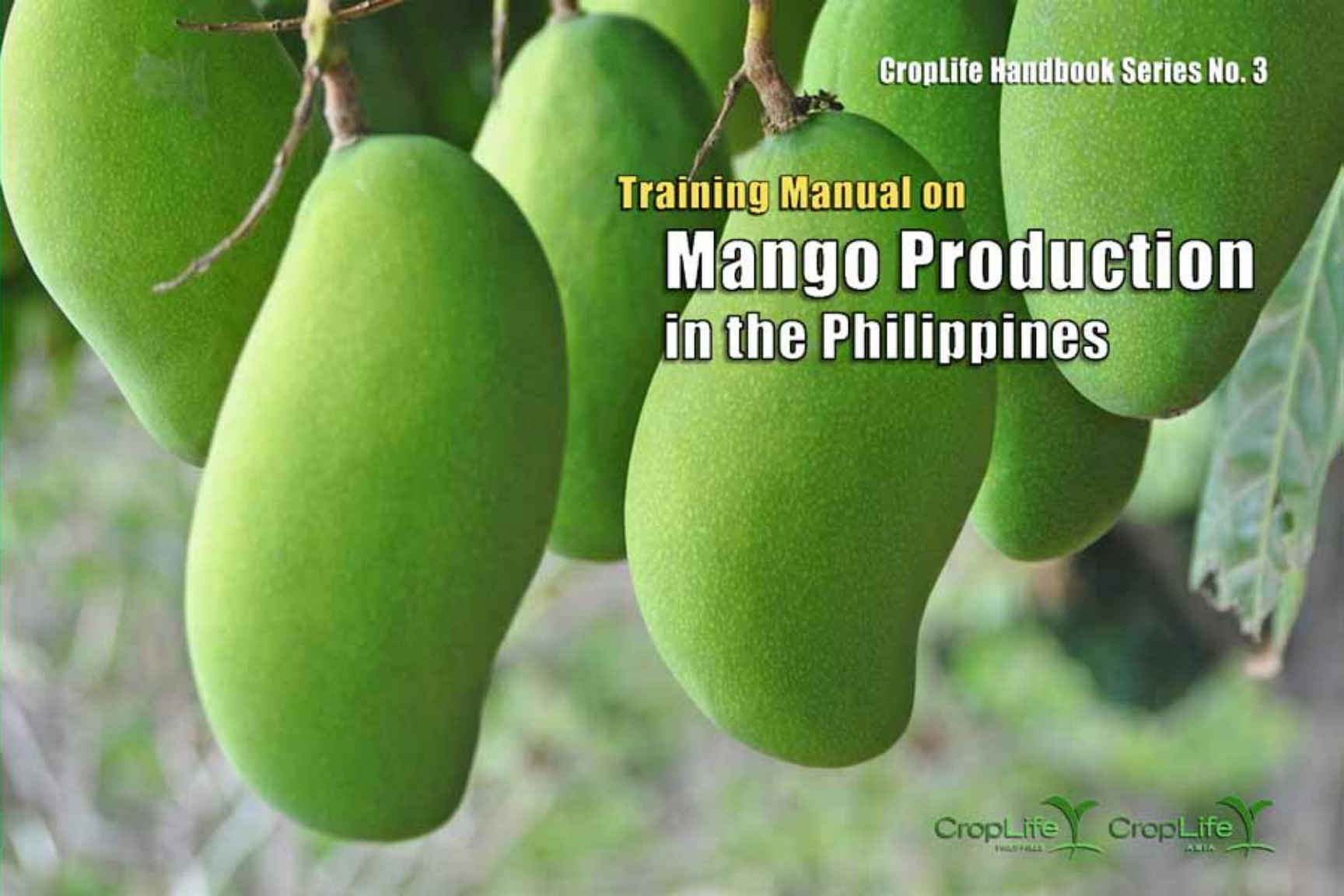

CropLife Handbook Series No. 3

Training Manual on Mango Production in the Philippines

CropLife PHILIPPINES CropLife ASIA

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was published by *CropLife Philippines.*

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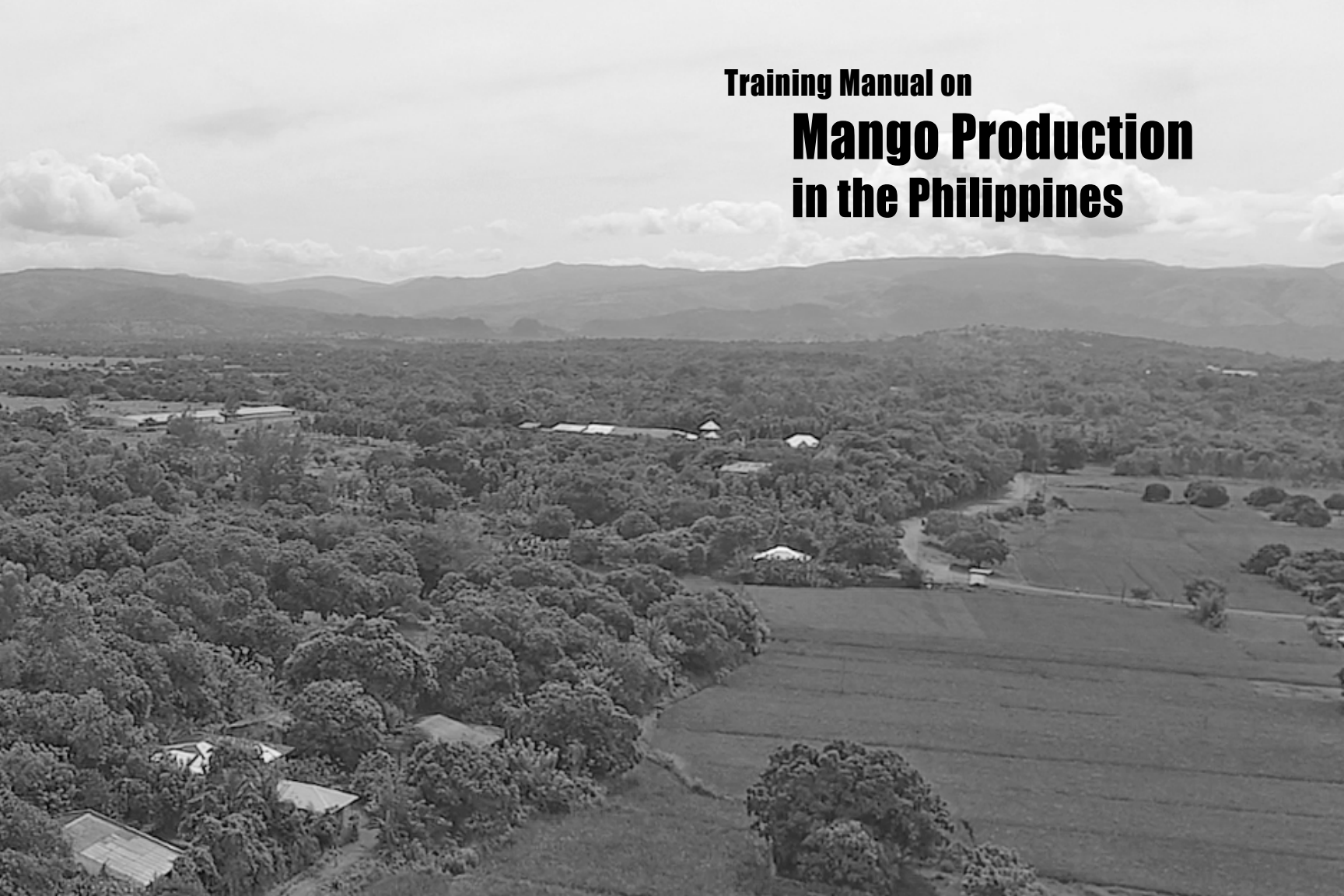

