सत्यमेव जयते

IPM Package of Practices for Apple

(For Producing Quality Fruits for Export)

Government of India

Ministry of Agriculture & Farmer's Welfare

Department of Agriculture & Farmer's Welfare

Directorate of Plant Protection Quarantine & Storage

NH-IV, Faridabad

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IPM Package of Practices for Apple (For producing quality fruits for export) was compiled by the DPPQS technical team under the Chairmanship of Dr. J. P. Singh, Plant Protection Adviser and guidance of Dr. Pramod Kumar Meherda, IAS, Joint Secretary (PP). Dr. S.C. Dubey, Assistant Director General (PP & BS), ICAR, New Delhi provided review from crop specific ICAR institute - Central Institute of Temperate Horticulture, Srinagar.

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आज़ादी का अमृत महोत्सव

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FOREWORD

Pests and diseases cause significant losses to the farmers. Generally, farmers apply large quantity of pesticides to control pests & diseases during various crop growth stages either calendar based or on noticing damage symptoms in the crop. Indiscriminate use of chemical pesticides is a major cause of ecological imbalance, environmental pollution, pesticide resistance, pest resurgence and pesticide residues.

Integrated Pest Management (IPM) is a globally accepted strategy for promoting sustainable agriculture. Initially IPM strategy allow chemical pesticide application on pest population reaching at economic threshold level which has shifted to more ecologically sustainable Agro-Eco System Analysis (AESA) based decision making for selection of IPM technique. The AESA based decision making considers relationship among various components of an agro-ecosystem with special focus on pest- defender dynamics, abilities of plants to compensate for the damages caused by the pests and the influence of abiotic factors on pest buildup. IPM approach advocates utilization of alternate pest management techniques like cultural, mechanical and biological prior to judicious use of chemical pesticides. Pesticide residues in agricultural produce has emerged as a major impediment for agricultural exports, especially of fresh fruits and vegetables.

Apple is one of the most important temperate fruit crop of North Western Indian Himalayan region. Sincere efforts have been made by DPPQS & ICAR to incorporate all the aspects in the IPM Package of Practices for Apple that will help in production of pest and pesticide residue free Apples. I hope that IPM Package of Practices for Apple (for producing quality fruits for export) will be a handy document for Central and State government field functionaries involved in extension and for the farmers for production of residue free quality Apple fruits for domestic and export markets.

(Dr. Pramod Kumar Meherda)

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FOREWORD

IPM is a science-based, decision-making process that combines biological, cultural, physical and judicious use of chemical to minimize crop loss due to pest in a way that to reduce overall economic loss with due consideration to health and environment.

During late 1990s, FAO started advocating Agro-Ecosystem Analysis (AESA) based IPM practices. Experiences in different countries have shown that AESA, which takes into account ecological principles and relies on the balance approach that is maintained by biotic factors in an agro ecosystem has also resulted in reduction in cost of production and increase in yield. AESA based IPM also takes into account active participation of farmers and promotes experiential learning and discovery based decision making by them. AESA based IPM in conjunction with ecological engineering for pest management promotes bio-intensive strategies against chemical intensive approaches, while retaining the option to apply chemical pesticides judiciously as a last resort.

I am glad to see that resource persons of ICAR & DPPQS have made sincere efforts in developing IPM Package of Practices for Apple (For producing quality fruits for export) by incorporating agro-ecosystem analysis, ecological engineering, pesticide application techniques, other IPM options and post-harvest management for the pesticide residues free Apple and hope this will certainly support the export of Apple after following appropriate plant protection measures including Good Agricultural Practices (GAP).

I covey my sincere thanks to Dr. S.C. Dubey, ADG(PP & BS), ICAR, New Delhi for providing review from crop specific ICAR institute - Central Institute of Temperate Horticulture, Srinagar.

I hope this IPM package on Apple will serve as a ready reference for field functionaries of Central / State Governments, NGOs and farmers for producing good quality, pest and pesticide residue free Apple fruits.

Dr. J. P. Singh
Plant Protection Adviser

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PREFACE

Phytosanitary and sanitary compliance are major aspects for export of any fresh fruits. Indiscriminate use of chemical pesticides for management of pests/ diseases results in pesticides residue in fruits and fails meeting sanitary requirement of various importing countries. In recent time, most of the countries incorporating Maximum Residue Level (MRL) as major sanitary requirement for import of Agricultural commodities especially for fresh fruits & vegetables. So there is challenge to produce pest as well as pesticide free fruits for export. Adoption of Agro-ecosystem Analysis (AESA) based Integrated Pest Management (IPM) can promise production of pests as well as pesticide residue free fruits and comply with Phytosanitary and Sanitary requirements of most of the Apple importing countries. In addition, AESA based IPM also conserves bio-diversity in agro-ecosystem, reduce environmental pollution and reduce cost of cultivation and thereby increase farmers' income.

I convey my sincere thanks to Joint Secretary (Plant Protection) & Plant Protection Adviser for encouragement and facilities for compilation of this PoP and also to ADG (PP), ICAR, New Delhi for review from crop specific ICAR institute - Central Institute of Temperate Horticulture, Srinagar.

This IPM Package of Practices for Apple (For producing quality fruits for export) will prove an important guide for extension functionaries of Central / State Governments, NGOs and farmers for producing exportable apple fruits.

Om PrakashVerma
Joint Director (IPM)

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1. INTRODUCTION

Apple is the most important temperate fruit crop of the North Western Indian Himalayan region. It is fourth among the most widely produced fruits in the world after Orange, Banana and Grape. China is the leading Apple producer in the world. In India, it is grown in Kashmir, Himachal Pradesh and hills of Uttarakhand. Apple cultivation also extended to Nagaland, Sikkim, Arunachal Pradesh and Meghalaya. India's share in the total Apple production of the world is only 2.0 %. In India, total area under Apple cultivation is 2.50 lakh hectare producing 14.70 lakh MT fruits with productivity of 5.9 MT/ha. In Jammu & Kashmir, total area under Apple is 90.10 thousand hectares with production of 909.60 thousand MT. The state of J&K leads the other Apple producing states in India, in terms of productivity with production of 10.1 MT fruits per hectare.

Majority of existing temperate fruit plantations are on seedling rootstocks and planted under low density. Trees on seedling rootstocks are more vigorous, having long gestation period, and low in productivity, therefore, high density is considered as most important method to achieve high productivity. The trees on dwarfing and semi-dwarfing rootstocks are more precocious, easily manageable, and produce more fruits of better quality. India also imports large quantity of Apple from different countries.

2. CLIMATE

Temperature is one of the most important factors affecting Apple cultivation. The varieties of high density Apple plants are high coloring strains and require slightly less chilling (800 to 1200 hours) as compared to traditional Red and Starking Delicious cultivars. These varieties are highly suitable for cultivation in areas ranging between 1500-2500 m AMSL altitudes. However, these cultivars can also be planted at high elevation in dry temperate zone of the state. Warm day time temperature around 20-25^{0}C at bloom time is ideal for good bee activity, rapid pollen germination and plentiful fruit setting. Fruit set is likely to be reduced if extended cold, wet and cloudy daytime conditions persist over bloom period. Apple can be grown in a wide range of rainfall from evenly spread rains of 25-37 cm per year to heavy seasonal rains up to 125-175 cm during monsoons.

3. SOIL REQUIREMENT, TOPOGRAPHY AND LAND PREPARATION

Apples grow best on a well-drained, loam soils having a depth of 45 cm and a pH range of 5.5-6.5. The soil should be free from hard substrata and water-logged conditions. Soils with heavy clay or compact subsoil are to be avoided. For high density plantation, the plants are raised on dwarfing and semi-dwarfing rootstocks thus the sites should be flat or with gentle slopes. Very steep and sloppy areas are not suitable for high density plantation especially for dwarfing rootstocks. The Apple plants raised on dwarfing rootstock M9 should necessarily be planted in land having deep soil, and assured irrigation. Apple plants on semi-dwarfing rootstock MM106 and on semi-vigorous rootstock MM111 also require deep soil but can be planted in site having gentle slope land.

Land preparation starts about 1-2 month before planting and following points should be taken care during site preparation.

- Remove all the bushes, weeds, stones, and pebbles from the soil. Make terraces in the steep slopes.
- Take soil sample from 0-30 cm and 30-60 cm depth to test soil fertility status and soil pH.
- Make proper provision of drainage in wet soil site. Use of cut-off drains, slightly raised rows or mounds to plant trees on and slightly depressed inter-rows.
- Soil solarization and fumigation with fumigants is suggested for re-plant sites in flat lands.

4. CULTIVARS/ ROOTSTOCKS AND VARIETIES

Scab Resistant Varieties

Prima, Priscilla, Sir Prize, Jonafree, Florina, Macfree, Nova Easy Grow, Coop 12, Coop 13 (Redfree), Nova Mac, Liberty, Freedom, Firdous, Shireen, Emra, Ambstraking, Ambroyal, Ambrich and Ambred.

Powdery Mildew Resistant Varieties

Maharaji Chunth, Golden Chinese (Apple cultivars), Yantarka Altaskya, Dolgoe (crab Apple cultivars), Prima, Priscilla and Nova Easy Grow

Source: (http://www.omafra.gov.on.ca/english/crops/facts/98-013.htm).

Low Chilling Varieties

Michal, Schlomit, Anna, Tamma, HRM-99, Vered, Neomi, Dorsett Golden, Tropical Beauty, Parlin's Beauty

Varieties recommended for J&K, H.P and Uttarakhand

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

   Based on popularization and performance of new varieties like Gala Redlum, Red Velox, Jeromine, Scarlet Spur-II, King Roat, Super Chief etc, these are suggested for UT of J & K.
2. **Himachal Pradesh**: Golden Delicious (Late Season), Red Delicious (Mid season), McIntosh, Scarlet Spur II, Jeromine, Red Cap Valtod, Red Velox, Super Chief, Schlect Spur, Gale Gala (P), Redlum Gala (P), other strains of Gala (P), Fuji (P), Granny Smith (P), Sun Fuji (P)
3. **Uttarakhand**: McIntosh, Chaubattia Anupam Varieties recommended for J & K and HP can be grown in Uttarakhand also keeping in view the desired location for different varieties.

*(*P=Pollinizer variety)*

Rootstocks

Rootstock selection needs to take account of many inter-related factors:

- Variety vigour and growth habit
- Elevation - tree vigour usually decreases with increasing elevation
- Fertility- more vigorous rootstocks are more suited to lower fertility.
- Soil water and aeration - trees usually grow best in loamy soils because they have the best condition of good water holding capacity and freedom from poor drainage and aeration. Water can easily become a limiting factor in lighter, sandy soils & tree growth more likely to be restricted if soilbecomes dry. Soil with high clay content have higher water holding capacity which favours their drought tolerance but are more likely to adversely affected by water logging and/or poor root aeration in winters of higher rainfall areas.

Table: Superior Apple Cultivars Identified Under Various Groups

S. No.	Type	Varieties
1.	***Spur type and semi spur***	Super Chief, Red Chief, Red Spur, Ruby Red, Hardi Spur, Sturdy Spur, Well Spur, Super Red Chief, Stark Spur Red, Stark Spur Gold, Golden Spur, Spur Type Red Delicious, Bright N Early, Oregon Spur, Starkrimson.
2.	***Colour strains***	Red Velox, Scarlet Spur, Jeromine, Top Red, Hi Red, King Roat
3.	***Low chilling***	Tropical Beauty, Dorsett Golden, Shlomit, Michal, Mayan. Vered, Tamar, Anna, Naomi, HRM-99
4.	***Scab resistant***	Priscilla, Sir Prize, Macfree, Freedom, Coop 12 and Coop 13. Firdous and Shireen are indigenously developed scab resistant cultivars
5.	***Varieties of promise***	Fuji, Red Fuji, Gala, Scarlet Gala, Gala Must, Granny Smith, Braeburn, Jonagold, Empire, Criterion.
6.	***Processing cultivars***	Delicious groups, Granny Smith, Liberty, Rome Beauty, York Imperial, Stayman Winesap, Northern Spy
7.	***Indigenously developed varieties***	Lal Ambri, Sunhari, Firdous, Shireen, Akbar, Ambred, Ambrich, Ambroyal, Ambstarking etc
8.	***Root stocks***	M-7, M-9, M-26, M-27, MM-106, MM-109, MM-111 and EMLA-106. • For lower elevations and flat land: M-9 • For well drained soils (higher and lower elevations): MM-106 • For higher elevation and gentle slope: MM-111, MM-106 • EMLA series is virus free so may be preferred.

