adaptive capacity of farmers to adapt to climate change impacts. Natural farming, which involves on-farm preparation of biological inputs such as *jeevamrutam, amritpani, and brahmastra*, from natural raw materials, has the potential to revive degraded soils by increasing the beneficial microorganisms, organic matter, water retention capacity, and soil organic carbon, However, it is a labour-intensive process where farmers need to put extra manual effort over and above their regular farming activities. Alternatively, they must employ wage labourers, which adds to the input costs.**

**A solar powered bio-fermenter automatizes the fermentation process for preparation of biological inputs for natural farming. The solution consists of two tanks (fermentation and filtration), a battery-powered motor, and a time controller. The solution can be adopted by individuals, or by a community where one farmer becomes the entrepreneur and provides the service to the community for a nominal fee.**

**Economic benefits include reduced manual labour and drudgery for the farmers, reduced costs of employing wage-labour, while improving output quality of the product through uniform stirring. Environmental benefits include avoided GHG emissions, easing the adoption of natural farming for apple farmers, and consequently better soil health.**

needed, making them less dependent on large amounts of fertilizer at the start of vegetation than short-lived crops.

**Influence of competing plants:**
The fruit tree's shallow root system, particularly in its youth, can be affected by weeds, which consume nutrients and water from the upper soil layer, preventing optimal growth. Therefore, weed control is crucial for apple tree nutrition.

**Influence of harmful organisms in the soil:**
Replanting apple trees in the same location after removing old crops can cause soil fatigue or replant disease. Old woody roots require additional nitrogen for decomposition into humus. After uprooting, old roots should be removed. The area should be planted with another crop for one year. At the very least, avoid planting the new tree in exactly the same place.

## 3.3 Optimal Nutrient Supply and Availability of Nutrients

Too little or too much nutrient (s) can weaken or damage a plant. The optimum supply range varies depending on the nutrient. Nutrient deficiencies can impact plant growth, with poorer development and slower growth. Acute deficiencies can be identified visually, while latent deficiencies are harder to detect without a reference culture. Abundance of nutrients can lead to disharmonious growth or toxicity, while excessive amounts can cause toxicity. Optimal supply is crucial for optimal plant growth.

## 3.4 Guidelines to Identify Nutrient Disorders in the Field

Fruit trees are perennial plants with the ability to store nutrients. The removal of nutrients via the fruit is low compared to other agricultural crops. Visible symptoms affecting the growth behaviour of trees can only be observed for most macro- and microelements in the case of extreme under- or oversupply.

Pronounced deficiency symptoms are rare in practice and often cannot be clearly determined visually. They are also masked by other symptoms that are not caused by a lack of nutrients.

In order to do equal justice to the interests of fruit growing and environmental protection, it is essential to monitor fertilization measures, with nutrient analyses of soil, leaves, and fruit being crucial. Equally important is the observation of the development and nutritional status of the tree to identify under- or over-nourishment. Visual symptoms of nutrient deficiency can be expressed on all plant

**Table 1:** Common symptoms for important nutrients and their preferred age on leaves

| Nutrient | Symptoms | Plant part |
|---|---|---|
| **N** | Uniform yellowing of leaves | Older leaves |
| **P** | Dark green/purple colour of leaves | Older leaves |
| **K** | Leaf margins become scorched | Older leaves |
| **Ca** | Growing tips or terminal show abnormal symptoms | Younger leaves |
| **Mg** | Interveinal chlorosis (inverted V) | Older leaves |
| **Fe** | Interveinal chlorosis only | Younger leaves |
| **Mn** | Interveinal chlorosis | Younger leaves |
| **Zn** | Interveinal chlorosis with short internodes | Younger leaves |

organs, but it's difficult to differentiate between nutrient deficiency and disease problems based on leaves. Nutritional problems often affect all plants within a small area or site, and within a plant, all parts of the same physiological age.

## 3.4.1 Precautions in identifying the deficiency symptoms:

Various problems can arise when analysing deficiency symptoms in plant nutrition:

**Visual similarities:** Deficiency symptoms can look visually similar, which can make it difficult to accurately identify the deficiency. For example, deficiencies of nitrogen, iron or magnesium may initially show similar leaf symptoms.

**Complexity of causes:** A deficiency can be caused by various factors, such as insufficient nutrients in the soil, pH imbalances, too much or too little water, temperature fluctuations or disease. It can be difficult to determine the exact cause.

**Interactions between nutrients:** A deficiency of a particular nutrient can affect the uptake or metabolism of other nutrients. The appearance of a deficiency can be complicated by interactions between different nutrients.

**Soil differences:** Different soil types have different chemical and physical properties that affect the availability of nutrients to plants. A deficiency can therefore have different manifestations in different soils.

**Time delay:** After a deficiency has been corrected, the visible symptoms may take some time to disappear. This can complicate the monitoring and evaluation of remedial measures.

**Laboratory analysis vs. field conditions:** Laboratory analysis of soil samples may provide clues to possible deficiency symptoms, but actual field conditions and interactions may vary and must be considered.

**Pseudo (false) deficiency symptoms:** deficiency symptoms may appear due to drought, excess water, disease and pesticide residues.

**Russeting:** Russeting is caused by callus formation in response to injuries to the fruit surface that may be caused by spray mixtures, low temperatures, excessive nitrogen, high humidity or free water on the fruit surface. It can occur on the stem end, calyx end, or side of the fruit. Certain Delicious group varieties and color strains, like Red Velox and Jeromine, can experience serious problems when temperatures drop below freezing during flowering, resulting in a ring russet shape.

**Cracking:** Fruit cracking occurs during long rainy periods or dewy nights after fruits have reached over 2 inches in diameter. It can occur near the stem end or on the side, with stem end healing within a few weeks. Side cracks usually do not heal due to stopped cell division. Dry periods followed by rain cause sudden water content increase and swelling, leading to fruit cracking. Fruits from vigorous trees crack more severely, while orchards with heavily dormant pruned, fertilized, or rough fruit finishes experience more cracking.

# 3.6 Availability, Uptake, Role and Deficiency Symptoms of Various Nutrients in Apple Crops

## 3.6.1 Nitrogen

Nitrogen is a crucial nutrient in plant cultivation, playing a vital role in nucleic acid synthesis and cell division. It is a component of chlorophyll molecules and stimulates vegetative growth, with excessive growth being undesirable for apple trees. Nitrogen is primarily absorbed by plants as nitrate and ammonium, primarily through roots, as it cannot be absorbed from the air through leaves. Therefore, nitrogen is the “engine of growth” in plant cultivation. The plant absorbs nitrogen from the soil via the roots mainly as nitrate, and to a lesser extent as ammonium. Nitrogen from the air cannot be absorbed via the leaves.

**Nitrogen deficiency:** Nitrogen deficiency is a common issue in fruit crops, causing reduced top growth and pale yellowish green leaves. Symptoms are fairly uniform and can develop at any time during the growing season, depending on weather conditions and available nitrogen. Fruits are smaller and earlier in maturity, and bud differentiation may decrease, leading to reduced fruit set.

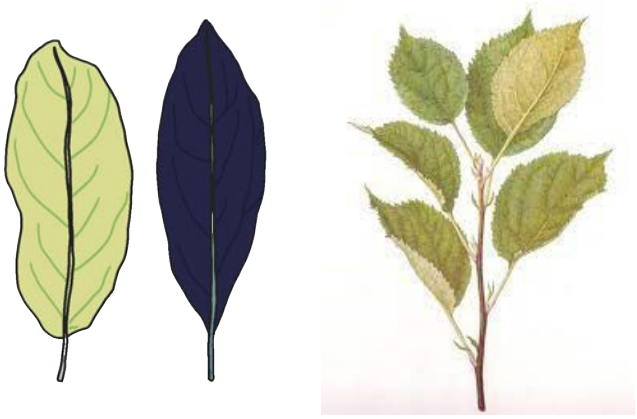


Figure 3.1: Nitrogen deficiency

**Recommendation for Nitrogen Deficiency:** If soil levels were low in the previous year, increasing the dose by 25 to 50%, depending on the severity of nitrogen deficiency, is recommended. For quick recovery during cropping, spray with 0.5% Urea (1 kg in 200 ltr of water) for acute nitrogen deficiency. Calcium nitrate is a common but more cost-intensive source of nitrogen, sprayed at 1 kg per 100 litres of water. Repeated sprays can be done depending on the severity of the deficiency. In young orchards, nitrogen supplies can be maintained by intercropping with leguminous crops like pulses/peas, which have rhizobium bacteria that help in nitrogen fixation from the environment.