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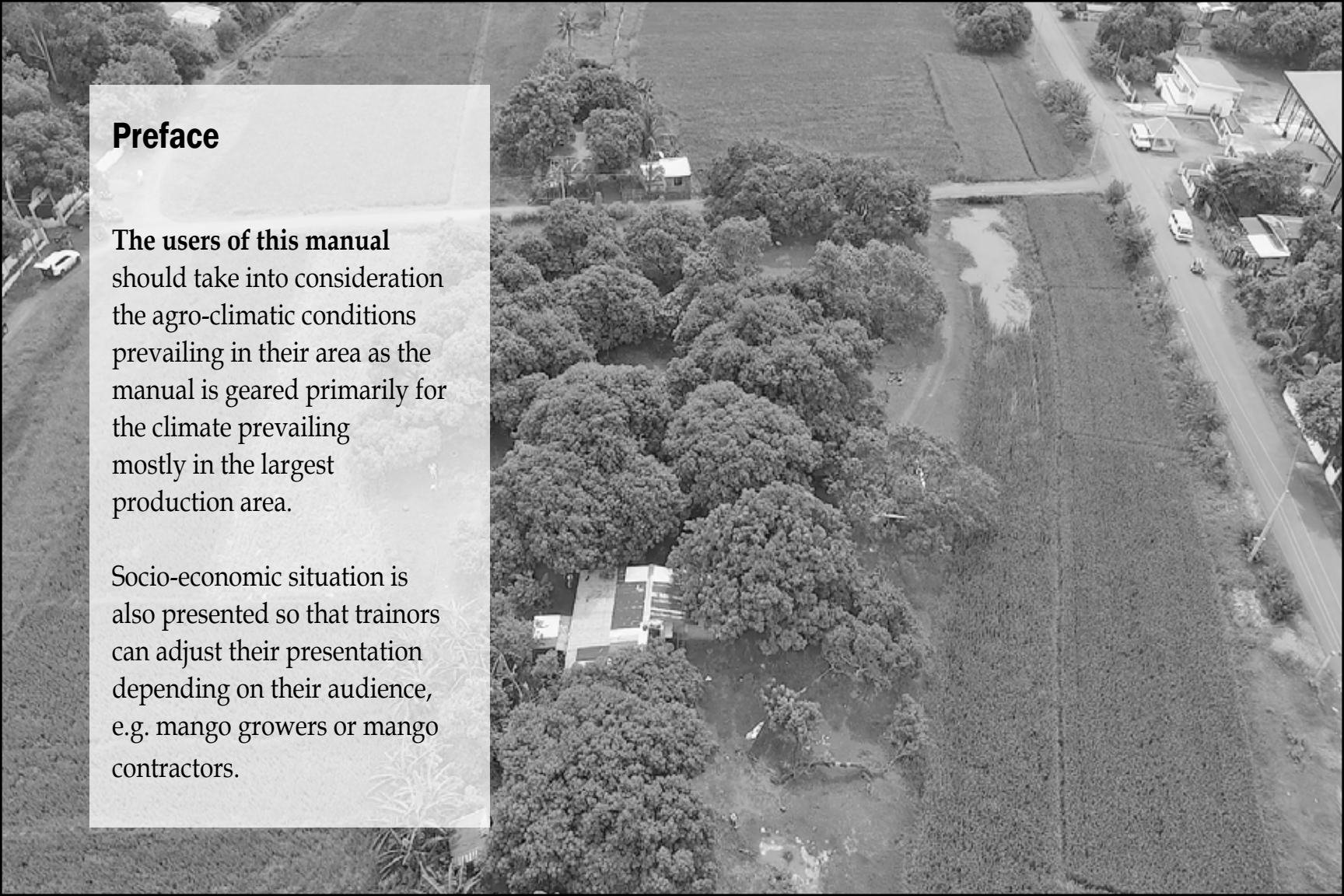


Preface

The users of this manual should take into consideration the agro-climatic conditions prevailing in their area as the manual is geared primarily for the climate prevailing mostly in the largest production area.

Socio-economic situation is also presented so that trainors can adjust their presentation depending on their audience, e.g. mango growers or mango contractors.

Foreword

CropLife presents this comprehensive training manual on the production of mango in the Philippines as the plant science industry's contribution to the continuing efforts of government, our producers, their community and other stakeholders in boosting the country's production of the country's most famous fruit around the world.

With its growing popularity, the Philippine mango production needs collective interventions to help further improve both the quantity and quality of our local production through science-based technologies.

The first part of the manual discusses the Cultural Management Practices in Mango. It provides an exhaustive amount of information that can help farmers effectively manage their mango farms from planting and pruning to a good harvest.