Table: Productivity Potential of Some Indigenously Developed Apple Cultivars

Cultivar	Year of release	Av. Yield (kgs/tree)	Yeild (Mt/ha)
Lal Ambri	1973-74	150-160	35-40
Sunhari	1973-74	64-72	16-18
Akbar	2000-01	160-170	40-45
Firdous	1995	50-60	12-15
Shireen	1995	50-60	12-15
Gulshan	2001-02	119-120	29-30

Besides elite varieties it is also important to introduce and identify rootstocks as they are important in high density planting system and have precocity and resistant to various biotic and abiotic stresses. Common rootstocks recommended in India are M 27- very dwarf; M 9- Dwarf; M 7, M 26 & M106- Semi Dwarf; MM 104, MM109, MM 111- Semi vigorous to Vigorous and MM 111 drought tolerant. These have to be made available in large quantity if productivity and quality to be increased. Micro propagation in this regard has provided an opportunity for obtaining large quantity of disease free plants as against conventional mound or stool layering. M-9 is the most common root stock recommended for high density apple cultivation at spacing of 3.0m x 1.5m accommodating 2222 plants per ha. But apple varieties grafted on M-9 clonal rootstock need support system and assured irrigation. On the other hand, apple varieties grafted on clonal rootstock MM-106 does not need support system but need assured irrigation. Apple plants grafted on MM-111 are tolerant to drought and other stress conditions besides providing strong anchorage to the plants but being vigorous in nature can accommodate about 625 plants

Poor yield in apple is attributed to faulty pollination management with inadequate pollinizer and pollinating insects. Bloom synchronization among the main varieties and pollinizers is essential with fruits of the pollinizers should preferably have commercial value as dessert, processing or ornamental. The pollinizers should be self-fruitful diploid or reciprocally cross compatible, have high bloom density, extended flowering period and should not be susceptible to any diseases or insects.

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

a) **Early Bloomer:** McIntosh, Black Ben Davis, Tydeman's Early Worcester, Manchurian, Everest, *Malus floribunda*.

b) **Mid Bloomer:** Winter Banana, King of Pippin, Rus Pippin, Lord Lambourne, Yellow Newton, Summer Queen, Snow Drift, Gloster, Red Gold, Red Flesh, Chestnut, Gala, Spartan, Commercial, Dolgo, Cox Organe Pippin, Yellow Transparent, York Imperial, Jonathan, Spur type Winter Banana, Lodi.

c) **Late Bloomer:** Golden Delicious, Golden Spur, Rome Beauty, Granny Smith, Worcester Pearmain, Golden Hornet, Starkspur Golden.

d) **Crab apples as pollinizers:** Crab apples are regular in flowering with high bloom index. Most crab apples bear flowers on spurs as well as on one year shoots and have a long flowering duration due to blooming first on spurs followed by flowering on shoots. Trees can be easily trained on pillar shape and tree volume can be regulated by pruning of current year shoots. Crab apples can also be planted as filler tree without interfering main variety spacing. In India Manchurian crab, Snowdrift, Golden Hornet and Japanese crab have been recommended as pollinizers. Blossom colour of crab apples is important as honey bees or bumble bees if become habitual for foraging on pure pink, red or purple blossoms shows a foraging tendency only on trees with such coloured flowers thereby avoid white blooms on main varieties.

5. PROPAGATION & PLANTING

Seedling Rootstocks

The Apple plantations are raised on seedling rootstocks. The seeds of commercial varieties are used by nurserymen for raising rootstocks. Apple seeds need stratification in moist sand at 4^0-7^0C for 60-90 days.

The water-soaked seeds are placed between 2 and 3 cm thick layers of moist sand in wooden boxes or polythene bags during December. The stratification can be accomplished in the lower chamber of the refrigerator.

The stratification requirement is also met with, in areas having very cool winters, by direct sowing of seeds in nursery beds in November-December.

The pre-stratified seeds are sown during February-March on raised beds. One-year-old seedling stocks are ready for grafting during February-March.

Clonal Rootstocks

Clonal rootstocks of Apple are propagated through mound layering. The rooted layers of the clone are planted in stool beds during winter at a distance of 30 cm in row and 60 cm apart rows. The 3-4 years old layers give rise to numerous suckers during spring. The suckers are ringed or notched near the base during the rainy season and covered with soil to encourage rooting. Difficult to root rootstocks like M 9 are treated with 1000-2000 ppm Indole-3-Butyric Acid (IBA)at the notched/ringed portion for quick root initiation. The rooted layers are separated at

the onset of dormancy (December) and lined out in nursery beds for further grafting with scion varieties during February-March. The rootstock should be healthy and disease free and should attain the thickness of 0.9-1.25 cm at grafting height.

Time of Grafting / Budding

Tongue grafting	:	February-March
T-budding	:	June – July
Chip budding	:	August

Precautions for Budding/Grafting

- The scion should be collected from the mother plants of known pedigree.
- It should be collected from bearing trees only, during dormancy.
- One year old shoot growth is ideal for scion wood.
- Scion sticks should have only vegetative buds and not the reproductive buds.
- The scion should have 3-5 well developed buds with smooth internodes.

Micropropagation: In the last 20 years new and improved micropropagation techniques have been developed for many rootstocks including the apple clones M.9, M.26, M.27, and MM.lll. These hi-tech propagation techniques can be employed for production of large-scale virus free planting material of apple clonal rootstocks.

The planting density and spacing depend upon the scion and rootstock combination and fertility of the soil and training system.

Table: Suggested Planting Distance and Training System

Variety/rootstock combinations	Planting distance			Training system
	Row to Row (m)	Plant to Plant (m)	No. of plants/ha	
Standard (Jeromine, Red Velox, Gala and Fuji rootstock (M9) strains)/ dwarfing	3.0	1.5	2222	Tall Spindle

Spur type (Super Chief, Scarlet Spur-II, Schlect Spur, Red Cap Valtod)/ Semi-dwarfing on rootstock (MM106)	3.0	1.0	3333	Tall Spindle
Standard (Jeromine, Red Velox, Gala and Fuji rootstock MM-106)/ semi-dwarfing	3.0	3.0	1111	Mini center Modified Central Leader Central Leader Open Centre
Spur type (Super Chief, Scarlet Spur-II, Schlect Spur, Red Cap Valtod)/ Semi-dwarfing on rootstock (MM106	2.5	2.5	1600	Mini center Spindle Bush Modified Central Leader Central Leader Open Centre
Standard/ Semi dwarf	3.0	1.75m	1900	Tall Spindle or Mini Centre

6. NUTRIENT MANAGEMENT

Soil pH

The first stage of effective nutrient management is ensuring soil pH is within the range of 5.8 and 6.5. Maintaining the pH within this range ensures there is optimum nutrient availability for plant uptake. Low pH can result in high solubility of some nutrients, such as manganese, leading to toxic levels within the plant. High pH can lead to deficiencies due to low solubility of nutrients and subsequent low plant uptake. Ground lime is used to raise soil pH.

A sandy soil requires less lime, and a clay soil can require more lime to make the same change.

It can take 12 to 18 months for the lime to be fully dissolved, and raising pH, depending on how finely the lime is grounded. The finer the lime the earlier it is effective.

Fertigation Schedule

Recommended dose (N- P_2O_5 - K_2O) 35-17.5-35 g/tree/year

In addition, apply FYM @5 kg/ plant or vermicompost @ 2.5 kg/plant (one-year- old) and increase the amount progressively upto 7 years i.e 35 Kg FYM/ plant or 17.5 kg/plant vermicompost.

Apply 35, 17.5 and 35 g/plant N, P_2O_5 and K_2O for one- year-old plants, respectively. Increase the amount by same amount for progressive increase in age up to 7^{th} year i.e., 245, 125 and 245 g/plant N, P_2O_5 and K_2O.

In case N application is made through urea, apply lime@ 60g and 425 g/plant in one and seven-year-old plants, respectively to neutralize the acidity.

Fertigation

Fertigation offers the potential to overcome the low fertility of soils by timely delivery of key nutrients to the main rooting zone in orchards. Efficient use of N, however, depends upon reducing excessive drainage of the water and improving N uptake. In addition, delivery of more immobile nutrients such as P and K directly to the roots is facilitated when these nutrients are supplied in solution. The recommended numbers and discharge of drippers/ micro jets/ micro sprinklers in apple with plant to plant and row to row spacing of 15 x 15 ft.; 4- drippers per plant with 4- litres per hour discharge under loamy and clay loamy soils; 3- drippers per plant with 4- litres discharge per hour under clay soils; 2- micro jet per plant of half circle type with low discharge; one micro sprinklers per plants at 40 litres of peak water requirement per day per plant.

Integrated Nutrient Management

The growth potential of apple trees and to sustain the development initiatives for Hitech horticulture, nutritional management plays a key role. The plant nutrient deficiency and excess are the major concerns. Therefore, it becomes important that we understand our land put to fruit cultivation i.e. land quality, fertility, slope and location of the orchard. In general apple orchard yielding 25 t/ha on an average removes 100 kg nitrogen, 45 kg phosphorus and 180 kg potassium annually.

Organic Manures

Manure contains beneficial organic matter and many macro and micronutrients. The organic nitrogen in manure is mineralized over time, providing nitrogen in diminishing quantities for several years. Important manures include FYM, vermicompost and biofertilizers.

Micronutrient Spray Schedule

On some trees deficiency of zinc, boron, manganese and calcium may be observed which is corrected with the application of appropriate chemicals through foliage spray.

Nutrient element	Salts	Quantity (g) per 100 litres of water	Spray interval	Time of spray
Zinc	Zinc sulphate	500	1-2 sprays at 15 days interval	May-June
Boron	Boric acid	100	-do-	2 sprays, one at pink bud stage & another after petal fall in May-June
Calcium	Calcium chloride	500	-do-	1st spray 45 days before harvest & 2nd spray after 15 days of 1st spray

Note: *Spray above chemicals separately and mix hydrated lime equal to half quantity of zinc sulphate, i.e. 250 g/100 litres of water*

7. IRRIGATION

Irrigation Schedules (litre/plant)

Months	Quantity of irrigation water (litre)*						
	1^{st}yr	2^{nd}yr	3^{rd}yr	4^{th}yr	5^{th}yr	6^{th}yr	7^{th}yr& above
March (Bi-weekly)	5.0	5.0	7.5	7.5	7.5	10.0	10.0
April (Bi-weekly)	7.5	7.5	7.5	10.0	10.0	12.5	12.5
May (Bi-weekly)	12.5	12.5	12.5	15.0	15.0	15.0	15.0
June (Bi-weekly)	15.0	15.0	15.0	17.5	17.5	20.0	20.0
July**	--	--	--	--	--	--	--
August**	--	--	--	--	--	--	--
September (Weekly)	5.0	5.0	7.5	7.5	7.5	10.0	10.0
October (Weekly)	5.0	5.0	7.5	7.5	7.5	10.0	10.0
November (Weekly)	5.0	5.0	7.5	7.5	7.5	7.5	7.5

** Volume of water for one square meter tree basin & increase with the increase in the size of basin.*

***In July & August, irrigations should be given as per schedule of May in case there are long dry spells.*

In Micro irrigation system, four emitters/plant each having a discharge rate of 4 litre/hour.

Under conventional surface irrigation, a total of 8 irrigations, each of 4 cm (40 litre water for a tree basin of 1.0 m^2) at 20 days interval in March and April and at 10 days interval during May and June.

Integrated Water Management

Proper irrigation is essential to maintaining a healthy and productive apple orchard. Over irrigation slows root growth, increases the potential for iron chlorosis on alkaline soils, and leaches nitrogen, sulphur and boron out of the root zone leading to nutrient deficiencies. Excessive soil moisture also provides an environment ideal for crown and collar rots. Over irrigation can also induce excessive vegetative vigour. Applying insufficient irrigation water results in drought stress and reduced fruit quality.