**Toxicity:**

$NO_3^-$ excess: Brown necrotic lesions

$NH_4^+$ excess: Whitish Brown

N excess includes unusually large leaves with or without marginal chlorotic or necrotic lesion. Such leaves are often attacked by insects and pathogens.

## 3.6.2 Phosphorus

Phosphorus uptake in plants is influenced by root density, water and nutrient availability, and soil structure. Colonization with soil fungi (mycorrhiza) can improve phosphorus supply, especially when soil phosphorus content is low.

Phosphorus is a vital plant component, responsible for genetic information transmission, building bio membranes, energy transfer, and enzymatic reactions. It is found in the petals, pollen, and seeds, with the largest amount found in leaves.

**Phosphorus deficiency:** The deficiency normally occurs during their early growth cycle when the P requirement is high. The initial high P content declines with age. Young expanding leaves are dark green, with purplish discoloration on lower sides. They may have a leathery texture and form abnormally acute angles with the stem.

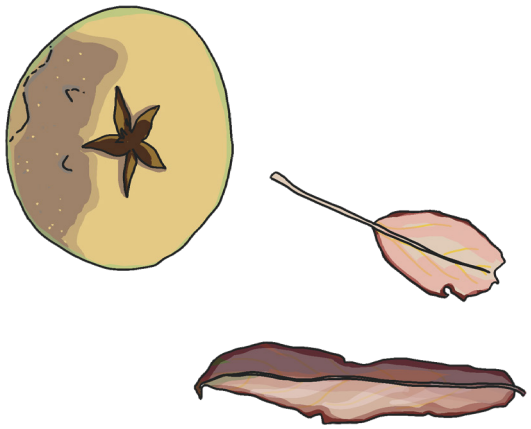


Figure 3.2: Phosphorus deficiency

Phosphorus deficiency symptoms hardly ever occur on the leaves of adult outdoor trees. The good phosphorus mobility in the plant, the low content and its economic utilisation in the plant are probably responsible for the fact that a positive influence of the phosphorus supply on growth, yield and fruit quality is rarely observed in the open field.

**Toxicity:** Toxic phenomena due to over-supply are not known. However, a greatly excessive supply often reduces N and Zn uptake and causes typical N and Zn leaf deficiency symptoms.

**Recommendation for deficiency:** Phosphorus deficiency is rarely seen in apples, but its requirement is crucial during leaf cell division and in the developing leaves and when roots length is at a minimum. Phosphorus is principally applied to soil as single super phosphate, however, foliar application of soluble phosphorous compounds like potassium dihydrogen phosphate @ 1% within 4-6 weeks of bloom is suggested for improved fruit quality.

## 3.6.3 Potassium

Potassium, a highly mobile element in plants, positively influences fruit size, sugar, acid content, and colour, provided there is an undersupply of potassium. When potassium accumulates in cells, it causes large cells. If potassium enters cells without anions, organic acids are enriched, increasing the fruit's acid content.

**Potassium deficiency:** Potassium deficiency in fruit and nut crops is characterized by scouching of older leaves' margins, which do not extend between veins. Symptoms appear first on older leaves, and fruit accumulates large amounts of potassium, making severe deficiency more likely during heavy crop years. Potassium-deficient plants are not drought-tolerant, curl their leaves in dry conditions, and are susceptible to frost. Severe deficiency results in tissue death, while damaged leaves remain attached to the tree

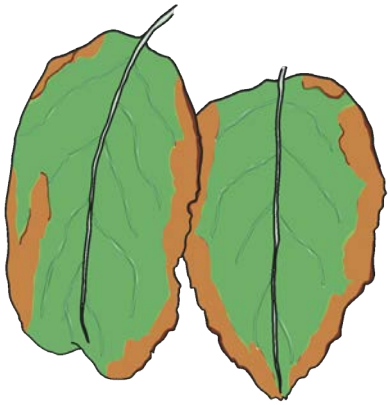


Figure 3.3: Potassium deficiency

**Toxicity:** Symptoms specific for excessive accumulation of K is unknown. High concentration of K in the soil, however, may affect the uptake of other nutrients like Mg, Ca, Mn and Zn.

**Recommendation of Potassium Deficiency:** Moderate potassium requirement is crucial for maintaining a calcium: potassium balance. Overcoming potassium deficiency can be achieved by applying 0.5% potassium sulphate or manipulating soil with Muriate of potash, if reported.

## 3.6.4 Calcium

**Calcium:** Calcium is crucial for root development and function, as a deficiency can lead to browning and death of roots. A sufficient calcium supply stimulates root system development, supports cell division, chromosome stability, and regulates respiration, ensuring overall health.

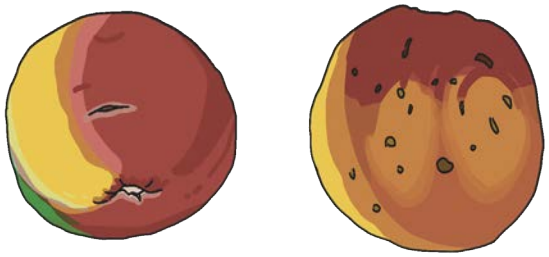


Figure 3.4: Calcium deficiency

During the growth phase, fruits absorb less calcium. With more growth, the less Ca they absorb (dilution effect), leading to an increase of physiological disorders. Apple varieties with storage problems should have a minimum calcium content of 4.5 to 5 mg in 100 g fresh matter. The supply of calcium is particularly important for the shelf life of the fruit. The Ca content in the fruit cannot be increased by fertilisation via the soil. Relatively high Ca contents in the leaves of problem trees show that a fundamental Ca deficiency is not responsible for low contents in the fruit.

**Deficiency:** The most prominent symptom of Ca deficiency in apple is bitter pit, corky spots, water core and lenticels breakdown. The first indication of Ca deficiency on apple foliage is the upward cupping of the margins of the youngest leaves, which may become entirely chlorotic and terminal growth stops.

- Bitter pit appears as slight indentation in the skin towards calyx end. These areas turn brown and soft desiccated tissues develop in the flesh immediately beneath the spots. Bitter pit is usually a storage

disorder but may develop while the fruit is on the tree.

- Cork spots may appear early in the development of the fruit. Hard brown cork spots develop in the flesh. These spots consist of hard compressed tissues caused by cell proliferation.
- Ca deficient fruits are also more susceptible to sunburn, which appears as large, depressed dehydrated areas on the exposed surface.
- Lenticels breakdown appears first as pale areas around the lenticels. White hales develop around the lenticels and later turn brown or black. More prominent lenticels may be the only symptoms of Ca deficiency.
- Water core and internal breakdown is associated with Ca deficiency.
- A bark symptom of apple called “measles” or internal bark necrosis results from a complex involving low Ca and high Mg.

**Recommendations for Calcium Deficiency:**
Calcium can only be supplied to the fruit in the short term from the outside by repeated Ca spraying with 7 times 7 kg CaNO3 as supplementary tank mixtures during the entire growth period. Spraying the fruit with calcium salt solutions is even safer and more effective. Calcium deficiency can be overcome by programming 3-4 sprays of calcium chloride 0.5% at 14 days interval starting from Mid-June onwards.

# 3.7 Fertilizer Application

The main source of nutrients for fruit plants is the soil. In principle, all above-ground plant organs can absorb nutrients. Nutrient sprays can therefore supplement fertilisation via the soil or even replace it in the case of trace element deficiencies.

## 3.7.1 Soil Fertilisation or Surface Fertilisation

Mineral fertilizers and farm fertilizers are applied to the soil surface, with the type of fertiliser and amount of precipitation affecting the nutrient mobility. Some nutrients migrate quickly with seepage water, while others are retained by soil particles and microorganisms and may only reach the root area of fruit plants after application.