Iiinas Ivan T. Lao
CropLife Philippines
President

Edilberto M. De Luna
CropLife Philippines
Executive Director

This manual also contains valuable information on how to properly mitigate pests through Integrated Pest Management and prevent it from developing resistance through the concepts of IRM, or Insecticide Resistance Management, and Pesticide Management.

By adopting effective strategies from the experts that helped prepare this manual, we are confident that we can achieve the maximum potential of our mango farmlands.

Philippine Mango Industry in Brief

By Prof. Calixto M. Protacio, PhD
University of the Philippines Los Baños

The Philippine mango industry is composed of 73% small growers (less than 3 hectares), 24% with 3- 10 ha while only 3% have more than 10 hectares (HVCC, 2006). The average farm size is 1.68 ha.

In general, soil applied fertilization as a cultural practice is done regularly by the bigger commercial farms which accounts for 27% of the industry but not widely practiced by the small mango growers. Instead, foliar fertilization became common with the emergence of the mango contractor who act as production and marketing consolidator for the small growers.

Mango contractors only apply foliar fertilizers when the inflorescence has emerged, at fruit set and during the fruit enlargement stage because they are reasonably assured of a return on their investment in fertilizers. They do not apply ground fertilizers because their tenure is seasonal and the trees might not flower but produce leaf flushes only.

The cost to produce a kg of mature mango is Php 18.02 in 2014 for a total cost of P73,418 .00 per hectare with cash costs having the highest share (60%) . The average yield per hectare is 4,800 kg/ha (USAID, 2017).

Only 6% of country's produce is exported as we have a very big domestic demand.

Geographical distribution of mangoes within the country

Mango is produced all over the country (Fig. 1) although some areas are more suited to production particularly in the island of Luzon which contributed 57% share of production (Table 1). The historic absence of typhoon in Mindanao resulted in the rapid expansion of hectarage which now contributes almost 28% of the total national production. During the typhoon months of June until early December, Mindanao is the major source of mango fruits.

Mango trees are best grown in hot and dry areas with as much as six dry months as shown by the highest production in the Ilocos Region (35.24% share) in Luzon (Table 1). Other production areas like Cagayan Valley and Central Luzon each contribute only around 7% in production. Production in the Visayas Islands is low (14.82% share) since the growing areas are also typhoon-prone hence production is limited to the months of February until June. In Mindanao, higher production was obtained in Zamboanga Peninsula and SOCCSKSARGEN region where climatic conditions are more favorable for mango production than the rest of the island.

Table 1. Percentage distribution of mango production by region, Philippines, (BAS, 2011).

Island/Region	
Philippines	825,700 mt
LUZON(% share)	57.39
Cordillera Administrative Region (CAR)	0.45
Ilocos (Region I)	35.24
Cagayan Valley (Region II)	7.12
Central Luzon (Region III)	7.80
CALABARZON (Region IV-A)	5.44
MIMAROPA (Region IV-B)	1.16
Bicol (Region V)	0.18
VISAYAS (%)	14.82
Western Visayas (Region VI)	6.11
Central Visayas (Region VII)	8.60
Eastern Visayas (Region VIII)	0.11
MINDANAO (%)	27.79
Zamboanga Peninsula (Region IX)	8.97
Northern Mindanao (Region X)	4.55
Davao Region (Region XI)	4.11
SOCCSKSARGEN (Region XII)	6.81
CARAGA (Region XIII)	1.88
ARMM	1.47

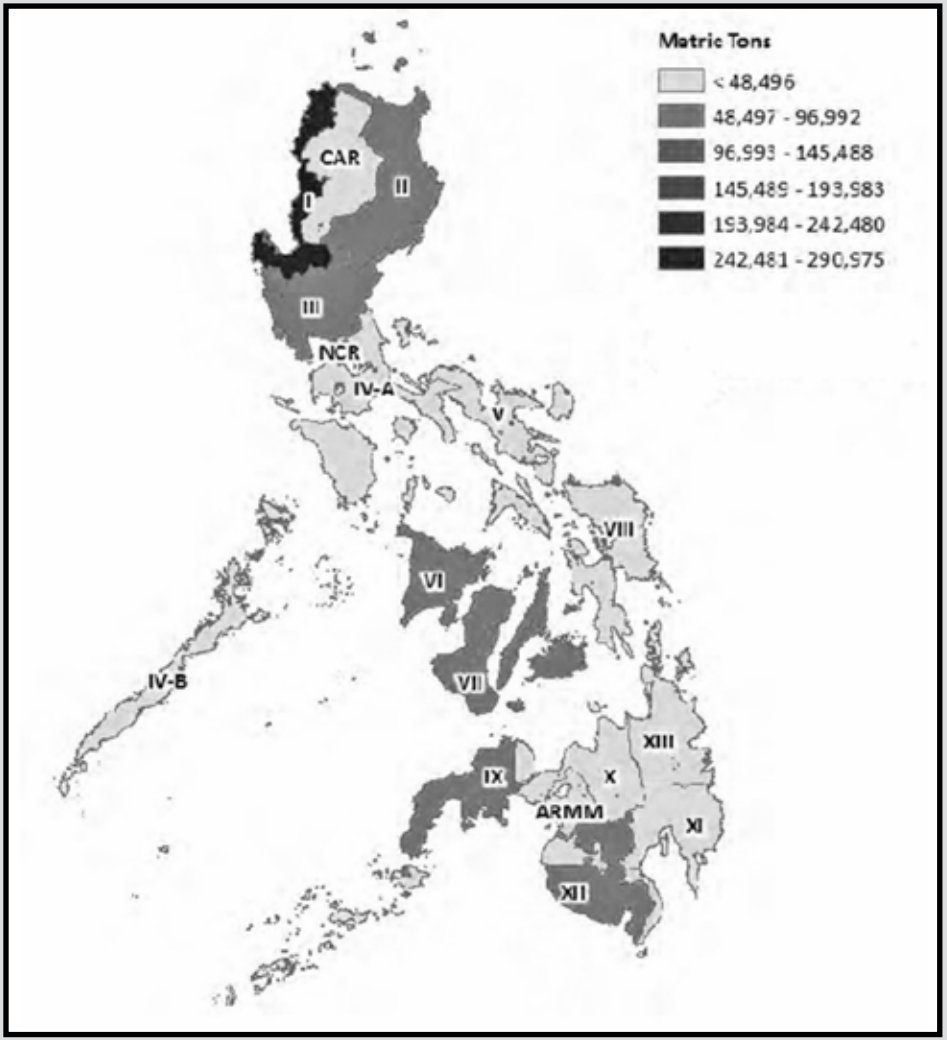


Figure 1.
Geographical distribution of mango production areas in the Philippines, January-December 2010 (BAS, 2011).