8. TRAINING & PRUNING

- In medium and high-density orchards on clonal rootstock, the main principles of training and pruning are-
  - To encourage rapid canopy development.
  - To minimize the pruning of young trees in favour of early intervention (pinching out of unsuitable growth) and branch training (to maximize the use of available branches).
- In high density orchards, the trees are to be trained either with **Tall Spindle** or **Mini Centre systems.** While doing the training and pruning of trees in these planting systems, the following points are to be kept in mind.
  - Keep only weak and horizontal branches. Remove upright and strong growing branches.
  - Make monthly thinning cuts, tipping cuts only in special situations such as forcing of laterals in an area devoid of branches.
  - Make 'Dutch' or bevel cuts on branches > 3-4 years of age to recycle back to axis.
  - Tie or put weight on branches as much as possible especially new succulent branches in the late summer.

9. AGRO-ECOSYSTEM ANALYSIS (AESA) BASED DECISION MAKING FOR PEST MANAGEMENT

9.1 AESA

The health of a plant is determined by its environment. This environment includes abiotic factors (i.e. sun, rain, wind and soil nutrients) and biotic factors (i.e. pests, diseases and weeds). All these factors can play a role in the balance, which exists between insect-pests and their natural enemies. If we understand the whole system of interactions, we can use this knowledge to reduce the negative impact of pests and diseases.

Decision making in Integrated Pest Management requires a thorough analysis of the agro-ecosystem. Farmers should learn to observe the crop, how to analyze the field situation and how to make the proper decisions for their crop management. This process is called the Agro-Eco-System Analysis (AESA).

9.2 AESA involves three steps

Observation → Analysis → Decision making

Farmers should make a drawing on a large piece of paper, in which they should include all their observations. The advantage of using a drawing is that it forces them to observe closely and intensively. It is a focal point for the analysis and for the discussions that follow, and the drawing can be kept as a record.

9.3 Principles of AESA based IPM

9.3.1 Grow a Healthy Crop

- Select a variety resistant/tolerant to major pests.
- Treat the seeds/seedlings/planting material with recommended pesticides especially Biopesticides.
- Select healthy seeds/seedlings/planting material.
- Follow proper spacing.
- Soil health improvement (mulching and green manuring wherever applicable).

- Nutrient management especially organic manures and bio fertilizers based on the soil test results. If the dosage of nitrogenous fertilizers is too high the crop becomes too succulent and therefore susceptible to insects and diseases. If the dosage is too low, the crop growth is retarded. So, the farmers should apply an adequate amount for best results. The phosphatic fertilizers should not be applied each and every season as the residual phosphate of the previous season will be available for the current season also.
- Proper irrigation

9.3.2 Observe the Orchard Regularly (climatic factors, soil and biotic factors)

Farmers should-

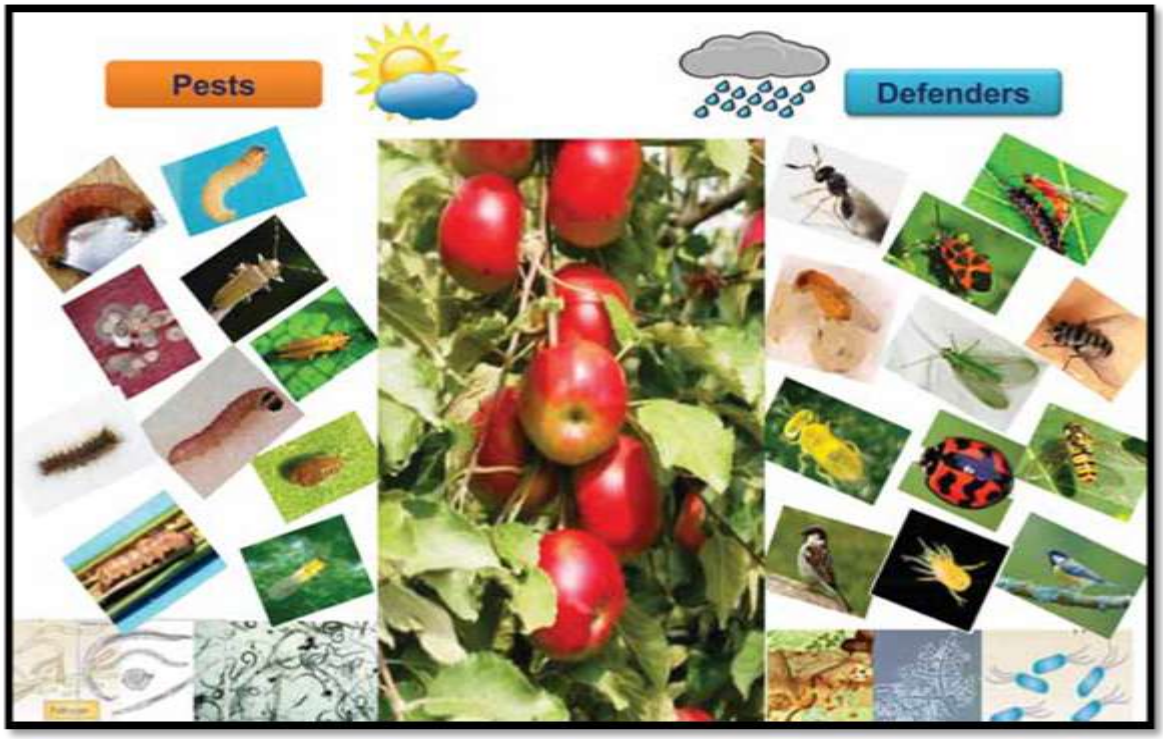
- Monitor the field situation of the orchard at least once a week (soil, water, plants, pests, natural enemies, weather factors etc.)
- Make decisions based on the field situation and Pest: Defender (P: D) ratio.
- Take direct action when needed (e.g. remove infested plants)

9.3.3 Plant Compensation Ability

Compensation is defined as the replacement of plant biomass lost to herbivores and has been associated with increased photosynthetic rates and mobilization of stored resources from source organs to sinks (e.g., from roots and remaining leaves to new leaves) during active vegetative growth period. Plant tolerance to herbivory can arise from the interaction of a variety of plant traits and external environmental factors. Several studies have documented such compensation through increased growth and photosynthetic rate.

9.3.4 Understand and Conserve Defenders

- Know defenders/natural enemies to understand their role through regular observations of the agroecosystem
- Avoid the use of chemical pesticides especially with broad-spectrum activity.



Pest: Defender Ratio (P: D ratio)

9.3.5 Decision Taken based on the Analysis of Field Situations:

Soil conditions :

Weather conditions :

Diseases types and severity :

Weeds types and intensity :

Rodent damage (if any) :

No. of insect pests :

No. of natural enemies :

P: D ratio :

Identifying the number of pests and beneficial insects helps the farmers to make appropriate pest management decisions. Sweep net, visual counts etc. can be adopted to arrive at

the numbers of pests and defenders. The P: D ratio can vary depending on the feeding potential of natural enemy as well as the type of pest. The natural enemies of Apple pests are given below:

Natural enemies	**Attractant/repellent/trap plants**
San Jose scale:	
Parasitoids:*Encarsia perniciosi*and *Aphytis* sp (nymphal and adult) etc. Predators:Coccinellid (*Chilocorusinfernalis*, *Pharoscymnusflexibilis)* etc.	Sunflower family, carrot family, buckwheat
Woolly Apple aphid :	
Parasitoids:*Aphelinusmali (*nymphal and adult) Predators:Coccinellids (*Coccinellaseptempunctata*, *Menochilussexmaculatus*), lacewings (*Chrysoperlazastrowisillemi*), syrphid flies (*Syrphusconfrator*, *Episyrphusbalteatus*) etc.	Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, cosmos (minute pirate bug and lacewing, syrphids, coccinellids) etc.
European Red Mite :	
Predators: Lacewings (*Chrysoperlazastrowisillemi*), predatory mites (*Amblyseius fallacies* and *Zitzelliamali*), *Coccinellids*(*Stethoruspunctum*) etc.	Carrot family, bishop's weed (spider mite destroyer) Sunflower family, marigold, buckwheat, spearmint (ladybird beetle) Carrot family, sunflower family, buckwheat, alfalfa, shrubs (minute pirate bug) French bean (predatory mites) Berseem clover, sub-terranean clovers (big eyed bugs)
Tent caterpillar :	
Parasitoids:Tachinid fly etc.	
Indian gypsy moth :	
Parasitoids:A*nastatuiskashmiriensis*(egg), *Telenomus*sp (egg), *Cotesiamelanoscela*(larval), *Glyptapantelosindiensis*(larval), *G. flevicoxis*(larval), tachinid (*Pales* sp) (larval), *Brachymeriaintermedia*(pupal), *B. lasus*(pupal) etc.	Attractant plants: Carrot family, sunflower family, buckwheat, alfalfa, corn, shrubs (minute pirate bug and lacewing) Nectar rich plants with small flowers i.e. anise, caraway, dill, parsley, mustard, sunflower,

	buckwheat and cowpea (Braconid wasp)
Blossom thrips :	
Predators:Antlion, predatory thrips, coccinellids, anthocorids, lygaeids etc.	French bean (predatory thrips) Carrot family, sunflower family, marigold, buckwheat, spearmint (syrphid fly, lacewing, minute pirate bug, damsel bug and ladybird beetle)
Apple maggot :	
Parasitoids:*Diachasmimorpha* sp,	

The general rule to be adopted for management decisions relying on the P: D ratio is 2: 1. However, some of the parasitoids and predators will be able to control more than 2 pests. Wherever specific P: D ratios are not found, it is safer to adopt the 2: 1, as P: D ratio. Whenever the P: D ratio is found to be favorable, there is no need for adoption of other management strategies. In cases where the P: D ratio is found to be unfavorable, the farmers can be advised to resort to inundative release of parasitoids/predators depending upon the type of pest. In addition to inundative release of parasitoids and predators, the usage of microbial bio pesticides and biochemical bio pesticides such as insect growth regulators, botanicals etc. can be relied upon before resorting to synthetic chemical pesticides.

9.4 Field Scouting

AESA requires skill. So only the trained farmers can undertake this exercise. However, other farmers also can do field scouting in their own orchards at regular intervals to monitor the major pest situation. Surveillance on pest occurrence in the orchard should commence soon after crop establishment and at weekly intervals thereafter. In each orchard, select five spots randomly. Select five random plants at each spot for recording counts of insects as per procedure finalized for individual insects.

Sampling in Fruit Crops

In orchard, select five trees such that four are from four corners and one from the centre of the orchard. Two rows of trees alongside of boundary of orchard in all directions should not be selected for observations. The tree selection for pest observations during each weekly visit

should be random. In each of the selected trees, the observations are to be made from four directions viz., East, South, West and North (make it a habit to start at East direction of a tree and follow anticlockwise direction). Use either beat or tap method for taking observations on pests' samples.

Survey/ Observation for Insect Pests

Woolly Apple aphids, San Jose scales, and mites: Count and record the number of both nymphs and adults on five randomly selected leaves per plant.

Blossom thrips: Count and record the number of nymphs and adults of thrips present on five terminal leaves per plant (tapping method also can be used to count thrips).

Apriona, Dorysthenes, Lymantria: Number of larvae of *Apriona* (stem borer), *Dorysthenes* (root borer) and *Lymantria* (foliage feeder) on individual plants should be counted using a suitable procedure.

For diseases: Whenever scouting, be aware that symptoms of plant disease problems may be caused by any biotic factors such as fungal, bacterial, viral pathogens or abiotic factors such as weather, fertilizers, nutrient deficiencies, pesticides and abiotic soil problems. In many cases, the cause of the symptom is not obvious. Close examination, and laboratory culture and analysis are required for proper diagnosis of the causal agent of disease. Generally fungal diseases cause the obvious symptoms with irregular growth, pattern & colour (except viruses), however abiotic problems cause regular, uniform symptoms. Pathogen presence (signs) on the symptoms can also be observed like fungal growth, bacterial ooze etc. Specific and characteristic symptoms of the important plant diseases are given in description of diseases section.

Root sampling: Always check plants that appear unhealthy. If there are no obvious symptoms on plants, examine plants randomly and look for lesions or rots on roots and stems. Observe the signs of the causal organism (fungal growth or ooze). It is often necessary to wash the roots with water to examine them properly. If the roots are well developed, cut them to examine the roots for internal infections (discoloration& signs). Count the total number of roots infested/infected due to rotshould be counted and incidence should be recorded.