## 3.7.2 Fertigation

Fertigation is the application of aqueous solutions of fully soluble mineral fertilizers through a drip irrigation system. Fruit trees require nutrients at the right time, especially in intensive orchards. Fertilization is not dependent on rainfall and can help address major problems like alternance or calcium supply. It can also accelerate juvenile development and yield onset due to targeted nutrition of underdeveloped rootstock. Fertilization is only economically viable on irrigated sites, and liquid fertilizer can be applied using a spray barrel or garden sprayer. If drip irrigation is available, it should also be used for fertilization. In Europe, fertigation starts after flowering and continues for 10 to 12 weeks, depending on tree water and nutrient requirements. All fertilizers must be water-soluble, and single-nutrient or multi-nutrient fertilizers can be used. Concentrated stock solutions are prepared and fed to the fertigation lines. The fertilisation period can be divided into three phases, with trees receiving one-fifth of the total fertilizer in the first period and two-fifths in each of the following two periods. If the potassium calculated is significantly less than the amount taken up by the fruit, the required supplement should be applied to the soil.

## 3.7.3 Foliar Fertilisation

Foliar application is beneficial in situations where soil nutrient uptake is limited, particularly for micronutrients like Fe, Zn, Mn, Cu, and B. These nutrients are needed in small quantities, but their availability may be limited due to soil-related constraints like adverse pH, high organic matter, and excessive build-up of certain nutrients. Foliar application can help address these limitations, making the addition of these nutrients more efficient or effective.

**Advantages:**

- Foliar application brings about quick and near total absorption (>90 %) of the applied nutrient.
- Improve vitality, vigour of the plant and impart resistance to pests and diseases.
- Quantities of nutrients involved in foliar applications are minimal with high absorption efficiency.
- Foliar application is an easy quick and cost-effective method of supplementing mineral nutrients.
- Target nutrients directly rather than rely on indirect transportation through the soil and roots.

## 3.8 Organic Fertilizers

**Manure and other animal residues:** Nutrient content in manure and animal residues depends on bedding, feed, animal species, extraction, and storage methods. Fruit growers should know the amount of nutrients within the organic fertilizer they are applying. Organic matter contains two-thirds nutrient humus and one-third permanent humus, which is difficult to decompose. Most nutrients are organically bound and released gradually as the organic matter decomposes.

**Compost:** Plant and animal waste is broken down by microbes. This decomposition is accelerated by moisture and good aeration of the compost. The composition of compost varies greatly depending on the source material.

**Green manure:** A well-developed green manure crop can add about the same amount of organic matter to the soil as an average application of fertilizer. It also contributes to nutrient conservation, subsoil development and shade compensation.

## 3.9 Determining Fertilizer Requirements

Proper fertilisation only provides the plants with sufficient nutrients that are necessary to maintain soil fertility, growth, yield and fruit quality. Soil, plant and fruit analyses provide valuable information on this.

**Table 2:** Average nutrient content of organic fertilizers in the fresh mass

| Fertiliser | | Nutrient | | | | | |
|---|---|---|---|---|---|---|---|
| | TM % | Total N | NH -N | P2O5 | K2O | MgO | CaO |
| Solid manure | | Contents in kg/t | | | | | |
| Cattle manure | 23 | 5,6 | | 2,9 | 4,0 | 1,7 | |
| Horse manure | 32 | 4,9 | | 3,2 | 9,8 | 1,9 | |
| Sheep dung | 37 | 10 | | 6,9 | 13,6 | 3,4 | |
| Goat manure | 30 | 8 | | 6 | 20 | 1 | |
| Rabbit dung | 30 | 18 | | 19 | 45 | 1,5 | |
| Duck manure | 30 | 4 | | 3 | 11 | 1 | |
| Goose droppings | 30 | 8 | | 6 | 11 | 2,0 | |
| Turkey manure | 50 | 19,1 | | 18,1 | 16,4 | 6,2 | 19,7 |
| Chicken and | 30 | 18,1 | 7,6 | 12,5 | 10,4 | 4 | 18,4 |
| Chicken manure | 60 | 29,9 | 10 | 22 | 20,2 | 8,2 | 41,6 |
| Feces | | Contents in kg/t | | | | | |
| Fresh chicken droppings | 28 | 17 | 6,3 | 11,4 | 10 | 5,7 | 30 |
| Dry chicken droppings | 50 | 25,5 | 9,9 | 20,1 | 17,5 | 7,9 | 50,6 |
| Dried chicken droppings | 70 | 32 | 10,7 | 27,7 | 22,8 | 20,6 | 63 |
| Slurry | | Contents in kg/m³ | | | | | |
| Beef manure | 1,8 | 1,5 | 1,1 | 0,3 | 4 | 0,3 | |
| Mixed slurry | 2,5 | 2,5 | 1,8 | 0,9 | 4 | 0,5 | |
| Organic fertilisers | | Contents in kg/t | | | | | |
| Green / organic compost | 64 | 9,8 | 0,6 | 5,1 | 8 | 5,3 | 32,3 |
| Compost | 32 | 6,9 | 0,2 | 4,1 | 10,1 | 2,4 | 16,7 |

## 3.9.1 Soil Analysis

Soil analysis is crucial for orchardists to determine the mineral nutrition of their plants and to formulate fertilizer programs. It provides data on total and available nutrients, including pH and lime requirements. Soil samples are taken after harvesting and before fertilizer application, between the tree trunk and drip line. Samples can be taken from 15-30cm and 30-45cm depth from 4-5 trees in an orchard block. After mixing, samples are collected in a cloth bag, and about ½ kg is sufficient for analysis. If wet soil is present, it is dried in shade before being sent to the lab.

## 3.9.2 Leaf Analysis (Tissue Analysis)

Leaf analysis is a method that uses the nutrient content of leaves to determine the amount of nutrients absorbed up to the time of sampling. It is an essential supplement to soil analysis and is typically taken in July/August, because their nutrient content changes only slightly from this time onwards.
The third to fifth leaf from the current year's long shoots with completed terminal buds is taken, totaling around 200 leaves. After washing, drying, and placing them in paper bags, the leaves are sent to the laboratory.

## 3.9.3 Time of Fertilizer Application

- Apply FYM, phosphorus and potash during December-January.
- Apply half dose of Nitrogen with the onset of sap flow i.e., 20-25 days before flowering. The remaining half dose of nitrogen should be applied one month after the first.
- All the manure and fertilizers should be applied 30-45cm away from the trunk up to the periphery. Broadcasting should be preferred over band application. In case of continuous drought, the second dose of nitrogen should be avoided and be supplemented with 2 foliar sprays of urea (0.5%).
- Phosphorus application should be made in alternate years since uptake is very slow.
- Besides, 3-4 sprays of calcium should be given for better quality and storability.

**Post Harvest sprays:** As a maintenance dose spray of trace elements namely zinc and boron should be given when the leaves are still green. They are important for return bloom.

# INTEGRATED DISEASE AND INSECT-PEST MANAGEMENT (IPM)

# 04

## 4.1 Integrated Disease and Insect-Pest management (IPM)

Integrated pest management, or IPM, is a process to solve pest problems while minimizing risks to people and the environment. IPM can be used to manage all kinds of pests anywhere–in urban, agricultural, and wildland or natural areas.

Integrated pest management means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations, keep pesticides and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms.

## 4.2 Challenges of Plant Protection

A wide range of pests and diseases affect plants; worldwide, three of the more common diseases and insect pests of apple crop are scab, mildew, San Jose Scale, apple root borer, and woolly apple aphid. Apple orchards in India are under constant threat from a large number of fungal and viral pathogens. The most common diseases of apples in India are scab, powdery mildew, Alternaria leaf spot, Marsonina blotch, cankers, root rot, collar rot and mosaic. Similarly insect-pests affecting apples are Sanjose scale, woolly apple aphid, thrips, root borer, defoliating beetles, stem borer and red spider mite. Depending on the incidence and severity of infection of these diseases and insect-pests impacts range from unappealing cosmetic appearance, low marketability, and poor quality of fruit to decreased yield or complete loss of fruit or trees, thus causing huge economic losses. Plant protection products are used to maintain good fruit quality and to keep the trees healthy. But in Himachal Pradesh, excessive use of agrochemicals has led to adverse effects on the environment including soil health. The state lacks adequate diagnostic lab infrastructure.

This has caused problems to develop in the past, the results of which we can see today in the apple farms. Some examples that can help to solve the problems are outlined below. These and others will be explained in further chapters of the manual. There are plant protection products that may no longer be used in the future due to their harmful effects on the environment and human health. They are listed in the annex.