Production statistics

As of 2016, the area planted to mango (all varieties) was 187,800 hectares, 78% of which are traditionally devoted to 'Carabao' mango with a total production which amounted to 814,100 mt (PSA, 2017).

Mango fruits are produced year-round in the Philippines as shown by the quarterly volume of production in 2009 and 2010. Highest production amounting to 550,164 mt occurs during the second quarter (April to June) of the year (Fig. 2) which are the peak season months in Luzon where the major production areas are located. The first two quarters are also the harvest months in the Visayas Islands.

Production on the 3rd quarter (July to September) dropped dramatically since the major supplier during these months is Mindanao where the area devoted to mango is lower compared to Luzon. Lowest production occurred during the 4th quarter (October to December) with mangoes also produced in Mindanao, although a small volume comes from Luzon in December.

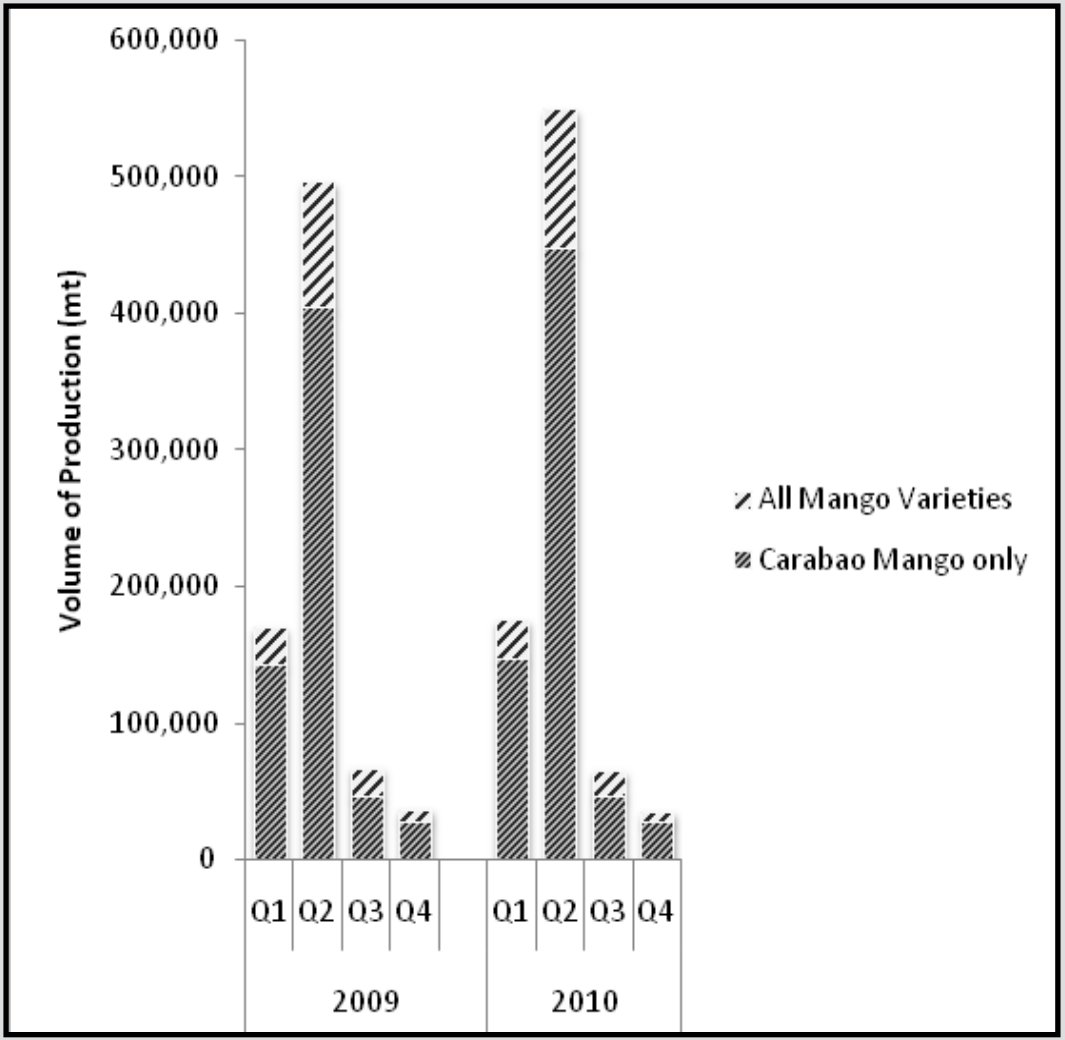


Figure 2.
Volume of production on a quarterly basis in 2009 and 2010, Philippines.
Q1 = January to March,
Q2 = April to June,
Q3 = July to September,
Q4 = October to December
(BAS, 2010 & 2011).


ZAMBALES
BGY. SAGANG
STA. CRUZ

CHAPTER 1:
Cultural Management Practices in Mango

Objectives:

To equip the trainees with knowledge on cultural management practices in mango.
At the end of this chapter, the participants shall be able to:

1) Explain the cultural management practices that can help optimize the yield potential of the crop and enhance fruit quality; and
2) Explain the postharvest treatments that can be applied, especially on fruits intended for export.

The Philippine Mango Industry

The Philippine Mango

- considered as one of the finest fruits in the world
- the 3rd most important fruit crop, next to banana and pineapple
- Carabao mango or Manila super mango is the number 1 export variety
- In 2005, the country produced 984.34 metric tons of mango; valued at P16.67 billion

For Young Trees

Pruning

Generally, young trees do not need pruning except for removal of parts affected by insects and diseases.

Formative pruning is done to reduce the height of trees. It should be done when grafts are about 1 meter tall.

The terminal portions are cut to encourage lateral branching. Maintain 3-4 strong branches.

Do the 2nd cutting when branches are 1 meter long, or until branches are evenly distributed.