Leaf sampling: Examine all leaves and/or sheaths of each plant for lesions. Leaf diseases cause most damage during the seedling and flowering stages of plant growth. Observe for the symptoms and signs on the infected plant parts. Determine the percent area of leaf/sheath infection by counting the number of leaves (leaf area diameter)/plant infected due to disease and incidence should be recorded.

Symptoms of Apple scab infestation on leaves

Stem, flower and fruit sampling: Carefully examine the stem, flower and fruit of plants for symptoms and signs of fungal or bacterial diseases. The stem, flower and fruit should be split or taken apart and examined for discoloration caused by fungi and bacteria. Count the number of stems, flowers and fruits infected due to disease and percent disease incidence should be recorded.

For weeds: The goal of weed scouting is to assess the infestation level of known weeds as pests and detect new weeds that may be at very low levels so that action can be taken to control or prevent them from becoming an economic concern. In some cases, early detection of a weed can make eradication possible**.**

Begin scouting as soon as weeds appear in the field and continue until freeze-up. Record stages of growth of all the weeds and the number of each weed species/square meter. Frequently, all scouting patterns must be used since weed habitat can be very species specific. Each field usually requires a pattern for a uniform sample and samples in low areas and field margins or ditches to assess immediate or future risk from weeds left uncontrolled. Detailed counts of the number of weeds per square meter provide the ideal record of a weed problem.

9.5 Monitoring through pheromone trap catches for Argyresthia, Archips, Apriona, Dorysthenes, and Lymantria:

Pheromone traps @ 4-5/acre have to be installed, if available, for *Argyresthia*, *Archips*, *Apriona*, *Dorysthenes* and *Lymantria*. Fix the traps to the supporting pole at the height of mid canopy. Change the lures once in 2-3 weeks. Number of moths/trap/weeks should be counted and recorded.

9.6 Yellow/Blue Water Pan and Sticky Traps:

Set up yellow water pan/sticky traps for monitoring woolly Apple aphids and blue water pan/sticky traps for blossom thrips at the height of mid canopy @ 4-5 traps/acre. Locally available empty tins can be painted yellow/ blue and coated with grease/Vaseline/castor oil on outer surface may also be used.

9.7 Light Traps:

Set up light traps @ 1 trap/acre at the height of mid canopy for monitoring and mass trapping of insects. Light traps with exit option for natural enemies should be installed and operate during6 pm to 10 pm.

9.8 Nematode Extraction:

Collect 100 to 300 cm^3 (200-300 g) representative soil sample. Mix soil sample and pass through a coarse sieve to remove rocks, roots, etc. Take a 600 cc subsample of soil, pack lightly into a beaker uniformly. Place soil in one of the buckets or pans half filled with water. Mix soil and water by stirring with paddle; allow to stand until water almost stops swirling. Pour all but heavy sediment through 20-mesh sieve into second bucket; discard residue in first bucket; discard material caught on sieve. Stir material in second bucket; allow to standuntil water almost stops swirling. Pour all but heavy sediment through 200-mesh sieve into first bucket; discard residue in second bucket. Backwash material caught on 200-mesh sieve (which includes large nematodes) into 250-ml beaker. Stir material in first bucket; allow to stand until water almost stops swirling. Pour all but heavy sediment through 325-mesh sieve into second bucket; discard residue in first bucket. Backwash material caught on 325-mesh sieve (which includes small to mid-sized nematodes and silty material) into 250-ml beaker. More than 90% of the live nematodes are recovered in the first 5-8 mm of water drawn from the rubber tubing and the sample is placed in a shallow dish for examination.

10. ECOLOGICAL ENGINEERING FOR PEST MANAGEMENT

Ecological engineering for pest management has recently emerged as a paradigm for considering pest management approaches that rely on the use of cultural techniques to effect habitat manipulation and to enhance biological control. The cultural practices are informed by ecological knowledge rather than on high technology approaches such as synthetic pesticides and genetically engineered crops.

Natural enemies may require:

1. Food in the form of pollen and nectar for adult natural enemies.
2. Shelters such as overwintering sites, moderate microclimate etc.
3. Alternate hosts when primary hosts are not present.

11. INTEGRATED PEST MANAGEMENT

11.1. San Jose Scale- *Quadraspidiotus pernicious* (Hemiptera: Diaspididae)

Life Cycle:

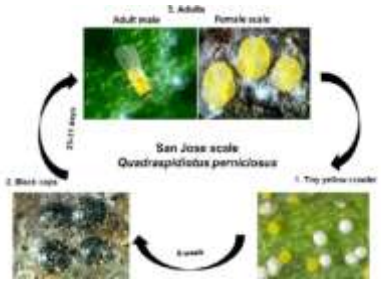
Nymph: Female reproduces ovoviviparously i.e., female directly give birth to living young that emerge from under the edge of the scale covering. Each female gives birth to 200-400 nymphs. These tiny yellow crawlers wander until they find a suitable place to settle. Immediately upon settling, the crawlers insert their mouthparts into the host plant and begin feeding and secreting a white waxy material (white cap stage); eventually the waxy covering turns black and is known as the black cap stage. Later the covers turn various shades from gray to black.

Adult: Immature male and female scales are indistinguishable until the first molt. At this time, the male scale covering begins to elongate, while the females remain circular. Males molt a total of four times. Following the final molt, adult male scales emerge from the scale covering as tiny, yellow winged insects. They mate with the females who remain under the scale covering. Female insect body covered with grey scales. Yellow lemon coloured female is visible when covering is lifted. It takes 25 days for males to mature and 31 days for females. Five to six generations in a year.

Nature of Damage & Symptoms:

Less infested trees show small greyish specks on the bark surface. Severely infested trees have the bark covered with grey layer of overlapping scales appearing as if sprayed with wood ash. On fruits red halo like discolorations are visible.

San Jose scale infested bark



Life cycle

Management:

- Grow attractant plants for natural enemies: viz., Sunflower, Carrot family etc.
- Pruning of infested part & destruction of infested material.
- Regular monitoring may be conducted for determining the ETL/intensity.
- Field release of *Encarsia* and *Aphytis* @ 10,000-20,000 per infested tree or Lady bird beetles @ 30-50 adults/infested tree or Chrysopa @ 10-20 1st instar larvae/tree.
- Need based chemical control may be taken as per Table No. 1.

11.2. Woolly Apple aphid – *Eriosoma lanigerum* (Hemiptera: Aphididae)

Life Cycle:

Native of Eastern United States. First noticed in 1909 in Shimla on nursery stocks imported from England. Reproduces parthenogenetically. There is partial migration from aerial parts to the roots of infested plant in December. Reverse migration from root to aerial parts takes place in April and May. Aphids are viviparous (give birth to nymphs and do not lay eggs) and reproduce both asexually, parthenogenetically and sexually after mating. The mid December to mid-February is a non-reproductive period for these insects. From March onwards, each female produce 30-116 nymphs parthenogenetically which could be alate (winged) or apterous (wingless).

Eggs: The female lays a single, long, oval, cinnamon-colored egg almost as large as her body. The egg is laid in the crevices of bark.

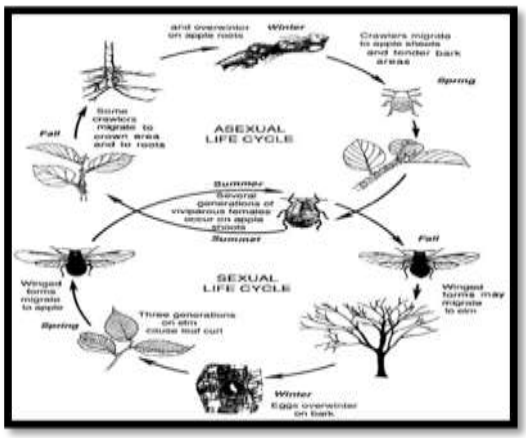
Nymphs: Eggs hatched in the spring into wingless, parthenogenetic, viviparous stem mothers. Nymphs hibernate underground on the roots of the tree. When elms are prevalent, eggs are usually laid in fall in the cracks or crevices of bark. These feed on elm buds and leaves for two generations during May and June, causing the elm leaves to curl into a rosette. They then produce a winged third generation that migrate to Apple. After establishing new colonies the migrants produce repeated generations during the summer.

Adult: Adult and nymph reddish are brown in colour. Covered with waxy filaments. They feed in wounds on the trunk and branches of the tree. In fall, winged aphids develop in both the aerial and the root colonies. They flew back to the elm, where they give birth to males and females. Both males and females are wingless. Each female produces 116 young ones in her life. There are 13 generations a year.

Nature of Damage & Symptoms:

The pest lives in colonies both on the roots and aerial parts of the plant. On the aerial part it is seen as white woolly mass. Damage is caused by sucking cell sap from stem, twigs and roots resulting in gall formation. Affected plants loose vigour which affects yield as well as the quality.

White woolly mass



Life cycle

Management:

- Ecological engineering with buck wheat may attracts parasitoid, *Aphelinus mali*
- Remove suckers/water sprouts and cover the cracks, crevices, wounds and cut ends with anti-fungal/ bacterial paste.
- Conserve the natural enemies & field release of *A. mali* @ 1000-15,000 per infested tree. Clip off of twigs having mummies without exit holes before spraying & tie such twigs with unsprayed trees supporting woolly aphid populations to enhance the parasitoids activity.
- Lady bird beetles @ 30-50 adults/infested tree or Chrysopa @ 10-20 1st instar larvae/tree.
- Need based chemical control may be taken as per Table No. 1

11.3 European red mite - *Panonychus ulmi* (Acarina: Tetranychidae)

Life Cycle:

Egg: The European red mite overwinters as fertilized eggs. The bulk of winter egg deposition occurs from mid to late August, but may continue until late September. Overwintering eggs are deposited in groups on roughened bark areas, especially around the base of buds and fruit spurs. These eggs may be so numerous that the infested areas take on a reddish cast. Egg hatch is closely correlated with bud development and first occurs when buds are in the tight cluster stage. The first summer eggs can be found at petal fall or at latest by fruit set. The summer eggs are globular and somewhat flattened (onion shaped). They are bright red to dark orange and average 0.13 mm in diameter. The overwintering egg is deeper red and slightly larger, averaging 0.14 mm. The egg surface is ridged with the grooves running toward the top center from which a slender tapering stalk (0.1 mm) arises. The average incubation period of the summer eggs for each generation varies from 6.7 to 14.4 days, the shortest period being in mid-summer.

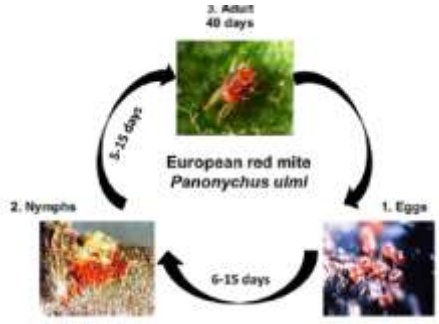
Nymph: The European red mite passes through 3 stages between egg hatch and adulthood. They are called the larva, protonymph and deutonymph. A quiescent or resting period precedes each molt to the following stage. The hatching larva is about 0.2 mm in length, light orange in color and 6 legged. All subsequent stages have 8 legs. With the exceptions of an increase in size and the ability to differentiate sexes in the deutonymphal stage, there are no conspicuous changes in structure or color between the nymphal instars. The average developmental time from eclosion to adulthood ranges from 5.5-15 days, depending on the generation.

Adult: There are 4-9 generations of the European red mite a year, depending on the locality and the length of the growing season. The sexes of the adults are readily differentiated. The female has a globular body which ranges in length from 0.38 to 0.40 mm, is velvety brown to brick red, and has 4 rows of dorsal setae or spines borne on raised white tubercles. The body color and setal pattern distinguish this species from all other plant feeding mites. The male is smaller, 0.26-0.28 mm in length, lighter in color and has a pointed abdomen and proportionately longer legs. The rate of development is temperature dependent, being slower in the spring and fall and more rapid during the hot summer months. The first generation generally requires about 3 weeks developing, while summer generations may develop in 10 to 14 days. Reproduction can be both sexual and parthenogenetic. Unfertilized eggs give rise to males only, while mated females produce both sexes. The average preoviposition period of females is about 2-3 days. Although some females in insectary studies have lived 39 days, the average life span is 18 days. The oviposition period averages 12.5 days with 18.8 eggs produced per female.