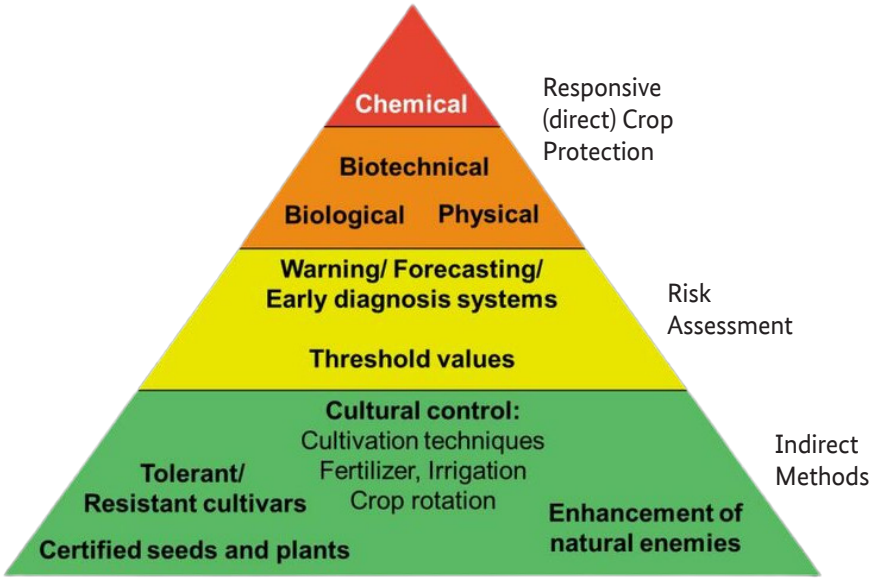



Figure 4.1: Principles of IPM

# 4.3 Aims of IPM

## 4.3.1 Principles of IPM

- Identification of key pests and beneficial organisms.
- Establishment of economic thresholds limit.
- Development of assessment techniques.
- Evolving description of predictive pest models.
- The prevention and/or suppression of harmful organisms should be achieved or supported among other options especially by :
    - crop rotation
    - use of adequate cultivation techniques (e.g. sowing densities),
    - use, where appropriate, of resistant/tolerant cultivars and standard/certified seed and planting material,
    - use of balanced fertilisation, liming and irrigation/drainage practices,
    - preventing the spread of harmful organisms by hygiene measures (e.g. by regular cleansing of machinery and equipment),
    - protection and enhancement of important beneficial organisms, e.g. by adequate plant protection measures or the utilisation of ecological infrastructures inside and outside production sites.
- Harmful organisms must be monitored by adequate methods and tools, .
- Such adequate tools should include observations in the field as well as scientifically sound warning, forecasting, and early diagnosis systems, where feasible, as well as the use of advice from professionally qualified advisors.

## 4.3.2 Key Benefits of Using IPM

- Promotes healthy plants.
- Promotes bio-based pest management i.e., control by useful insects.
- Reduces air and ground water contamination.
- Maintains soil fertility.
- Prevent soil depletion and reduces soil erosion.
- Lower risks to human health and the environment (e.g., water resources, pollinating insects)
- Delayed development of pesticide resistance
- Cost effective as the pesticides are costly.
- Improved public image of agricultural product.

# 4.4 Pest Scouting

The scouting can be carried out for entire growing season or at certain critical periods in the life cycle of insect pests and diseases. It is classified as qualitative (dealing with pest detection – type of species) or quantitative (dealing with pest abundance), where count of insect or a measure of their presence is obtained. The latter are more common in relation to IPM/ IDM. The most efficient method to estimate population density of insect / incidence of disease is through “sampling”. Two types of sampling techniques are employed.

### Direct Techniques

In such techniques direct count of insects/ diseased leaves /fruit/ plants is taken. Data obtained are expressed as number of insects or number of fruit/ leaves/ plants infected. For insect count it can further divide into

- In situ count,
- Knock down (Berlese funnel, chemical, jarring),
- Netting (Sweep net, vacuum net, rotary net),
- Trapping: Attractive traps (Visual trap, bait trap, pheromone trap), passive traps (Suction trap, water pan trap, window trap, sticky trap. pitfall trap).

### Indirect Techniques

In these techniques population estimates are made on effects or products of insect pests and disease and called population indices.

- Effects of the insect feeding and pathogen infection: Per cent defoliation, per cent incidence/ severity, number of plants cut by cut worm/ infected by disease, dead hearts caused by borers.
- Products of insects: Measures of larvae and pupal skins, frass (dropping including insect excrement), webs/ tents.

# 4.5 Overview of Beneficial Insects

A high level of biodiversity is without doubt a prerequisite for well-functioning integrated pest management. Natural antagonists of various pests help to minimize the need for direct plant protection measures.

Figure 4.2: Predatory Mites

## 4.5.1 Predatory Mites

**Description:** Predatory mites are drop-shaped, very agile and have long legs. They are most easily found on the leaf veins on the underside of the leaf and in the leaf axils. There are various species in our apple orchards.

**Beneficial insect performance:** 30 to 50 spider mites

**Prey/ Host:** spider mites, rust mites

Figure 4.3: Predatory Bugs

## 4.5.2 Predatory Bugs

**Description:** The predatory bugs include, for example, flower bugs, soft bugs and sickle bugs. These beneficial insects are characterized by their flat bodies, short, three-limbed, strong proboscis and large neck shield.

**Beneficial insect performance:** 200 spider mites

**Prey/ Host:** spider mites, aphids, pear sucker

Figure 4.4: Seven-spot Ladybug

## 4.5.3 Seven-spot Ladybug

**Description:** Seven-spot ladybug has , as the name suggests, seven black dots on their orange-colored, strongly curved wing covers. The egg clutches are yellow and upright. Ladybugs are already active before the apple blossom.

**Beneficial insect performance:** 400 aphids

**Prey/ Host:** aphids, spider mites


Figure 4.5: Asian Ladybug

## 4.5.4 Asian Ladybug

**Description:** The Asian ladybug is variably colored. It can have black, red or orange elytra. These can have up to twenty red or black spots. This ladybug sometimes displaces other species.

**Beneficial insect performance:** > aphids, number may be added

**Prey/ Host:** aphids, wolly aphids


Figure 4.6: Black Spherical Ladybug

## 4.5.5 Black Spherical Ladybug

**Description:** The black spherical ladybug, better known as the spherical ladybug, is approx. 1.5 mm in size and black. Its body is densely hairy, the antennae and legs are yellowish

**Beneficial insect performance:** 240 spider mites, 600 mites

**Prey/ Host:** spider mites


Figure 4.7: Green Lacewings

## 4.5.6 Green Lacewings

**Description:** Green lacewings are characterized by the filigree structure of their transparent wings, which are folded like a roof. The eggs of the 6 to 10 mm long lacewings sit on long stalks.

**Beneficial insect performance:** 200 to 500 spider mites

**Prey/ Host:** aphids, spider mites


Figure 4.8: Lacewing Wasps

## 4.5.7 Lacewing Wasps

**Description:** Lacewing wasps belong to the family of parasitic wasps, which are very host-specific parasites. The females lay their eggs directly in the host. The hatching larvae feed on their host animal. The intensive parasitization phase begins in June.

**Beneficial insect performance:** one wolly aphid per larva

**Prey/ Host:** wolly aphids

Figure 4.9: Ichneumon Wasps

## 4.5.8 Ichneumon Wasps

**Description:** Several ichneumon wasp species of the genera Trissolcus, Anastatus and Telenomus can lay their eggs in the egg clutches of bugs and thus render them harmless. The picture on the left shows a clutch of the marmorated stink bug with the characteristic dark discoloration of the parasitized eggs.

**Beneficial insect performance:** Varies depending on the species

**Prey/ Host:** stink bugs

Figure 4.10: Earwigs

## 4.5.9 Earwigs

**Description:** The earwigs, which are mainly nocturnal, have been shown to decimate aphid colonies. In recent years, the omnivores have also occasionally caused damage through leaf feeding. Healthy apples are not usually eaten, but existing skin damage, for example in the stem pit, can be enlarged.

**Beneficial insect performance:** several aphids per day

**Prey/ Host:** aphids, wolly aphids, mites

In addition to arthropods, there are also numerous other beneficial animals such as various mammals (hedgehogs, weasels, bats), reptiles (lizards and snakes) and birds (birds of prey, insectivores). They can play an important role in pest control and should be encouraged in integrated farming systems.