Fertilization

a) One year old mango tree:
   - split application of 100 g of Urea or;
   - 200 grams of well-decomposed cattle/ chicken manure + 100 g Urea

The fertilizer should be placed in the soil near the base of the stem

b) Two-year old mango tree:
   - split application of 200 g Urea or;
   - 500 g manure + 200 g Urea

c) Three-year old mango tree:
   - split application of 300 g triple 14 or;
   - 1 to 2 kg manure + 300 g triple 14

d) Four-year old mango tree:
   - split application of 400 g triple 14 or;
   - 2 to 3 kg manure + 400 g Urea

Irrigation/Watering

a) During the dry season, water plants weekly. Saturate soil with enough water, or use up about 5-10 liters of water per tree.
b) To minimize evaporation or drying of the plant, mulch or place dry leaves and other plants parts around the mango tree.
c) If available, use drip irrigation or sprinkler.

Deblossoming

The process of removing flowers in very young mango trees.

This makes possible the proper development of the tree canopy.

Weed Control

Weeds compete with the nutrient use of mango plant. To control weed in the orchard, the following are recommended:

a) ring cultivation, about 1 meter radius from trunk
b) inter-row cultivation (plow/tractor/grass cutter)
c) cover cropping
d) apply herbicides, only when necessary

For Fruit-Bearing Trees

Pruning

a) remove crowded branches or those that are already dried up; affected by insect pests and diseases.
b) it should be done, preferably, during summer after harvest
c) it should be done only within the canopy
d) avoid excessive pruning on fruit-bearing trees; minimal pruning for small trees and open center for big trees
e) to change the variety or to rejuvenate old trees, drastic pruning is recommended.

Fertilization

a) Five to six year-old mango tree:
- 500 g to 1kg triple 14 or;
- 3 to 4 kg well-decomposed manure of chicken or cattle + 500 g to 1 kg triple 14

b) Seven to eight year-old mango tree:
- 2 kg triple 14 or;
- 4 to 5 kg well-decomposed manure of chicken or cattle + 2 kg triple 14

c) Eleven to fifteen year-old mango tree:
- 5 kg triple 14 + 10 kg manure

d) Sixteen to twenty year-old mango tree:
- 6 to 7 kg triple 14 + 12 kg manure

e) More than 20 year-old mango tree:
- 10 kg triple 14 + 15 to 20 kg manure

The fertilizer may be applied twice:
- at the start of the rainy season
- before the end of the rainy season

It can be placed in any of the following:
- canal constructed around the tree

- 1meter radius from the trunk and 15-30cm deep
- 6-8 holes around the tree

For big and old trees – apply fertilizer following the drip line of tree canopy

At 18-25 DAFI & before bagging, apply foliar fertilizer as supplement to the soil-applied fertilizer
- the foliar fertilizer should have zinc, boron, magnesium, and calcium

Flower Induction

Chemical flower inducer, potassium nitrate (KNO3) should be applied when the leaves are between 7 and 8 months old, dark green in color, and brittle.

Spray KNO3 or (1-3% concentration) by thoroughly wetting the leaves.

During the cold and rainy months, use higher concentration (2-3%).

During the hot months, apply lower concentration (1-1.5%).

When the tree shows poor flowering response, a follow-up spray using a lower concentration of KNO3 may be applied. This can be done within a week after the first spraying.

NOTE: Importation and sale of the technical grade KNO3 is subject to regulation by the Fertilizer and Pesticide Authority and the Philippine National Police under EO 522. The technical grade KNO3 can be used for the manufacture of explosives.

Flower Management

To maximize and enhance the flowering capacity of the plant, the following management practices are recommended:

a) foliar application of liquid fertilizer at 18-25 DAFI;
b) control pest – insect pests are dominant during the dry season while diseases are prevalent during the dry season;
c) do not spray pesticides when the flowers are in full bloom, to encourage activities of pollinators such as bees;
   As spot treatment for pest infestations, apply 5% sugar or honey solutions;
d) irrigate trees weekly – about 100 to 200 liters of water per week to enhance vigorous growth of flowers.

Fruit Management

Foliar application of fertilizer at fruit set (35 to 40 DAFI) and before bagging of fruits.

Pest control against major insect pests and diseases.

Weekly irrigation until 1 month before harvest.

Bagging of fruits at 55-60 DAFI, to minimize fruit damage and to reduce the number of spraying.

Proper Harvesting and Post Harvest Handling

Fruits can be harvested at 105-115 days (late flower induction) or 120-130 days (early induction) after flower induction.

Maturity indices:

a) Flattening of shoulders and fullness of cheeks
b) Presence of "bloom" or powdery deposit
c) Yellow green color near pedicel and yellowing of pulp
d) Floatation in 1% salt solution (100 grams salt/10 liters of water).

Harvesting

Use of picking pole

The fruits should be harvested between 9:00 and 11:00 am.

The fruits should have about 2-5 cm of pedicel to minimize latex flow.

Sorting and Packaging

Sort fruits according to size and quality.

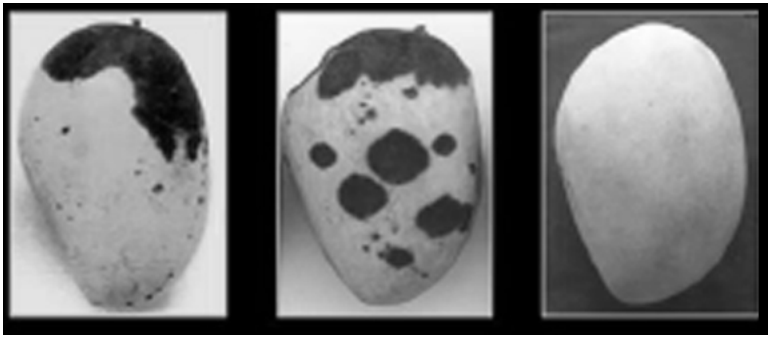
Pick out and remove fruits with damages to avoid contamination of the whole lot.

Use packaging materials such as bamboo baskets, lined with newspaper, and plastic crates.

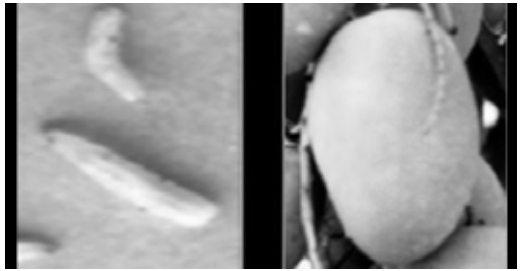
Postharvest Treatment

a) **Hot water treatment (HWT)**
- Dip the newly harvested fruits in warm water (about 52oC-55oC) for about 10 minutes.
- Rinse in cool water for 10 minutes.
- Air dry and pack.