Nature of Damage & Symptoms:

Damage the foliage by feeding on green matter and sap causing loss of chlorophyll resulting in crop loss.

Mites infested leaf



Life Cycle

Management:

- Clean cultivation, collection & destruction of fallen leaves & pruned material.
- Conserve coccinellids, anthocorids, lygaeid, predatory thrips etc.
- Need based chemical control may be taken as per Table No. 1

11.4 Apple Root Borers - *Dorysthenes hugelli* (Coleoptera: Cerambycidae)

Life Cycle:

Egg: Female lays 200 eggs singly or in small clusters in soil. Eggs are 1.3 mm in size. Newly laid eggs are white with a tinge of yellow and become dark brown before hatching.

Grub: Grubs feed on the root. Grub longevity 3.5 years. Grubs are eruciform, yellowish-white in colour and have 8–9 instars. Development period can be either 1 or 2 years. Theyexhibit 10 larval stages that develop over 20-21 months, with mature larvae almost reaching 80 mm in length and 12 mm in width.

Pupa: The pupae are about 48 mm long and usually found about 20–30 cm deep in the soil. Pupation takes place in earthen cell inside soil.

Adult: The adult beetle is chestnut red in color and bears long serrated antennae. Full grown grub is creamy white, 7.5-10 cm long.

Nature of Damage & Symptoms:

Causes damage to root, stem and shoots as a result of which plants become weak and may even die. The above ground borers are evident from the frass and faecal pellets or drying up of the terminal shoots. The borer infested trees loose upright posture become shanky, stunted and weak. The leaves of affected trees are small and pale green.

Root Borer infestation

Life Cycle

Management:

- Keep orchard healthy following good agricultural practices
- Install light traps @ 1 trap/acre and operate between 6 and 10 pm in the field to trap adults from May end to July.
- Need based chemical control may be taken as per Table No. 1.

11.5 Blossom Thrips - *Thrips flavus* (Thysanoptera: Thripidae)

Life Cycle:

Egg: The eggs of thrips are deposited within plant tissues singly.

Larva and pupa: Larvae have two stages, which feed on plant tissues. The second instar larvae, when mature, fall to ground, where they molt to pre-pupae and pupae in the soil.

Adult: After emergence, the adults move to the growing parts of the plants such as young leaves, flowers, or young fruits, where they feed and lay eggs (about 200 eggs per female). Adults are usually found on young leaves, while larvae are found on lower or older leaves. At 25°C, the life cycle is completed in approximately 17 days. Adults are winged sucking rasping insects ranging from 5-14 mm in length. Their slender bodies are shiny pale or black with silver stripes. Life cycle completed in 11-43 days. Produce many generations in a year. In colder region, life cycle is longer with fewer generations

Nature of Damage & Symptoms:

Very small yellow, pale brown and black slender insects feed within the floral buds and flowers. Fruit set gets affected. More damage occurs in spring.

Thrips

Life Cycle

Management:

- Clean cultivation, collection & destruction of fallen leaves & pruned material.
- Conserve coccinellids, anthocorids, lygaeid, predatory thrips etc.
- Need based chemical control may be taken as per Table No. 1.

11.6 Tent Caterpillar - *Malacosoma indica* (Lepidoptera: Lasiocampidae)

Life Cycle:

Eggs: In late spring or early summer, female moth deposits an egg mass encircling small twigs or on tree trunks. Egg masses are present on trees during most of the summer, fall and winter. The adult moth uses a sticky, frothy substance called Spumaline as an adhesive to attach eggs to bark or twigs. Pest is active from March – May, passes 9 month of year in egg stage. Female lays the eggs in broad bands consisting of 200 to 400 eggs.

Larva: Caterpillars hatch from the eggs in early spring about the time host plants leaf out. The tent caterpillar feed on new leaves, forming small webs within a few days after hatching and enlarging the webs as they grow. The web or tent is most often in a crotch of small limbs, and serves as a refuge for the larvae during the night and during rainy spells. Larvae move from the

tents to feed on leaves, so damage can be found for some distance around the web. Tent caterpillars feed in groups, and thus concentrate their defoliation. The tent caterpillars form conspicuous, large webs that are easily recognized. Molting, or skin shedding, occurs several times as the larvae grow. The larvae do not live in these small webs at other times. Caterpillar is progeny of a light reddish brown moth with two whitish stripes running across each of the forewings.

Pupa: During the last stage of larval development, which occurs in late spring, larvae wander considerable distances and may feed on a variety of tree, shrubs and even herbs before finding a site for pupation, or cocoon spinning. Cocoons are formed in the web, under bark, in dead plant material on the ground, or inside a rolled leaf. Cocoons are loosely constructed of silk and have a white or yellowish crystalline substance scattered throughout the mass.

Adult: Adult tent caterpillars are brown and yellowish moths with two diagonal markings on the front wings. Their wingspread is about 1 inch. They are attracted to lights and can occasionally be very abundant. The moths live for only a few days, during which they mate and lay eggs. Adults do not feed. There is only one generation of tent caterpillars per year. Male are short lived and female may survive for 2 to 5 days.

Nature of Damage& Symptoms:

Caterpillars during the night rest at their nest and during the day they feed on leaves. In severe infestation, the entire plant may be defoliated and subsequently the caterpillar may feed on bark of twigs. When severe infestation, 40 -50 per cent plants in orchard may be defoliated producing a poor harvest.

Tent caterpillar infestation

Life Cycle

Management:

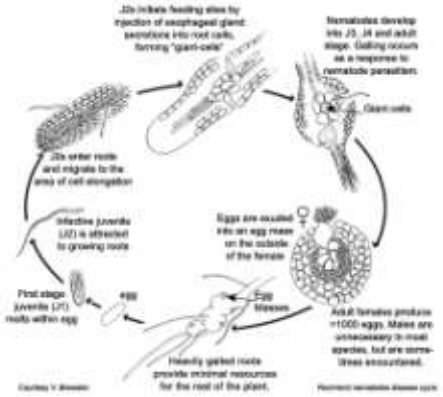
- Regular monitoring is required for moths.
- Release and conserve parasitoids Tachinid fly
- Collect and destroy the egg masses of caterpillar from the Apple trees, particularly from the shade trees (willow and popular) planted on the peripheries of the orchards.

11.7 Root-knot Nematode- *Meloidogyne* spp.

Nature of Damage & Symptoms:

Root-knot nematodes penetrate into roots and cause damage by feeding and migrating through the cortical tissues. Feeding by root-knot nematodes can impair root functions such as uptake of nutrients and water. They are capable of suppressing growth of young trees. Damaged trees generally occur in a circular area within the orchard. Aboveground symptoms of nematode damage are lack of vigor, twig dieback and decline in growth and yield. Infestation of older trees also results in chlorosis or yellowing of leaves, orange bark, fruit sunburn or sunscald typical in green varieties, and small fruit. Heavy infestation on young trees may result in stunting, and sometimes death. Nematode infestations may occur without inducing any aboveground symptoms. Below ground symptoms include poor growth of feeder roots or main roots and soil adhering to roots. Root-knot nematode infestation will produce characteristic swelling of roots, called galls.

Root-knot nematode infestation



Life Cycle

Management:

Remove old roots and plant green manure cover crops resistant to root lesion nematodes for 1 to 2 years or fallow the site for 4 years.

- Use certified rootstocks or seedlings to establish new orchards.
- Improve soil tilth and drainage.
- Proper irrigation and fertilizer application will also reduce stress on trees.

12. INTEGRATED DISEASE MANAGEMENT

12.1 Apple scab - *Venturia inaequalis*

Symptoms:

Apple scab disease is regulated through domestic quarantine in India since 1979 and only restricted in Himachal Pradesh and Jammu Kashmir. Although, in the year of 2005 there is one publication related to status of apple scab in India and it was observed that scab is present only in traces on leaves & fruits. (Thakur *et.al*., 2005). The symptoms of scab are produced on all the aerial parts like leaves, petioles, blossoms, sepals, fruits and pedicels but less frequently on bud scales. The early symptoms normally appear as small dull olive-green patches mainly on the underside on young leaves during the early spring. Later, as the disease progress, darker spots develop on both the surfaces of the leaves. Young lesions are velvety brown to olive-green and have indistinct margins. When several lesions coalesce on young leaves, they become curled, dwarfed and are distorted. Small superficial corky lesions or large patches develop on the fruit surface. Severe early attack also results in serious cracking and formation of misshapen fruits.

Primary Infection

Secondary Infection

Disease Development:

The pathogen survives through perithecia in the soil debris. Secondary infections continue throughout the summer, until the leaves and fruit fall from the tree at the onset of winter. Suitable temperatures and moisture promote the release of *V. inaequalis* ascospores.

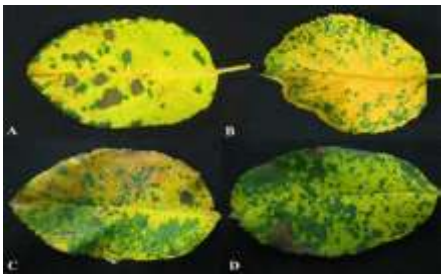
Management:

- Practice field sanitation to reduce the initial inoculum.
- Collect and destroy the fallen leaves in winter.
- Proper pruning of the trees to allow free air movement and rapid drying of foliage.
- Apply urea (2 Kg/acre at pre-leaf fall stage spring and dolomitic lime (2.5 ton/acre) in autumn over fallen leaves to accelerate decomposition.
- Need based chemical control may be taken as per Table No. 2.

12.2 Premature Leaf Fall / Marssonina Blotch - *Marssonina coronaria*

Symptoms:

Symptoms appear both on leaves and fruits. On upper surface of mature leaves initially dark green spots later becoming dark brown in colour appears. Appearance of large number of lesions turn leaf colour to yellow, which fall of pre-maturely. Small dot like structures (3-5mm size acervuli) are also seen in such lesions. Dark brown, oval, depressed, spots develop on fruits which turn almost black in colour. Fruit tissue below these spots is often soft, but corky as in case of scab.



Premature leaf fall symptoms

Disease Cycle

Disease Development:

The pathogen survives in infected leaf litter on orchard floor in the form of conidia and the sexual stage of pathogen *Diplocarpon mali* is also intercepted in nature. This disease favoured by high rainfall and moderate temperature ranging from 20-22°C during the fruit development stages of Apple.

Management:

- Collect the fallen leaves and fruits from orchard floor and destroy them preferably in a Composting pit.
- Follow appropriate pruning allows adequate air circulation and help to reduce disease development.
- Need based chemical control may be taken as per Table No. 2

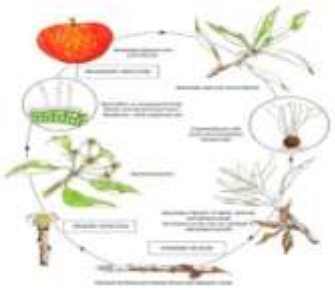
12.3. Powdery Mildew - *Podosphaera leucotricha*

Symptoms:

The disease symptoms are observed immediately after bud-burst when all the freshly produced tissues are completely mildewed and resulting flowers and leaves appear as white rosette. Infected lateral buds may produce completely mildewed side shoots in the same manner. From the mildewed surfaces numerous spores are released which infect young unexpanded

leaves, young buds, lateral buds on new shoots and growing points. Pollinizing cultivars are more susceptible.

Mildewed leaves



Disease Cycle

Disease Development:

The fungus survives in the form of a resting mycelium or encapsulated haustoria in the buds and the secondary spread occur through wind borne conidia. Powdery mildew infections occur when the relative humidity (RH) is greater than 70%. Infections can occur when the temperature lies between 10 to 25°C.