# 4.6 Plant Protection Practices Against Diseases

## 4.6.1 Apple scab *(Venturia inaequalis)*

Figure 4.11: Symptoms of apple scab

### SYMPTOMS

- Apple scab predominantly appears on leaves and fruits.
- On leaves, it first appears on the lower side as velvety brown to olive green or mousy black spots.
- It becomes more definite in outline, turns dark brown to black with age, and develop on both sides of leaves.
- Affected leaves finally turn yellowish brown and drop (midsummer) prematurely.
- Sometimes, the entire leaf surface is covered with velvety black coloured scab lessions, called as “sheet scab”.
- It develops on fruit in early spring as (dark olive green spots) usually at calyx end; later become almost circular, brown to black and corky.
- Severely infected fruit become disfigured, knotty and develop cracks

### RISK FACTORS

- A high infestation from the previous year (over 10% of shoots with scab infestation in autumn).
- All factors that prolong leaf wetness and increase air humidity (e.g. dense trees).
- Strong-growing trees with late or no shoot termination.
- Locations with humidity
- A rainy winter and/or a rainy spring
- Snow cover in apple orchards over a longer period
- Leaf wet periods around flowering

### CULTURAL MEASURES

- In order not to disrupt leaf decomposition, copper should not be used after the harvest.
- If scab-infected leaves are found on more than 10% of the shoots in the fall, 5 kg/ha of urea should be applied shortly before leaf fall. The amount of nitrogen thus applied must be considered in the annual nitrogen balance.
- If possible, the fallen leaves should be raked into the lane in late fall or swathed and shredded with a flail mower. This will speed up the decomposition of the fallen leaves. If this measure is not carried out until spring, the expected effect is less.
- Due to a loose tree structure and calm growth, the trees are less susceptible to scab infections.
- Promote early shoot closure.
- Use drip irrigation or when watering with overhead sprinklers, make sure that the trees do not remain wet for longer than eight hours.

### CONTROL MEASURES: Key Points

- All scab-susceptible varieties must be preventively covered with an effective scab fungicide before each rainy period from budding until the end of the primary scab season. The scab-resistant varieties, on the other hand, should be covered with a scab fungicide if heavy periods and/or heavy sporulation are expected.
- The result of the primary scab defence must be checked at the beginning of June. To do this, the leaves of 100 shoots are scanned for scab spots. If scab spots are found on two shoots, this indicates a scab infestation of 2%.
- During periods of leaf wetness in summer that last longer than two days, there is a risk of fruit scab infections in the sensitive varieties even with a low initial infestation (0 to 2% shoots with scab infestation). These varieties should therefore be treated preventively with a contact fungicide if

longer periods of leaf wetness are expected. In the case of higher leaf scab infestation, care must also be taken after the primary scab period to ensure that the infection potential does not build up further. In this case, the fungicide coating should be renewed approximately every 10 days in May and every 14 days from June onwards.

- For varieties that are less susceptible to secondary scab, no more than one fungicide spray per month against scab is necessary in summer if the infestation is below 5%. If the primary scab infestation is above 5% and in the case of longer periods of leaf wetness (more than two days) the plants should be covered with effective fungicide.
- Scab-resistant varieties do not need to be treated against scab in summer. However, these varieties should still be treated with fungicides against other fungal pathogens about once a month before longer periods of leaf wetness (see the chapter on white mould, sooty mould and rain spot, Marssonina leaf drop, etc.).
- In order to be able to better assess the supply of ascospores in the spring, we recommend determining the leaf scab infestation on the long shoots in the fall by counting. If scab-infested leaves are found on more than 10 % of the shoots in the fall, a high supply of Ascospores can be expected.

## ALTERNATIVE PRODUCTS AGAINST APPLE SCAB

Alternative products with a lower environmental impact are already being used successfully around the world to regulate apple scab. They are listed below and should be used in the summer months. The effectiveness is partly comparable with chemical products (e.g. carbonates).

**Table 3:** Alternatives products with a lower environmental impact against apple scab

| Active ingredient | Use | Dosage for 200 l of water | Rainfall in mm | Additionally effective | Environmental impacts/ Hazardousness | Tree Stage |
|---|---|---|---|---|---|---|
| **Bacillus subtilis** | | 200 gm | | | harmless | Orchard floor after harvest |
| **Cladosporium cladossporioides** | Preventive /curative | 250 gm | | | harmless | Secondary Season |
| **Cu-hydroxide** | preventive | 10 g Cu met. | 60 | | harmless | Secondary Season |
| **K-hydrogen Carbonates** | curative | 250 gm | 20 | Powdery mildew | harmless | Secondary Season |
| **Na-hydrogen Carbonates** | curative | 250 gm | 20 | Powdery mildew | harmless | Secondary Season |
| **Lime Sulphur** | curative | 750 ml | 20 | Alternaria leaf spot/ Core rot | harmless | Primary / Secondary Season |
| **Microsphaeropsis ochracea** | | 200 gm | | | harmless | Orchard floor after harvest |
| **Sulphur** | preventive | 100 gm | 10 | | harmless | Secondary Season |
| **urea** | | 10 kg | | | harmless | pre-leaf fall |

**Carbendazim and Flusilazole are harmful to environmental and human health and therefore, not recommended by GIZ. As previously mentioned, we have sufficient alternatives available.**

## 4.6.2 Powdery mildew *(Podosphaera leucotricha)*

Figure 4.12: Symptoms of powdery mildew

### SYMPTOMS

- Initial infections appear as white powdery mass on the lower side of young leaves causes chlorotic patches on the upper surface. Later fungus appears on both the leaf surfaces, and the infected leaf tends to crinkle, curl, or roll upward along the edges giving a narrow appearance. Severe infection results in dropping of affected leaves during summer months.
- Infected new shoots become stunted with shortened internodes and covered with silver grey fungal growth show die-back
- Flower buds and petals are also affected by this disease. Such an infected bud is covered with a solid layer of white powder. These buds either do not bear fruit or the fruit remain small in size.

Polliniser varieties are more affected by this disease.

### RISK FACTORS

- Previous year's infestation
- Dry, warm climate
- Shoot growth in summer
- Hill and mountain locations

### CULTURAL MEASURES

- Cutting or tearing off mildew-infested shoots during winter pruning and in the growing season significantly reduces the infection pressure. This measure is particularly necessary in heavily infested plants, as chemical control alone is not sufficient.
- In summer, shoot closure/clipping should be encouraged. The mildew fungus primarily attacks young leaves.
- Orchard sanitation and planting resistant varieties. Before selecting the varieties, the varieties are tested for suitability in the respective region.

### CONTROL MEASURES

#### Chemical Products Against Powdery Mildew

- A four-spray schedule starting with wettable sulphur (600 gm/ 200 liters water) after pruning at late dormancy followed by another three sprays at green tip, petal fall and after 2 weeks of petal fall with above effective systemic fungicides has been recommended.
- Use only products, that are environmentally friendly: Spray effective mildew fungicide as difenoconazole (30 ml/ 200 litres water), fluxapyroxad +difenoconazole (60 ml/ 200 liters water), boscalid + pyraclostrobin (50 gm / 200 lt liters water) or metrafenone (20 ml/ 200 liters water). Starting with the first appearance of disease/ bud swell stage followed by another 2-3 sprays at an interval of 15-20 days.
- Carry out the first mildew spraying in yielding plants from the beginning of the bud swell stage. The highest infection pressure occurs from flowering to shoot closure. During this period, treatment intervals should not be long .
- In new plants, mildew treatments must be carried out from the budding stage. The choice of agent must be adapted to the vegetation stage of the new plants. Sterol synthesis inhibitors, for example, should only be used from the ballooning stage. If the budding of the young trees is delayed, the treatments must be carried out at shorter intervals. Not required

## 4.6.3 Marssonina blotch *(Marssonina coronaria / Diplocarpon mali)*

Figure 4.13: Symptoms of Marsonina blotch

### SYMPTOMS

- Disease symptoms first appear on mature leaves as dark green irregular spots becoming brownish, during summer.
- These spots later turn dark brown to black and coalesce to form a big blotch.
- Small black pin head like structure “acervuli” are visible in the leaf spots.
- Surrounding areas around the blotch turn yellow followed by severe defoliation during rainy season and only the fruits are seen hanging on the leafless shoots of the trees.
- As a result, the size of the fruit remains small. They also do not get full color and sometimes they also fall off.
- The development of spurs is also affected, and the yield of the next year is reduced. About one-third of the flowers of such plants bloom in November-December.
- Clear brown spots develop on the fruit surface near harvest, become oval, depressed, and dark brown with age and almost black at harvest. Small black acervuli are visible in the lesions.