  Modified HWT can be used. In this method, the fruits are submerged into hot water (60oC) for one minute and hydro cooling is no longer required.



b) **Vapor heat treatment (VHT)**
- Heat fruits in a chamber with vapor saturated air until pulp reaches a temperature of 46oC.
- Maintain temperature for 10 minutes.
- Ventilate chamber.



CHAPTER 2:
Integrated Pest Management in Mango

Objectives

To equip the trainees with knowledge on integrated pest management for mango. At the end of this chapter, the participants shall be able to:

1) Define integrated pest management (IPM) and its components;
2) Explain recommended IPM interventions based on crop phenology;
3) Identify and describe biology and damage of pests; and
4) Explain various cost-effective pest management strategies.

Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is an effective and environment-friendly approach to pest management.

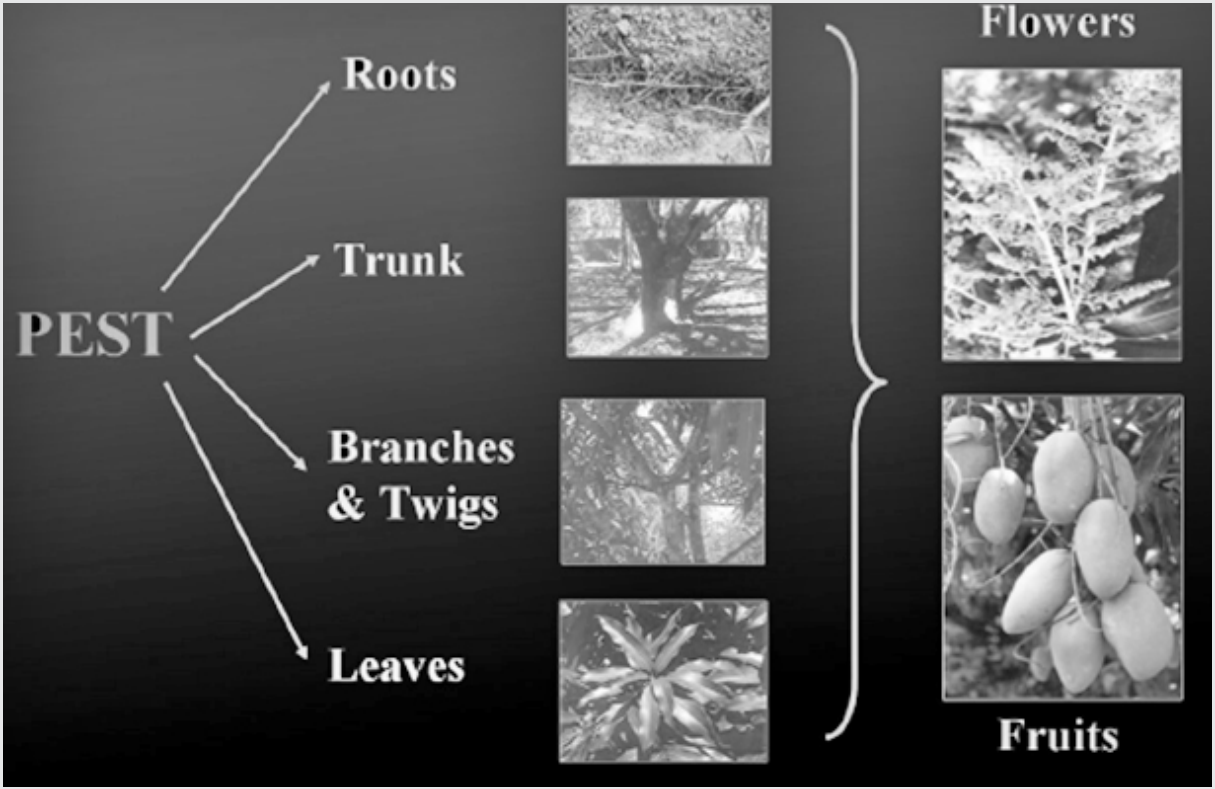
To control and minimize pest damage, it combines the use of current and comprehensive information on the life cycles of pests; their interaction with the environment and the available pest control methods. Use of chemicals should be on a need basis and oftentimes employs selective rather than broad spectrum pesticides.

Why is there a continuing problem with insect pests and diseases?

1) Changes in cultural practices
   - Flower induction technology has resulted to the intensification of mango production and has made conditions conducive to the development of insect pests and diseases
   - Higher crop density provides shelter for their development
2 Weak and undernourished mango trees are susceptible to pest infestations
3) Calendar and cocktail application of pesticides with little regard to whether the same types of pesticides are being mixed
4) Lax implementation of quarantine regulations

   Examples:
   - Spread of thrips to Guimaras Island
   - Mango pulp weevil in Palawan