Management:

- Sanitation of orchard,
- Use of resistant varieties and removal of over wintering infected terminals by pruning is good for reducing the inoculums.
- A combination of special winter and spring pruning is necessary to keep disease under check.
- In severely affected orchards one-year-old shoots should be removed with top few buds up to 2-3 inches in winter.
- At the pink bud stage the diseased blossoms and leaves should be pruned in the wee hours avoiding shaking of twigs
- Need based chemical control may be taken as per Table No. 2

12.4. Leaf Spots and Blight - *Alternaria mali, Alternaria alternata, Phyllosticta* spp.

Symptoms:

Spots of various shapes and sizes develop on the leaves in summer and rainy season. Premature defoliation follows yellowing of the diseased leaves thereafter.

Leaf Spots and Blight symptoms

Disease Development:

Primary infection occurs about one month after petal fall in the following year. The fungus can overwinter as mycelium on dead leaves on the orchard floor, in mechanical injuries in twigs, or in dormant buds. Primary infection occurs by soil and secondary by conidia through rain or wind. At optimum temperatures infection occurs with 5.5 hours of wetting, and lesions can appear in the orchard two days after infection, causing a serious outbreak. The disease is favoured by temperatures between 25–30°C and by wet conditions. Infection occurs at optimum temperatures with 5.5 hours of wetting and an outbreak can become serious within two days of infection.

Management:

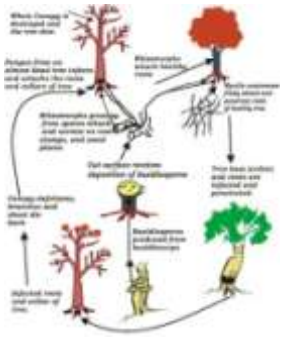
- Destroy diseased shoots, leaves and other pruning material and plough fallen leaves in soil.
- Need based chemical control may be taken as per Table No. 2.

12.5. White Root Rot - *Rosellinia necatrix*

Symptoms:

On the foliage, the symptoms are premature chlorosis, small leaves and fruits and cessation of shoot growth. Rapid spread and development of pathogen may result in bronzing of foliage and premature defoliation. These symptoms are similar to those produced by other soil- borne pests and pathogens and thus underground diagnosis of the disease is required for confirmation. The rotting starts from the fine roots, which further extends to the upper roots ultimately reaching the tree trunk. After a few days of infection, the roots are covered with white cottony mycelial growth of the fungus, which may extend to adjacent areas. Subsequently, the mycelium on the roots turns greenish grey or black and aggregate to form thick hyphal strands. In advance stages, the roots are completely devoured and diseased seedlings or trees are easily uprooted from the soil.

White Root Rot symptoms



Disease Cycle

Disease Development:

The fungus survives in soil or plant debris which is the source of primary inoculum. The disease is favoured by cool and moist soils.

Management:

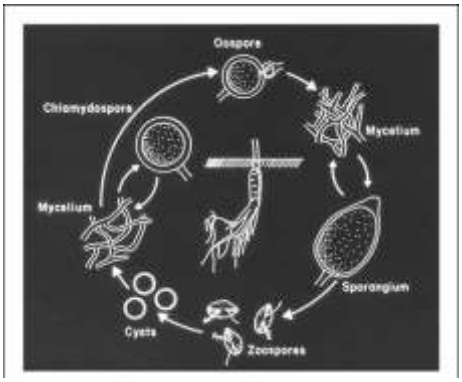
- The infected orchard should be avoided for planting new trees as far as possible; else, before planting trees in infested orchards, soil sterilization with formalin should be done.
- Infected soil should be kept fallow with frequent cultivation of crops like maize to starve the pathogen.
- Drainage in the orchard should be improved as the disease progress is faster in waterlogged areas. The acidic soil should be amended by applying lime for some years.
- Application of organic amendments such as neem cake and deodar needles or green manures should also be practiced.
- Need based chemical control may be taken as per Table No. 2

12.6. Collar Rot - *Phytophthora cactorum*

Symptoms:

Collar rot symptom often appears near the graft union of the plant, but sometimes may originate on the lower trunk or at the pruning wounds. The bark in the diseased plant parts is discolored and turns into a moist rot in which necrotic tissues eventually turn dark brown and develop an alcoholic odour. Wood beneath the necrotic bark is stained dark brown and such staining may extend beyond the edge of the lesion. Bark above ground dries out and eventually splits away from the wood. In the subsequent years infected trees become unthrifty with pale, sparse leaves; fruits remain small and colour prematurely and there is little or no shoot growth.

Collar Rot necrotic bark



Disease Cycle

Disease Development:

Fungus overwinters as dormant resting spores or as mycelium within infected tissues. New infections occur when the pathogen releases motile spores that are carried via water to susceptible hosts. Soils that are saturated from rain or over-watering provide the moist conditions necessary for *Phytophthora* spp. to thrive and spread. The lack of oxygen in saturated soils may also increase the rootstock's susceptibility to this disease

Management:

- General orchard management practices such as improved drainage around the tree base, removal of crop effuse and avoiding injury to the stem during field operation are helpful in restricting the disease spread.
- Grafting point should be kept at least 18-20 cm above the ground level.
- Putting sand around the stem upto one-foot area upto 10 cm depth does not allow the water to stand and thus avoid the infection by pathogen.

12.7 Seedling Blight – *Sclerotium rolfsii*

Symptoms:

It can infect and kill up to 3 years old trees, the infected plants show blightening of leaves, which upon inspection at the base of plant near soil line normally reveals the presence of mustard seed size light to brown coloured sclerotia specially during August.

Seedling Blight Symptoms

Disease Development:

The fungus survives in soil. Primary infection occurs by soil and secondary by conidia through rain or wind. High humidity, high soil moisture, cloudiness and low temperatures below 24° C for few days are ideal for infection and development of disease.

Management:

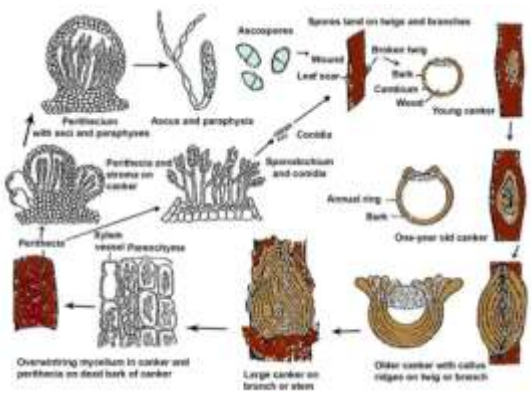
- Nursery must be rotated every 3-4 years.
- Removal and destruction of infected plants is mandatory to avoid further disease spread.
- Soil solarization by spreading transparent polythene sheet for 60 days during summer months or sterilization of nursery beds with formalin is recommended.
- Addition of neem and mustard cake @2t/ha.

12.8. Cankers - *Botryosphaeria obtusa*

Symptoms:

Cankers may appear as sunken areas or swollen areas on infected branches. Most canker diseases are caused by fungi, but there are a few bacterial canker diseases. The fungi that cause canker diseases will often colonize the bark of newly planted trees under water stress. If a canker disease girdles the entire branch or trunk, all growth beyond the canker will die.

Canker infected tree



Disease Cycle

Disease Cycle:

The pathogen survives through ascospore in the soil debris which is the source of primary infection. In the spring, the black pycnidia and perithecia release their respective conidia and ascospore and causes secondary infection. Favorable temperature for disease development is 20-24°C. Winter injury in plants is favorable for the development of the diseases.

Management:

- Remove and destroy infected plant parts, mummified fruits, dead twigs and pruned branches.
- Application of balanced fertilizers on the basis of soil analysis.
- Properly irrigate during hot dry periods to avoid stress.
- Proper pruning should be done to avoid mechanical injury.
- Protect plants from high and low temperature injuries.
- For treatment of wounds the canker portion is scarified upto healthy part with sharp edged knife during winters, cleaned with spirit and then paste or paint is applied during the dormancy in winter months.
- Need based chemical control may be taken as per Table No. 2

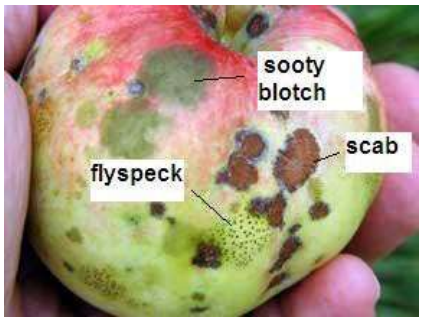
12.9. Sooty Blotch and Fly Speck - *Gloeodes pomigena, Schizothyrium pomi*

Symptoms:

Sooty blotch appears as sooty or cloudy blotches on the surface of the fruit. The blotches are olive green with an indefinite outline. The blotches are usually one fourth of an inch in diameter or larger, and may coalesce to cover much of the fruit. The “smudge” appearance results from the presence of hundreds of minutes, dark pycnidia that are interconnected by a mass of loose, interwoven dark hyphae. The sooty blotch fungus is generally restricted to the outer surface of the cuticle. In rare cases, the hyphae penetrate between the epidermal cell walls and the cuticle.

Flyspeck:

Groups of a few to 50 or more slightly raised, black and shiny round dots that resemble fly excreta, appear on the Apple fruit. The individual "fly specks" are more widely scattered and much larger than the pycnidia of the sooty blotch fungus. The flyspecks are sexual fruiting bodies (pseudothecia) of the fungus, and are interconnected by very fine hyphae. The blemishes can be removed by vigorous rubbing or bleaching.



Sooty Blotch and Fly speck


Sooty Blotch Infected fruits

Disease Cycle:

Flyspeck: In late spring, this fungus produces both ascospore and conidia that are wind-borne and survive into orchards from other plants. Sooty blotch: The pycnidia on host plants produce large numbers of spores (conidia) that ooze out of infections and collect in a gelatinous mass. Moist condition and 18 to27°C temperature are essential for infection and disease development.

Management:

- Conduct regular monitoring for the built up of the disease and determine the ETL.
- Need based chemical control may be taken as per Table No. 2

12.10. Virus/ Viroid Diseases

a) Apple Chlorotic Leaf Spot

Symptoms:

The symptoms include translucent or chlorotic leaf spots with asymmetric leaf distortion, irregular diffused chlorotic rings and line patterns on leaves which are reduced in size and often drop prematurely. Symptoms on stem include stunted growth, terminal die back of some clones and pitting of the xylem vessels with inner bark necrosis.

Management:

- Use of disease free plant material for propagation.
- Plant only healthy plants.

- Destroy the infected plants.
- Although, most of the viruses are unstable, yet use of disinfected farm implements like knives and secateurs for budding, grafting and pruning of each tree separately with rectified spirit.

Apple Chlorotic Leaf Spot symptoms

Infected fruit

b) Apple Mosaic

Symptoms:

Leaves of infected Apple plants show different forms of mottling, the most common being the presence of a number of small irregular creamy or yellow spots that stand out conspicuously against the dark green colour of normal leaf tissue. These areas often become chrome yellow or white as the active season progresses. In a diseased plant all the leaves may not express symptoms. Affected leaves may be interspersed with normal leaves on individual shoots. Differences in virus strains and varietal sensitivity can cause variation in the severity of symptom expression.

Apple Mosaic Symptoms

Management:

- Use of disease free plant material for propagation.
- Plant only healthy plants.
- Destroy the infected plants.
- Although, most of the viruses are unstable, yet use of disinfected farm implements like knives and secateurs for budding, grafting and pruning of each tree separately with rectified spirit.

c) Dapple Apple Viroid

Symptoms:

Symptoms first appear as small circular spots in mid-July which stand out against the background colour on the young fruits. The spots on fruits remain greenish as the background colour develops and enlarges as the fruit matures; sometimes coalescing into large discolored areas, especially at the calyx end of the fruit. Dappling of the fruits become more intense as the fruit approaches maturity.

Dapple Apple Viroid infected fruit

Management

- Use of disease free plant material for propagation.
- Plant only healthy plants.
- Destroy the infected plants.
- Use of disinfected farm implements like knives and secateurs for budding, grafting and pruning of each tree separately with rectified spirit.

Other viruses like apple stem pitting, virus, apple stem grooving virus and viroids like apple skin scar viroid etc infect apple crops and may cause huge losses. Apple proliferation (AP) and pear decline (PD) are the most severe phytoplasma diseases in pome fruit growing areas. AP-infected trees show typical symptoms such as witches' broom, enlarged stipules, tasteless, and dwarf fruits. PD-infected pears show a progressive weakening, reduced terminal growth, smaller fruits, and die within weeks (quick decline) or years (slow decline). The diseases are caused by the cell-wall lacking bacteria *Candidatus Phytoplasma mali* (AP phytoplasma) and *Candidatus Phytoplasma pyri* (PD phytoplasma), respectively.