### RISK FACTORS

- Previous year’s infestation
- Damp dew layers
- Reduced plant protection
- In integrated cultivation, Red Delicious has so far been the most severely infested variety. All varieties grown in Northern India are infested by Marssonina coronaria.

### CULTURAL MEASURES

- Ensure calm growth and a loose tree structure.
- All measures that promote rapid drying of the trees.

### CONTROL MEASURES

#### Non-Chemical

- Orchard sanitation by removing the fallen leaf litter and infected fruit helps in lowering the primary source of inoculum.
- Adopt proper pruning of trees for adequate penetration of sunlight and air circulation.
- Effective weed management in rainy season prevents the development of disease to a greater extent.

#### Chemical Products

- Spray of urea 5% (10 kg/200 litres water) before general leaf fall in the month of October – November helps in the rapid decomposition of the fallen leaves on the orchard floor and devoid the formation of primary inoculum, thus intrupt the disease cycle.
- Protective spays of dodine (150 gm/ 200 litres water), mancozeb (600 gm in 200 litres water), ziram (600 ml in 200 litres water) starting from the walnut stage till fruit harvest at an interval of 15 - 20 days are recommended.
- Strobilurins based combi-products fungicides viz., tebuconazole + trifloxystrobin (80 gm in 200 litres water), metiram + pyraclostrobin (200 gm in 200 litres of water), fluxapyroxad + pyraclostrobin (20 ml in 200 litres water) is recommended for spray after the appearance of disease during the rainy season at an interval of 15-20 days as eradicated.

## 4.6.4 Alternaria Leaf Spot *(Alternaria alternata)*

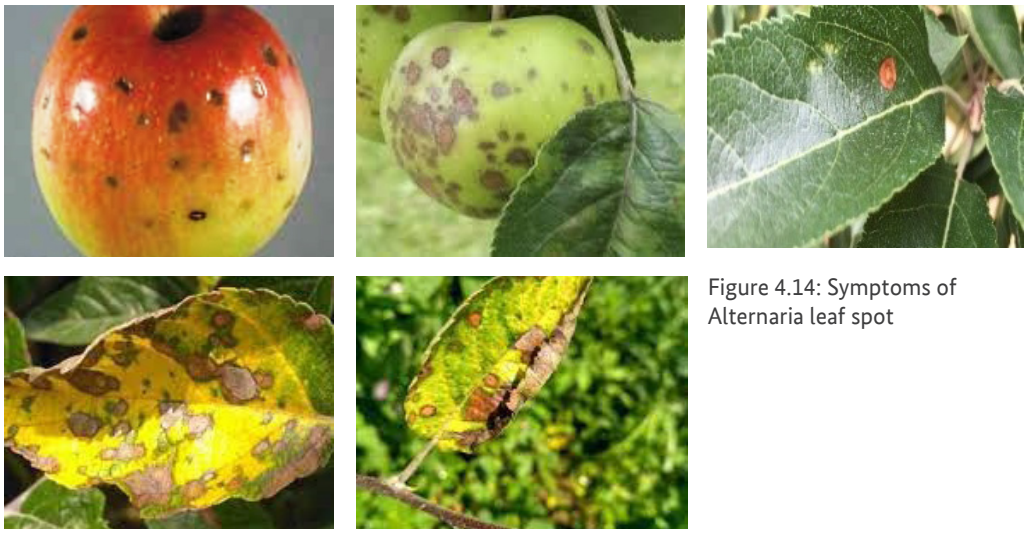


Figure 4.14: Symptoms of Alternaria leaf spot

### SYMPTOMS

- In late summer and during the rainy season, it appears often in the leaves as circular, dark-brown spots with dark purple edges. Sometimes, when the environment is favourable for the disease, irregularly shaped spots which are dark brown to black in colour develop.
- Infection on petiole appears as brown to dark brown elongated lesions.
- Heavily infected leaves become yellow and fall prematurely.
- On fruits sunken slightly circular brown spots appear about 6-8 weeks before harvest significantly reducing the quality and the shelf or storage life of affected fruit.
- A minimum of 10-12 hours leaf wetness is required at temperature around 20-25 °C for infection to take place.

### RISK FACTORS

- Damp locations where the surface moisture of the trees dry out slowly.
- Heavy infestation from the previous year
- The fruit mummies remaining on the tree as well as dead branches and leaves are breeding for the Alternaria fungus.
- If it stays wet for more than six hours in summer and the temperature rises above 20 °C, leaf and fruit infections can occur.
- Use of overhead sprinkling in summer
- Stress factors such as periods of heat in summer

### CULTURAL MEASURES

- The Alternaria fungus develops on dead plant substrate. The decomposition of the organic matter (fallen leaves, pruning wood) should therefore be encouraged. Treatment with urea (5 kg/ha) in the fall accelerates leaf decomposition. The shredding of the fallen leaves with a flail mulcher promotes decomposition. All maintenance measures should be aimed at preventing leaf spot.

# 4.7 Plant Protection against Insect-Pests

## 4.7.1 Woolly Apple Aphid *(Alternaria alternata)*

Figure 4.15: Symptoms of Woolly apple aphid

### DAMAGE SYMPTOMS

- It is a small purple colored (1.5–3.0 mm) sap-sucking insect bearing slit like cornicles and short rounded cauda. They live in colonies and their body is covered with a white woolly waxy substance, which is visible from a distance in the form of wool.
- Adult and nymph, suck sap from twigs and underground parts.
- Feeding on aerial parts and root system roughens the bark, results in formation of galls, which interfere in nutrient uptake and movement, thus reduces the vitality and fruit yield. Heavily infested trees often develop a short fibrous root system, yellowish foliage, become shaky and can be easily uprooted.
- Wooly aphids secrete sticky material called honeydew which can cause russet spots as well as sooty growth on the fruits. Its waxy flocculant when covers the fruits result in fading its colour.
- It also attack the roots of young plants in the nursery and hinder their growth.

### RISK FACTORS

- Strong shoot growth
- Delayed shoot termination
- Dense vegetation
- Winter pruning with lots of cuts

### CULTURAL MEASURES

- Calm building growth, moderate fertilization
- Avoid excessive pruning cuts during winter pruning.
- Prioritize a few large cuts over many small ones.
- Encourage early shoot termination.
- Encourage beneficial insects such as earwigs, aphid wasps, lacewings and hoverflies.

### CONTROL MEASURES

#### Non-Chemical

- Raise new apple orchard by planting healthy aphid free plants.
- Remove the water sprouts and cover the pruning cuts, cracks and crevices and wounds with as

#### Recommended Points

- Pruning and burning of infested plant parts.
- Woolly aphids can be managed by the release of nymphal parasitoid, *Aphelinus mali.* Syrphids-Episyrphus balteatus, Eupeodes corollae can target superficial woolly apple aphid root colonies,
- Conserve endo parasitoid Aphelinus mali and other predators like coocinellids, syrphids and chrysophids of this pest for natural control.
- Coccinellids- *Coccinella transversoguttata, Hippodamia convergens* etc. and chrysopids-are known to suppress the population of aphids.
- European earwig, *Forficula auricularia L.* (Dermaptera: Forficulidae) is another localized, omnivorous predator feeding on woolly apple aphids.
- Flowering plants in or on the borders of the

orchards provide nectar and pollens, which helps to conserve and attract natural enemies.