Parts of the Mango Commonly Affected by Pests

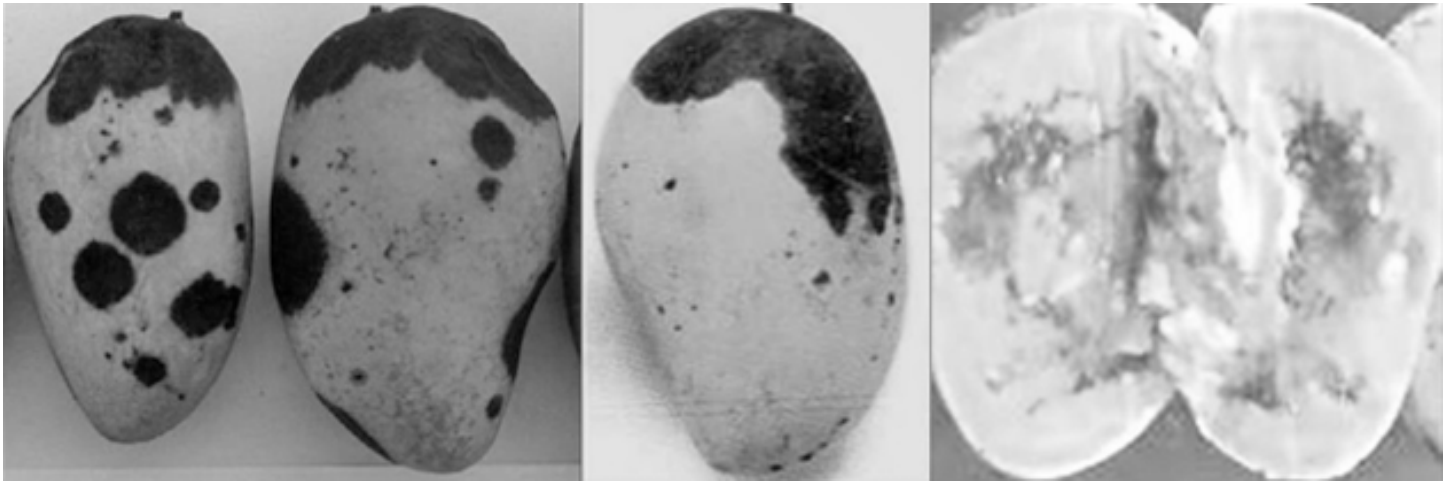


Why is there a need for IPM?

1) Pests significantly reduce yield.

   Ball park estimate of yield loss in Guimaras Island alone due to fruit fly damage is conservatively placed at five percent of marketable yield. The five percent yield reduction results in a conservative opportunity loss of P19.5 M in Guimaras alone.

2) Pests downgrade fruit quality



Why is there a need for IPM?

3) Pests affect marketability of mango fruits. Mango pulp weevil presence in Southern Palawan has placed the island under quarantine.

   Mango pulp weevil-free status of Guimaras Island enables mango growers there to exclusively send fruits to USA and Australia.

Current practices in the control of mango pests

1) Confined to the use of pesticides, mainly insecticides and fungicides which comprise 60-70% of production inputs.
2) Applied mainly during the flowering and early fruiting stage.
   Example: leafhopper and anthracnose control at flowering stage
3) Cocktail/mixing of pesticides.
   Example: mixing of different brands of the same pesticide compound or chemical

What happens when pesticides are not used properly?

1) Development of pest resistance
2) Destruction of natural enemies/ beneficials
3) Potential for minor pests becoming major pests, example: thrips
4) Environmental contamination
5) Health hazard
6) May result to increase in the cost of production

What do you need to know for the successful implementation of IPM?

1) Crop phenology
2) Cultural management
3) Pest identity, biology and damage
4) Pest/weather monitoring
5) Beneficial organisms
6) Pesticide management

Crop Phenology

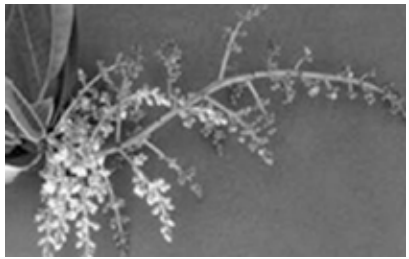
The appropriate time to apply flower inducer is when the mango leaves are already brittle and dark green in color and when its terminal and auxiliary buds are prominent and well-developed, usually 8-10 months from flushing.

Stages of panicle development and fruit maturation

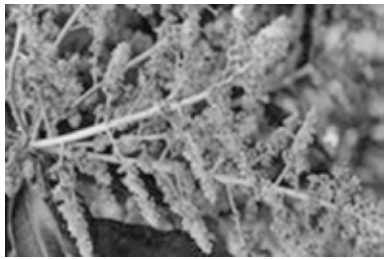
Bud break (6-8 DAFI*)

Bud emergence (9-12 DAFI)

Panicle elongation (13-22 DAFI)



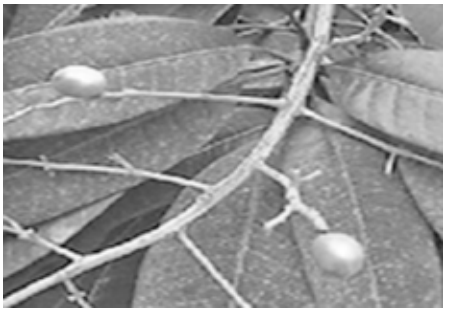
Pre-anthesis (23-25 DAFI)



Full-bloom (26-30 DAFI)

Fruit set (mungbean size)
31-35 DAFI

Fruit enlargement (corn size)
36-42 DAFI



Fruit enlargement (marble size)
43-50 DAFI

Fruit enlargement (chicken-egg size)
51-60 DAFI

Fruit enlargement 61-90 DAFI

Start of maturation 91-109 DAFI

Full maturity110-120 DAFI

Cultural Management

1) **Pruning**
   Pruning of crowded branches (after harvest) allows light penetration and improves air circulation; creating an environment unfavorable for pest development.

2) **Field Sanitation**
   Underbrushing and clearing of surroundings.

3) **Fertilization and Irrigation**
   To improve tree vigor, fertilize and irrigate trees. Vigorous trees are less prone to infection from anthracnose and other pests.

4) **Fruit Bagging**
To minimize the use of insecticides and enhance fruit quality, bag the fruits between 55 and 60 days after flower induction.

5) **Collection and proper disposal of fruit droppings**
Collect fallen fruits and dispose properly by either burying or burning. This prevents the pests inside the fruits from completing their life cycle.

Pest identity, damage and management

Major pests of mango

Flowers	Insects	Disease
	Mango leafhopper	Anthracnose
	Mango tip/twig borer	Sooty mold
	Mealy bugs	
	Scale insect	
	Mango thrips	

Fruits	Insects	Disease
	Fruits Flies	Anthracnose
	Mango seedborer	Scab
	Pulp Weevil	Sooty Mold
	Mango thrips	Diplodia stem-end rot
	Mealy bugs	
	Scale insect	
	Capsid bug	
	Cecid Fly	
	Ants	

INSECTS

Ants

Description:
Ant infestations in mango trees are encouraged by the presence of scale insects and mealy bugs that produce honeydews, which are ants' excellent food source.

Damage:
Ants do not really create harm or damage the tree or fruit, but they can make harvesting very cumbersome because of the painful bites they can inflict to the farmers/ harvesters.

Management:

- Prune the mango tree and remove all unnecessary branches that provide favorable environment for ants.
- Control mealy bugs, scale insects and leafhoppers.
- Apply insecticides during heavy infestation, particularly directed on the nests.