In order to avoid the proliferation of these viruses and phytoplasma proper virus indexing should be done by using latest diagnostic technologies which are robust and accurate like LAMP, PCR, Q-PCR, DAS-ELISA, NGS etc. Temporal and spatial expression of these agents should be done to rule out their presence in the germplasm and use of infected plants in further propagation or import.

Detection of Apple Viruses:

- Biological Detection
- Serological Detection
  - Enzyme-Linked Immuno Sorbent Assay
  - Antibody development
- Electron Microscopy
- Molecular Detection
  - Reverse Transcription Polymerase Chain Reaction (RT-PCR) / Immuno capture RT-PCR (IC-RT-PCR)
  - Nucleic Acid Hybridization
  - Real Time PCR

13. DISORDERS IN APPLE FARMING

Generally, it has been observed that besides presence of weed, insect, disease and nutrient deficiency there are fruit drop issues in Apple farming. These fruit drops are due to three reasons.

1. Early drop resulting from unfertilized or un pollinated blossoms
2. Due to moisture stress
3. Pre harvest drop

Non-infectious disorders in some cases are easy to identify, but others are difficult or even impossible to recognize. Most of them are non-reversible once they have occurred. For the identification of physiological disorders, it is important that one must know that:

- Physiological disorders are often caused by the deficiency or excess of something that supports life or by the presence of something that interferes with life.
- Physiological disorders can affect plants in all stages of their development.
- They are non-transmissible because they occur without or in absence of infectious agents.
- Plant reacts differently to the same agent and sometimes response is seen as a little reaction to death.
- Dealing with physiological disorders often means dealing with the consequences from a past event.
- Generally damaged and undamaged tissue is clearly demarcated.
- Physiological disorders not only cause damage themselves but also serve as the 'open door' (entry) for pathogens.

There are many physiological problems of apple which should be controlled to get good economic returns.

Bitter Pit: This is a physiological disorder, which reduces the fresh market quality of fruit. Young trees that are just coming into bearing are the most susceptible. Immature fruit are more susceptible to bitter pit than fruits harvested at the proper maturity stage. Small brown lesions of 2-10 mm in diameter (depending on the cultivar) develop in the flesh of the fruit. The tissue below the skin becomes dark and corky. At harvest or after a period in storage the skin develops depressed spots on the surface. These spots appear as water soaked spots on the skin near the calyx. The spots generally turn darker, become more sunken than the surrounding skin and get fully developed after one or two months in storage.

Control: Calcium sprays prior to harvest and calcium dips before storage control the incidence of bitter pit. The plants should be sprayed 45 days prior to harvest followed by a repeat spray after 15 days. The post-harvest dip for 1-2 minutes should be given before storage.

Brown Heart: This physiological disorder is associated with large and overmature fruits. It can also occur when the CO concentration in storage increases above 1%. The symptoms appear as brown 2 discoloration in the flesh, usually originating in or near the core. Brown areas have well defined margins and may include dry cavities developed due to desiccation. Symptoms range from a small spot of brown flesh to entire browning of flesh with a margin of healthy white flesh remaining just below the skin. Symptoms develop early in storage and may increase in severity with extended storage time.

Control: Harvesting of overmature fruits should be avoided. In case of storage in controlled atmosphere (CA) the fruits should be harvested at optimum maturity The CO concentrations in CA 2 should be below 1% to reduce the development of brown heart incidence.

Cork Spot: The initial symptoms of this physiological disorder appear as small blushed area on the skin of the fruit above the affected brown spot The affected tissue is usually much harder than the healthy tissue. Boron and calcium deficiencies are occasionally found responsible for development of cork spot.

***Control*:** Proper nutrient management especially boron and calcium help in preventing this disorder.

Scald: This physiological disorder is a serious concern for apple growers. Susceptibility to this storage disorder varies with the variety of apple, environment and cultural practices. Incidence and severity of scald is favoured by hot, dry weather before harvest, immature fruit at harvest, high nitrogen and low calcium concentrations in the fruit. Inadequate ventilation in storage rooms or in packaging boxes also promotes this disorder. Irregular brown patches of dead skin develop within 3 to 7 days due to warming of the fruit after removal from the cold storage. The warm temperatures do not cause the scald but allow symptoms to develop from previous injury, which occurred during cold storage. Symptoms may be visible in cold storage when injury is severe.

Control: Harvesting at proper maturity and ventilation in cold storage help to reduce the scald incidence. The most common method used to control scald is application of an antioxidant immediately after harvest. Diphenylamine (DPA) is commonly used. Ethoxyquin is also effective for some varieties, but can cause damage to other apple varieties. Antioxidants should be applied within one week of harvest for maximum control.

Water Core: This physiological disorder is promoted by high leaf to fruit ratio, high levels of nitrogen and boron in the fruits, low levels of fruit calcium, excessive thinning, and exposure of fruits to high temperatures. Large size fruits are mostly susceptible to this type of disorder. Disorder at pre-harvest stage results in the development of water-soaked regions in the flesh. These regions are hard, glassy in appearance and only visible externally when infection is very severe. Severely affected fruits may smell and have a fermented taste. Water-soaked areas are found near the core or on the entire apple. If symptoms are mild to moderate, they may disappear completely in storage.

Control: The most effective way to reduce the incidence is to avoid delayed harvests. As fruits approach maturity stage, samples of fruit should be examined for water core development. Fruit should be harvested before water core develops extensively. Fruits lots with moderate to severe water core symptoms should not be placed in controlled atmosphere (CA) storage but should be marketed quickly.

Sun Burn: This physiological disorder occurs due to intense heat of the sun. Fruit on the southwest side of the tree is generally affected. Water stress can also increase the incidence of sunburn. Initial symptoms are white, tan or yellow patches on the fruits exposed to the sun. With severe skin damage, injured areas of the fruit can turn dark brown before harvest. These areas may become spongy and sunken. Fruit exposed to the sun after harvest can develop severe sunburn.

***Control*:** The best method of control is to avoid sudden exposure of fruit to intense heat and solar radiation. Proper tree training and pruning are critical. Summer pruning must be carefully done to avoid excessive sunburn. Pruned orchards should be regularly irrigated to reduce heat stress. Careful sorting to remove affected fruit upon packing is the only solution once the injury has occurred.

Russeting: Russeting of apples in a humid environment is a major concern of the fruit growers. Russeting occurs shortly after petal fall. The apple cultivars, which have thin cuticle, are more susceptible to russeting. It is commonly noticed on exposed fruits than on fruits remaining in shade. Frost during the blossom or at the early fruit formation stage may also cause russeting. Russeting leads to rupture of the fruit skin and development of cracks.

***Control*:** Selection of less susceptible clones and adequate irrigation, manuring and effective pest management can reduce russeting

Fruit Drop: Most of the commercial varieties of apple exhibit 3 cycles of fruit drop viz., early drop, June drop and pre-harvest drop. The early drop is considered natural and is due to lack of pollination and fruit competition. Moisture stress and environmental conditions cause the June drop. These two drops neither cause substantial economical losses nor are controlled effectively by artificial means. The preharvest drop causes serious economic loss as the full-grown marketable fruits abscise before the harvest due to the reduction in the levels of auxins.

Control: The pre-harvest drop can be controlled by application with NAA (15 ppm) sprayed 20 days before the expected fruit drop or 20-25 days before the harvest.

14. WEED MANAGEMENT

- Keep the orchard weed free by adopting cultural practices.
- Maintain optimum and healthy crop stand which would be capable of competing with weeds at a critical stage of crop weed competition.

Integrated Weed Management

In apple orchards, annual, biennial and perennial weeds are grown. They compete for moisture, nutrients and harbour many insect pest and diseases by creating cool and humid climate. Therefore, controlling weeds maximizes orchard productivity. The critical stages of weed control are flowering, fruit set, fruit development, flower bud initiation and hardening off and hence weed control must be undertaken from bud break to July. There are several weeds generally found in apple orchards are wild daisy (*Chrysanthemum leucanthem*), European daisy (*Bellis perennis*), jewel weed (*Impatiens usticifolia*), bathua (*Chenopodium album*), like notion (*Verpasseum thepsus*), bera bichu (*Gerardinia diversifolia*), bhang/hemp (*Cannabis sativus*), khata palak (*Rumex dentatus*), barberry, wild rose (*Rosa* spp.), and poppy (*Papaver somanifera*) etc. Management of these weed species are a difficult task. However, clean cultivation, hand weeding, hoe and spud out the weeds are common methods. Spray of glyphosate (Roundup) @ 4 ml/litre of water is very effective to control these weeds. Pre-emergence herbicides should be applied in the early spring or fall before annual weeds emerge. Postemergence herbicide efficacy decreases as weeds grow.

15. DO'S AND DON'TS IN IPM

S. No	Do's	Don'ts
1.	Deep ploughing is to be done on bright sunny days during summer.	Do not plant or irrigate the field after ploughing, at least for 2-3 weeks, to allow desiccation of weeds bulbs and/or rhizomes of perennial weeds.
2.	Grow only recommended varieties	Do not grow susceptible varieties.
3.	Always treat the seedlings with approved chemicals/bio products for the control of seed borne	Do not use seedlings without seed treatment with approved chemicals/bio products.

	diseases/pests.	
4.	Plant in rows at optimum depths under proper moisture conditions for better establishment.	Do not plant seedlings beyond 5-7 cm depth.
5.	Apply only recommended pesticides at recommended dose, proper time, as appropriate spray solution with standard equipment along with flat fan or flat jet nozzles.	Pesticides should not be applied in dry soils. Do not apply pesticides along with irrigation water or by mixing with soil, sand or urea.
6.	Use NPK fertilizers as per the soil test recommendation.	Avoid imbalanced use of fertilizers.
7.	Use micronutrient mixture after planting based test recommendations.	Do not apply any micronutrient mixture after planting without test recommendations.
8.	Conduct AESA weekly in the morning preferably before 9 a.m. Take decision on management practice based on AESA and P: D ratio only.	Do not take any management decision without considering AESA and P: D ratio.
9.	Install pheromone traps at appropriate period.	Do not store the pheromone lures at normal room temperature (keep them in refrigerator).
10.	Release parasitoids only after noticing adult moth catches in the pheromone trap or as pheromone trap or as per field observation.	Do not apply chemical pesticides within seven days of release of parasitoids.
11.	In case of pests which are active during night, spray recommended bio pesticides/chemicals at the time of their appearance in the evening.	Do not spray pesticides at mid-daysince; most of the insects are not active during this period.
12.	Spray pesticides thoroughly to treat the undersurface of the leaves, particularly for mites, and other sucking pests harboring the lower side of leaves.	Do not spray pesticides only on the upper surface of leaves.
13.	Apply short persistent pesticides to avoid pesticide residue in the soil and produce. Follow Pre-Harvest Interval (waiting period) after pesticide application.	Do not harvest before the recommended Pre-Harvest Interval of used pesticide is completed.
14.	Follow the recommended procedure of trap crop technology.	Do not apply long persistent pesticides on trap crops; otherwise, it may not attract the pests and natural enemies.

16. HARVESTING AND POST-HARVEST MANAGEMENT

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

Pre-cooling

After picking, the fruit should be placed in a cool and ventilated place to remove field heat before packing. Cold water sprinkling or fruit washing with water also helps quick removal of field heat or another practical way to remove field heat is keep the fruits over-night near the tree basin for cooling down. Fruit surface must be free of moisture before grading, wrapping or packing in cartoons.

Sorting and Grading

After harvesting, unwanted fruits are sorted out. The healthy fruits are cleaned by washing to remove dust and spray residue. Washing can be done with tap water or a dilute solution of 1 percent hydrochloric acid to remove lead carbonate residues. Apple fruits are graded according to size and shape, color and permissible skin blemishes. Large, medium, small and extra small grade fruits are packed in four layers. The fruits of extra-large grade are packed in three layers. Pittoo grade fruits are packed with wrappers. However, mechanical grader can be employed for quick and efficient grading of apple fruits:

Packaging

Apple are packed in wooden boxes. Size of wooden boxes used in different apple growing areas of India are different and carry about 10kg or 20 kg fruits in a box.