- Plant new plants raised on resistant rootstocks viz., MM 111, M793, MM778, MM789, MM106, M21 and M25.
- Use sticky bands during April –May and October around the stem for mechanical control.
- Keep plant basin weed-free.
- Fungal pathogen *Verticillium lecanii* is the known fungal pathogen of E. lanigerum

### Chemical Products

- Treat the infested plants with Thiamethoxam (100 ml per 200 liters of water) to reduce the aphid population before plantation.
- In non-bearing young plants place Phorate granules (10-30 gm) or Carbofuran (30 - 50 gm) at 5 cm deep in the soil by making a furrow around stem during April –May and October month. However, in fruit bearing trees the dose can be increased to 2 times.
- Mark the infested plants and spray with Spirotetramat (150 ml/ 200 liters of water), or Thiamethoxam (100 ml/ 200 liters of water) during June to October or after fruit harvest.
- Drenching of the root system with thiamethoxam (0.05%) or Imidacloprid (0.05%) helps in reducing the root population of the aphid.

## 4.7.2 Sanjose Scale *(Quadraspidiotus perniciosus)*

Figure 4.16: Symptoms of Sanjose scale

### DAMAGE SYMPTOMS

- It is a small sap-sucking insect whose body is covered with a grayish coloured shell.
- If the shell is removed, a yellow lemon colored insect appears.
- Initially, small needle-tip-like brown spots is formed on the affected twigs and in case of severe infection, the entire part is covered with a layer of dark gray coloured coating.
- Sucking of plant sap results in the formation of a halo-like red coloration/ distinct measles spot around feeding point, more pronounced on twigs and fruits.
- Due to sucking of sap by this insect , the trees become weak with decreased production. In case of excessive attack, the affected plants dry up and die.
- The insect usually survives in winter by covering the twigs with a black layer called “black cap” and is active in spring.

### RISK FACTORS

- previous year’s infestation
- Dense trees
- Cracks in the bark prevent optimal wetting/ coverage with plant protection products.

### CULTURAL MEASURES

- Heavily infested branches and twigs, should be removed and burned.
- Ensure a appropriately developed tree structure so that plant protection products can reach on its entire surface.

### CONTROL MEASURES

#### Non-Chemical

- Raise new apple orchard from pest free nursery stock.
- Heavily infested branches and twigs should be pruned and burnt.
- Two parasitoids namely Aphytis sp. and Encarsia perniciosi attack scale population. A coccinellid predator Chilocorus inferrnalis (10 - 20 beetles / tree) is quite effective.
- Reduce the amount of pesticides in summer. Only spray insecticides if a pest is really present in the orchard and the damage is actually likely, for protection of the parasitoides.
- Reduce the use of pesticides for protection of the parasitoides.

#### Chemical Products

- Make a solution of oil (horticultural mineral oil) such as Orchex 796/DC Tron Plus / Arbofine / Orchol-13 / Servo / Mac Illusion / Hindustan Petroleum HMO / Rilso 999 / Atso Supreme Oil / Petro Star HMO / Balmirol Hair Spray HMO (4 liters per 200 liters of water) between half inch green and tight cluster stage. Due to the environmental impact, the use of Horticultural Mineral Oil should be prohibited. Only use the product in exceptional cases if the infestation is particularly high.
- If the above spraying has not been done due to some reason, then in the month of May, take 2 liters of summer oil per 200 liters of water and spray it.
- Mark the affected plants in the orchard and spray approved insecticides at the time of crawler emergence from mid-May till three weeks before harvesting.
- For monitoring the emergence of male scale insect and crawlers use pheromone trap starting from pink bud stage till harvest. These traps also catch the male insects and thus prevent the mating of females and thus lower the crawler population and subsequent population build–up.

## 4.7.3 Mites *(Panonycus ulmi and Tetranychus urticae)*

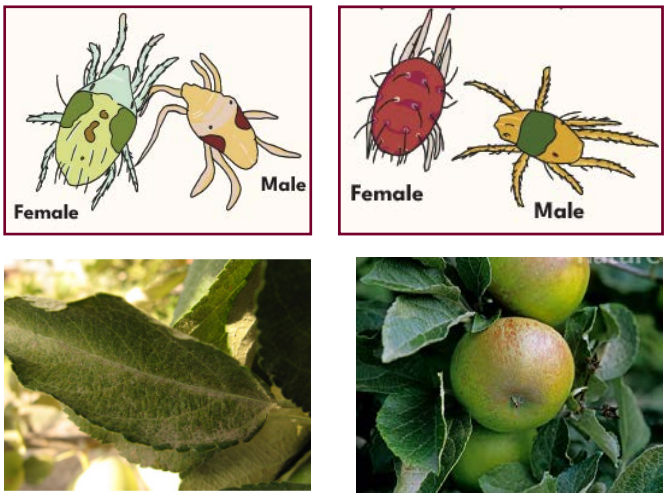



Figure 4.17: Different types of mites and their symptoms

It is a microscopic very small organism belonging to the eight legged spider species. Mainly two mites 'European red mite' and 'two-spotted spider mite' attack apples.

- European red mites *(Panonychus ulmi)*
- Two spotted spider mites *(Tetranychus urticae)*

### DAMAGE SYMPTOMS OF EUROPEAN RED MITE

- The female mite is red to chocolate brown in colour with fine white spots on body, and about 0.4 mm in size and just visible with naked eye.
- The male is yellowish red tinged with red colour and more slender than female.

The overwintering eggs are seen on spurs, twigs, and branches during October - November to March. They are spherical, pinkish to red in colour with hair rising from the centre.

## DAMAGE SYMPTOMS OF TWO SPOTTED SPIDER MITES

- The two spotted spider mite is normally pale yellow, pale green or straw coloured. The adult has two dark green or black patches on the anterior part of the body.
- Unlike the summer forms the hibernating mites produced during autumn are uniformly pink without spots on their body.
- Two spotted spider mites produce dense webbing to coat the surface of leaves. Overwintering females usually turn reddish-orange, and are often found near the calyx and stem of fruit near harvest. Two spotted spider mites cause bronzing on the leaves.
- The young and adult suck the sap on the lower surface of the leaves. As a result, sometimes numerous yellow spots appear on the upper surface.
- In excessive attack, the leaves turn from light green to copper in color and turn inwards.This mite forms a web.
- Fruit quality (size and color) and yield of affected plants are reduced. This also adversely affects the yield potential of the next year.

## RISK FACTORS OF MITES

- Previous year's infestation
- Proximity to roads (dust development, higher temperatures)
- Dry, hot weather
- Spray sequence damaging to predatory mites.
- Indescriminate use of broad-sprectrum highly toxic insecticides.

## CULTURAL MEASURES OF MITES

- In the event of localized occurrence, shoots with a high predatory mite population can be carried over from other apple trees.
- Use plant protection products that are gentle on predatory mites.

## CONTROL MEASURES OF MITES

### Non-Chemical

- Avoid indiscriminate spray of insecticides during growing period.
- During peak period of activity (July - August), predators namely Stethorus punctrum, Chrysoprela zastrowi sillemi , Orius sp., Predatory mites (Amblyseius longispinosus, A. fallacis, Zitzellia mali, Neoseiululus longispinosus ) and some thrips feed on different mite stages and control the mite population. Conserve these predators for biological control of mite pest.
- Three releases of predatory mite, Neoseiulus longispinosus at the predator prey ratio of 1:30 has proved helpful in controlling the infestation.

### Chemical Products

- Spray dormant oil at half inch green to tight cluster stage as against San Jose scale also kills overwintering eggs of European red mite and adults of two spotted spider mite.
- At petal fall stage, foliar application Spiromesifen (60 ml/ 200 liters of water) or Hexythiazox (200 ml / 200 liters of water) has been recommended.
- At walnut stage foliar application of HMO in a concentration of 1% (2 liters/200 liters) or Fenzaquin (50ml/ 200 liters water) is recommended.
- When the population becomes high in June – August (> 5mites per leaf) the application of acaricides namely Fenzaquin (50 ml/ 200 liters water) or Hexythiazox (200 ml/ 200 liters of water) or Spiromesifen (60 ml/ 200 liters of water) have been proved effective.

## 4.7.4 Apple Root Borer *(Dorysthenes hugelii)*

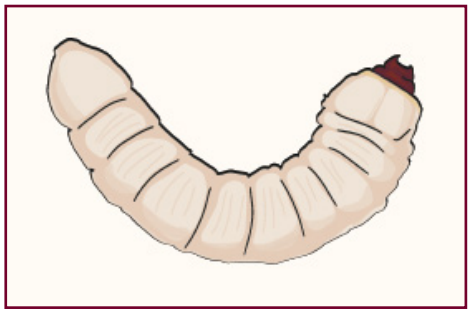


Figure 4.18: Diagrammatic representation of an apple root borer

### DAMAGE SYMPTOMS

- The leaves on infested plants become small, scattered with reduced green color.
- Infested plant show typical deep cuts on limbs and braches.
- Affected branches wither, tree become weak, shaky and die
- The grubs bore into or girdle around internal tissues of root.. As a result the main roots are severely damaged from the base and the trees, if young, die away while the older ones become weak and fall with strong winds.
- It is a polyphagous pest and it damages roots of crops.