Storage

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

17. MANAGED HONEY BEE POLLINATION

Use of Hive Bees for Pollination

- Three strong honeybee colonies per hectare are recommended for orchards having 25-33 per cent pollinizer proportion.
- Place honeybee colonies in Apple orchard at 5-10 per cent bloom.
- The colonies should be 6-8 bee frames strength with 3- 4 frames of brood having prolific queen.

Precautions

- Place colonies in sunny and sheltered location.
- Do not shift colonies from one orchard to another if the distance is less than 5 km.
- Do not spray pesticides while the crop is in flowering.

Movement of Honey Bee Colonies

- Provide proper ventilation by using entrance screens and even top screen in place of inner cover during hot days.
- Close all the cracks or openings in the hive.
- Nail all the movable parts of the hive properly or tie with migratory belts.
- Before packing the colony, remove frames of honey which are more than half sealed. The colonies should have sufficient food during long journey.
- Close the entrance in the evening when all bees have returned. Pack the inside of the hive to keep frames tight.
- Load the hive on to a vehicle and transport them (preferably at night).

Use of Pollen dispenser

Hive pollen dispenser are devices placed at the entrance of the hive and are so constructed that outgoing foragers are forced to walk through the pollen. This facilitates the adhering of pollen to the body of foragers and is effective in polliniser deficit orchard and in conditions when there is non-synchronization of flowering.

Fixation and use of pollen dispenser

- Pollen dispenser is fixed at hive entrance of *A. mellifera* strong colony.
- 2 g of dehisced pollen should be mixed with powdered dried anther husk in ratio of 1:1.
- The mixture should be kept in pollen dispenser daily at 09.00 and 11.00 h continuously for five days.

18. EXPORT PROCEDURES

Apple fruits are exported in small quantity mainly to Bangladesh, Nepal, UAE, Turkey, Oman, Italy, Germany and Saudi Arabia as per phytosanitary requirement of the importing countries. Registration of orchards & orchard growers with State Agriculture/ Horticulture Departments, implementation of Good agriculture practices and pest management in the Orchard, grading, packing & storage in pack house registered with DPPQS / APEDA, specific treatment, specific packaging, phytosanitary inspection & certification are some of the important factors to increase the export potential of Apple. Phytosanitary Regulations related to export is available in PQIS *website* *http://plantquarantineindia.nic.in*. Since apple is being sprayed with lot of pesticides/fungicides which are hazardous for human health and therefore residue analysis plays an important role for export of the fresh fruit. Interfering maximum residue limits (MRLs) for pesticides with agricultural trade is becoming important for food and trade policies in the early 21st century. Differing levels for pesticide residues among countries have the potential to disrupt trade significantly. In India, the food safety is based on the guiding principle of risk analysis of the Codex Alimentarius Commission (CAC). In order to exploit full potential of pesticides in agriculture and public health programmes without adversely affecting the environment, it is essential to study the facts about pesticide behavior and their persistence / dissipation under Indian conditions. There is also a need to know the status of pesticide residues to ensure the safety to the consumer and to overcome the trade barriers at international level. **GrapeNet** is an internet based electronic service offered by APEDA to the stakeholders for facilitating testing and certification of Grapes for export from India in compliance with the standards identified by NRC Pune, on the basis of consultation with the exporters. **GrapeNet** collects, stores and reports – forward and backward traces and quality assurance data entered by the stakeholders, ie., exporters, laboratories and PSC authorities within the Grapes supply chain in India. Similar kind of online services need to be developed in apple for quality assurance and export promotion.

Annexure

CIB&RC APPROVED PESTICIDES ON APPLE

Table 1. Insecticides

Sl. No.	Name of Pest	Registered Pesticide	Dosage/ha			Waiting Period (days)
			a.i (gm)	Formulation (gm/ml)	Dilution in Water (Liter)	
1.	**Mites**	Bifenthrin 08.00% SC	60.0	7.5ml/lit	10 lit/tree	21
		Cyenopyrafen 30.00% SC	60.0-90.0	200-300	1000	15
2.	**Woolly aphid**	Carbofuran 03.00% CG	05/tree	166/tree	-	-
		Oxydemeton-methyl 25%EC	0.025%	1500-2000	1500-2000	-
		Quinalphos 25.00% EC	0.05%	3000-4000	500-1000	-
		Malathion 50.00% EC	0.05%	1500-2000	1500-2000	-
3.	**Aphid**	Chlorpyrifos 20.00% EC	0.05%	3750-5000	1500-2000	-
4.	**Stem borer**	Dimethoate 30.00% EC	0.03%	1485-1980	1500-2000	In March April and June
5.	**Red spider mite**	Fenazaquin 10.00% EC	40.0	400	1000	30
		Spiromesifen 22.90% SC	72 (0.03%)	300	1000	30
6.	**Two spotted mite**	Fenazaquin 10.00% EC	40.0	400	1000	30
		Propargite 57.00% EC	2.85-5.7/tree	5-10 ml/tree	10 lit/tree	09
7.	**European Red Mite**	Hexythiazox 05.45% w/w EC	0.002%	0.04%	10 lit/tree	15
		Propargite 57.00% EC	2.85-5.7/tree	5-10 ml/tree	10 lit/tree	09
		Spiromesifen 22.90% SC	72 (0.03%)	300	1000	30
8.	**Sanjose scale**	Malathion 50.00% EC	0.05%	1500-2000	1500-2000	-
		Oxydemeton-methyl 25%EC	0.07%	4200-5600	1500-2000	-
9.	**Thrips**	Thiacloprid 21.70% SC	0.01-0.012%	0.04-0.05%	As per size of tree	30

Table 2. Fungicides

S. No.	Name of Disease/Pathogen	Name of registered fungicide	Dosage/ha			Waiting period (in days)
			a. i. (g)	Formulation (g/ml/%)	Dilution in water (L)	
1.	**Apple Scab** ***Venturia inaequalis***	Captan 50% WP	1250gm	2.5kg	750-1000	-
		Captan 75% WP (Scab, Fly speck & Bitter rot)	0.12%**	1667gm	15-20**	8
		Carbendazim 50%WP	1.25gm	2.5gm	10Lit./tree	-
		Chlorothalonil 75% WP	0.150% (150gm/10 L water)	0.200% (200gm/100 L water	10L water per tree	45
		Difenoconazole25% EC	0.004% or4 g/100L water	0.015%or 15ml/100 L water	Depending upon the size of the plant and equipment	14
		Dithianon 75%WP	1350gm	1800gms	2400L	14-21
		Dodine 65%WP	0.05%	0.075%	10	21
		Hexaconazole 5% EC	0.0025%	0.05% (50ml/100lt)	As required	30
		Mancozeb 75% WG	18.75- 22.5/tree	25-30/tree	10L/tree	40

		Mancozeb75%WP	22.5 g /tree	30gm/tree	10Ltr	-
		Myclobutanil 10% WP	0.004%	0.04%	10 lit/ tree	21
		Penconazole 10% EC	0.005% or5 gm /100 L water	50ml/100L water	10L Water per tree	30
		Propineb70%WP	0.21%or 210 g/100Ltr. water	0.30%or300 gram/100Ltr. water	As required depending upon size of the tree and plant protection equipment used	30
		Thiophanate Methyl 70%WP	500gm	715gm	750-1000	3
		Zineb75%WP (Scab and black rot)	1.125- 1.5KG	1.5-2KG	750-1000 Lt	-
		Ziram 80%WP	1.2- 1.6 kg	1.5-2.0kg	750-1000	21
		Azoxystrobin 11% + Tebuconazole 18.3% w/w SC	0.11+0.183	1.0	8 – 12	10
		Carbendazim12%+ Mancozeb63%WP	0.19%	0.25	As required depending upon crop canopy	20
		Fluxapyroxad 75g/l + Difenoconazole 50 g/l SC	125	1000	2500	33
		Hexaconazole 4% + Zineb 68% WP	200+3400	0.25% or 25 gm/10 lit. water	10 litre/tree	30
		Tebuconazole 6.7% + Captan 26.9% w/w SC	124+496 0.02% + 0.08%	1550 0.25% or 2.5ml/l of water	10 litre/tree	10
2.	**Alternaria leaf blight/Blotch *Alternaria mali, Alternaria alternata***	Dodine 40%SC	0.05	0.075	10 litre/tree	21
		Mancozeb 75% WG	18.75- 22.5/tree	25-30/tree	10 litre/tree	40
		Carbendazim 25 %+ Flusilazole 12.5% SE	0.03%	0.08%	650-1000	09
		Fluxapyroxad 250g/l + Pyraclostrobin 250g/l SC	187.5	15 ml formulation/ 100 lit water	2500	29
		Hexaconazole 4% + Zineb 68% WP	200+3400	0.25% or 25 gm/10 lit. water	10 litre/tree	30
		Metiram 55% + Pyraclostrobin 5% WG	1750g/ha	100g/100L	1750	12
		Tebuconazole 6.7% + Captan 26.9% w/w SC	124+496 0.02% + 0.08%	1550 0.25% or 2.5ml/l of water	10 litre/tree	10
3.	**Premature leaf fall *Marssonina coronaria***	Dodine 40%SC	0.05	0.075	10 litre/tree	21
		Mancozeb 75% WG	18.75- 22.5/tree	25-30/tree	10 litre/tree	40
		Azoxystrobin 11% + Tebuconazole 18.3% w/w SC	0.11+0.183	1.0	8 – 12	10
		Carbendazim 25 %+ Flusilazole 12.5% SE	0.03%	0.08%	650-1000	09
		Fluxapyroxad 250g/l +	187.5	15 ml	2500	29

		Pyraclostrobin 250g/l SC		formulation/ 100 lit water		
		Hexaconazole 4% + Zineb 68% WP	200+3400	0.25% or 25 gm/10 lit. water	10 litre/tree	30
		Metiram 55% + Pyraclostrobin 5% WG	1750g/ha	100g/100L	1750	12
4.	**Sooty blotch (complex of saprophytic fungi)**	Mancozeb 75% WG	18.75- 22.5/tree	25-30/tree	10 litre/tree	40
		Mancozeb75%WP	22.5 g /tree	30gm/tree	10 litre/tree	-
5.	**Powdery mildew *Podosphaera leucotricha***	Metrafenone 500 g/l SC	187.5	0.15ml/l	2500	42
		Sulphur 80% WP	2-4kg	2.5-5.0Kg	750-1000	-
		Aureofungin 46.15% w/v SP	-	0.005%	10 lit./tree	30
		Sulphur80%WDG	1.50-2.00 kg	1.875-2.50 Kg	750-1000	-
		Azoxystrobin 11% + Tebuconazole 18.3% w/w SC	0.11+0.183	1.0	8 – 12	10
		Boscalid25.2%+Pyraclostrobin12.8%WG	285	750	2500	41
		Carbendazim12%+ Mancozeb63%WP	0.19%	0.25	As required depending upon crop canopy	20
		Fluxapyroxad 75g/l + Difenoconazole 50 g/l SC	125	1000	2500	33
		Hexaconazole 4% + Zineb 68% WP	200+3400	0.25% or 25 gm/10 lit. water	10 litre/tree	30
		Tebuconazole 6.7% + Captan 26.9% w/w SC	124+496 0.02% + 0.08%	1550 0.25% or 2.5ml/l of water	10 litre/tree	10
		Lime Sulphur 22% SC	0.22%	The liquid is used at 1% in conventional sprayers.	2% pre & 1% post blossom	-
6.	**Black rot *Botryosphaeria obtuse***	Zineb75%WP	1.125- 1.5KG	1.5-2KG	750-1000 Lt	-
7.	**Core rot *Alternaria alternata***	Hexaconazole 4% + Zineb 68% WP	200+3400	0.25% or 25 gm/10 lit. water	10 litre/tree	30
8.	**White root rot *Dematophora necatrix***	Aureofungin 46.15% w/v SP	-	0.2%	5-10 injection 2 gm/tree	30

*** In case of fruit trees the values given pertain to the concentration of a.i. in spray solution and volume of spray solution required per tree.*

***Source:** Major Uses of Pesticides (CIB&RC), DPPQ&S*