### RISK FACTORS

- Problem is more severe in loamy and sandy-loam soils.Orchards near the deodar forest are more prone.CULTURAL MEASURES
- Keep the orchard healthy, following good agricultural practices.
- Manually catch and kill adults.
- Use cultural practices such as sanitation felling (destruction of damaged and infected plants or pruning).
- New plantations should be. Avoided in sandy soil and areas having previous history of borer infestation

### CONTROL MEASURES

#### Non-Chemical

- After cutting the wild plants from the garden, cut off the remaining stem upto the roots. These are ideal place for survival and multiplication of this pest.
- Open the tree basins during dormancy for collection and killing of the grubs.
- Install light trap in the orchard during June –July to attract the beetles, collect them and kill them by putting in kerosinised water.
- Alternatively, Install pheromones trap with the onset of rainy season to trap the male beetles. It will cause shortage of .male beetle available for mating, thus consequently lowers the population build-up.
- Improve plant health through bridge/approach graft.
- Use parasitic nematodes such as Steinernema pravassos and Heterorhabditis spp., and natural enemies such as Neoplectana nematodes and Elatrid beetle.
- Use insect pathogenic fungus Metarhizium anisopliae in the infested soil and it infects the damaging stage, larvae, of the borer.

#### Chemical Products

There are currently no effective chemical products to control very high infestation. In these exceptional situations, the active ingredient Chlorpyriphos can elp.

- Apply chlorpyriphos dust (300 gm/ tree) in the plant basin from June to July to kill the eggs laid in the plant basin.
- Drench the plant basins with Chlorpyriphos (1000 ml in 200 liters water) August – September to kill the neonate larvae.
- Irrigate the basin of affected plants with Chlorpyriphos (1000 ml/200 liter of water) in the 1.0-meter circle of the main stem from mid-November to March.

# 4.8 Pesticides - Handling and Application

## 4.8.1 Occupational Safety When Handling Plant Protection Products

**PREPARATION OF THE SPRAYING MIXTURE:** Weighing, dosing and preparing the spraying mixture poses the greatest health risk to the user as it is direct work with the undiluted plant protection product. It is therefore important to use personal protective equipment. When preparing the spray mixture, the mask, gloves and protective suit must be used to combat the chemical risks. To prevent damage to people and the environment, plant protection products must never be handled at the border areas. Care must also be taken to ensure that the stock tank does not overflow.

**THE FOLLOWING PERSONAL PROTECTION EQUIPMENT IS REQUIRED**

- Half mask to protect the respiratory tract:
- Protective gloves against chemicals:
- Protective suit for chemical risks:
- Safety goggles

**OBSERVE THE LABEL:** The label is particularly important. The label must be read before use, as it also contains important information on handling the plant protection product and the health risks for the user.

**SAFETY DATA SHEET:** There is a separate safety data sheet for each plant protection product. This contains information that enables the user to take all necessary measures to protect their own health and safety. Safety data sheets for plant protection products can be obtained from traders or online.

**PROTECTION DURING THE APPLICATION OF CROP PROTECTION PRODUCTS:** The application of the spray liquid also poses health risks for the user, as they can come into contact with it via the respiratory tract or skin. Personal protective equipment must be adapted accordingly.

**CLEANING THE PROTECTIVE CLOTHING:** All soiled parts of the protective clothing should be cleaned after spraying work has been completed. The manufacturer's cleaning instructions should be followed for protective clothing. Do not wash together with other items of clothing. Disposal instructions must be followed for disposable protective suits.

**OBSERVE THE RE-ENTRY TIME:** For all plant protection products, no work should be carried out in the plant before the spray mixture has dried. For the first 24 hours after treatment, the plant should only be entered wearing personal protective equipment. Even if a shorter re-entry time is specified on the label, this should be observed for safety reasons.

For some products, there are additional regulations on which protective clothing must be worn when working after the re-entry time has expired. This information is also printed on the label or safety data sheet.

# 4.9 Overview of the Active Ingredients used in India and their Hazards and Effects on the Environment

**Legend**

| Colour/ Symbol | Side Effect on beneficial oganisms |
|---|---|
| ● | No known side effect on beneficial organisms |
| ● | Slightly harmful side effect on beneficial organisms |
| ● | Harmful side effect on beneficial organisms |

| Colour/ Symbol | Explanation |
|---|---|
| D | Appropriate precaution |
| C | Only by authorized staff |
| B | For use only as exception |
| A | Not allowed |

**Table 4:** Overview of active ingredients used in India and their environmental hazards

| Environmental impacts/ Hazardousness | Effect on beneficial insects. | Active ingredient | Trade name(s) |
|---|---|---|---|
| A | ● | Carbendazim | Dhanustin/ Bavistin/ Mavistin/ Derosal/ Benfil/ Gilzim/ Carbestin/ Goldstin |
| D | ● | Captan | Captaf/ Dhanutan/ Kohicap/ Masstan/ Captax/ Capgold |
| C | ● | Copper oxychloride | Blitox/ Fytolan/ Masstox/ Copter/ Trucop/ Riva |
| C | ● | Difenoconazole | Score/ Scale/ Dizole/ Rubigon/ Dkarara |
| C | ● | Dodine | Superstar/ Syllit/ Himdin/ Tihfa/ Noor |
| B + D | ● | Metiram+Pyraclostrobin | Cabrio Top |
| B | ● | Hexaconazole | Contaf/ Hexzol/ Sitara/ Titan/ Glow/ Envil/ Hexcon/ Krozole |
| B | ● | Mancozeb | Indofil M-45/ Dithane M-45/ Abic M-45/ Emthane M-45/ Uthane M-45/ Dhanuka M-45/ Mass M-45/ Kohinoor M-/45/ Uthane M-45/ Hindustan M-45/ Gold M-45 /Marlett M-45 |
| C | ● | Myclobutanil | Systhane/ Boon/ Index/ Grapple |
| B | ● | Propineb | Antracol/ Aaroosh |
| B | ● | Thiophanate methyl | Roko/ Topsin M/ Alert/ Stop/ Trust/ Key |
| B | ● | Zineb | Indofil Z-78/ Kanji |

| Environmental impacts/ Hazardousness | Effect on beneficial insects. | Active ingredient | Trade name(s) |
|---|---|---|---|
| B |  | Ziram 27% | Cuman L |
| (C) |  | Ziran 80% | IPL Ziram |
| C +(C) |  | Tebuconazole +Trofloxystrobin | Nativo |
| C + D |  | Tebuconazole + Captan | Shamir |
| D + C |  | Fluxapyroxad + Difenoconazole | Sercadis Plus |
| A + B |  | Carbendazim + Mancozeb | SAAF |
| D + D |  | Boscalid + Pyraclostrobin | Signum |
| D |  | Metrafenone | Acisio |
| D + D |  | Fluxapyroxad + pyraclostrobin | Merivon |
| A |  | Flusilazole | Cursor |
| A + A |  | Carbendazim+Flusilazole | Lustre |

## BOX 3: Banned Chemical Products

| Active Ingredient | Trade Names(s) |
|---|---|
| Chlorpyriphos | Dursban /Durmet/ Danusban/ Massban/ Force/ Tricel/ Navigator/ Goldban |
| Fenzaquin | Magister/ Majestic |
| Hexythiazox | Maiden/ Endurer |
| Malathion | Cythion/ Massthion |
| Oxy-demeton Methyl | Metasystox |
| Spiromesifen | Oberon |
| Propargite | Omite/ Simba |
| Horticultural Mineral Oil | Orchex 796/ D-C-Tron Plus/ Arbofine/ Orchol13/ Srvo/ MAL All Season/ Hindustan Petroleum HMO/ Rilso-999/ Atso Supreme Oil/ Petro Star HMO/ Balmerol Balspray HMO |
| Thiacloprid | Alanto |

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