Capsid Bug

Description:
The adult insect looks like a small rice bug. Its pair of antennae is twice as long as its body. The female adult capsid bug has a black body with an orange thorax. Its eggs are white while young nymphs are red or orange.

The bug stays in wild vegetation and is active in the evening. It feeds on developing fruits, up to the size of a chicken egg.

Damage:
The bug excretes toxic materials that produce dry, brown irregularly-shaped corky spots on the fruit's skin. These spots are locally known as "kurikong," "saksak walis", "armalite", or "nora-nora" depending on the area or region.

Management:

- Bag the fruits at 55 to 60 days after flower induction.
- Remove weeds, underbrush shrubs and small trees under the mango canopy as well as infested fruits.
- Remove alternate hosts of adult bugs such as cashew, guava and cacao from the orchard.
- If infestation is heavy, apply registered insecticides, preferably at night.

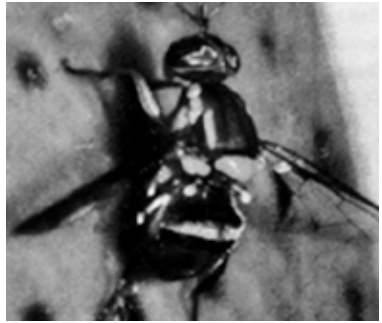
Prevention:

Prune trees after harvesting or before flushing.

Fruit Fly

The adult fruit fly is almost similar in size to the house fly. It has a light brown body, bright yellow spots on the shoulder and thorax, and has transparent wings.
The female fruit fly punctures the peel of a mature fruit and lays eggs on it. Its larvae grow and feed on mango fruits.

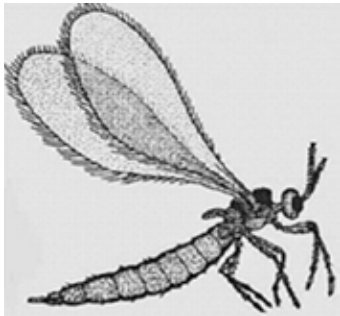
Damage:
Damage on the fruits starts during egg-laying. The punctures on the fruit are not readily recognizable. However, after four to five days, soft brownish spots appear, liquid oozes from the spots and the underlying tissue rots. The continuous feeding of the larva and the secondary microbial activity further destroy the fruit making it unsuitable for consumption.

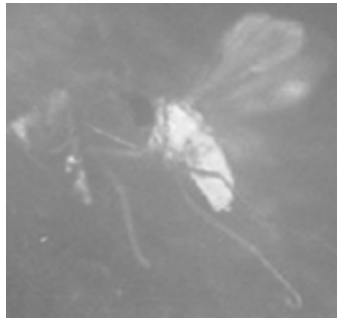


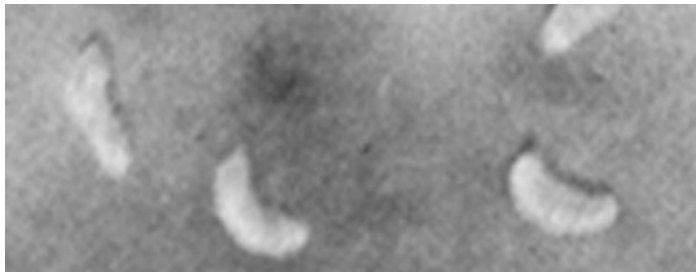
Management:

- Collect the infested fruits and bury deep into the soil to prevent the insect from completing its life cycle.
- Bag the fruits with appropriate bagging materials such as old newspapers at 55 to 65 days after flower induction or when the fruits are about the size of chicken-egg.
- Harvest fruits at mature green stage since fruit flies are attracted to them as soon as their surfaces become yellow.
- Do not intercrop with the following fruits trees: guava, papaya, jackfruit, sineguelas and santol since they are also preferred hosts of the fruit flies.

Mango Cecid Fly







Description:
Cecid fly is a very small and delicate fly with long legs and antennae, and hairy transparent wings. Its larvae are tiny bright yellow maggots.
The adult Cecid fly stays on wild vegetation while the larva stays in young mango leaves or fruits.

Damage:
The developing larvae cause gall formation in the leaves and round sunken spots on the fruits.

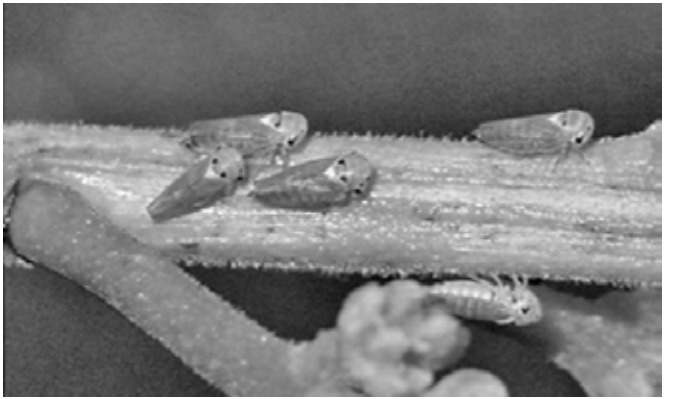
Management:
- Prune crowded branches and infested leaves, particularly flushes.
- Remove weeds, underbrush shrubs and small trees under the mango canopy.
- Collect and dispose the infested fruits properly.

Prevention:
- Bag fruits at 40 days after flower induction or at marble size or spray registered insecticides up to 55 days after flower induction.
- Bag fruits one to three days after insecticide application.

Mango Leafhopper

Description:
Adult mango leafhoppers are wedge-shaped insects which are greyish-green or brown. The young leafhoppers or nymphs are very small, wingless and yellowish.

They can be found hiding underneath the leaves, main stalk of the panicle and in emerging flowers.



Damage:
The nymph and adult mango leafhoppers pierce and suck plant sap resulting in the withering and falling of individual flowers. High hopper infestations results to production of sticky fluid "honey dew" which serves as medium for the growth of sooty mold beneath the leaves, flower buds and panicles.

Under severe leafhopper infestation, the entire canopy will turn black.

Management and Prevention:

- Prune all dead branches after harvest to improve light penetration and air circulation.
- Do light trapping before flower induction to reduce initial leafhopper population in the field.
- Induce early flowering. This can minimize heavy leafhopper infestations that usually occur during the summer months.
- Avoid excessive application of fungicides to conserve beneficial fungi that attack the leafhopper.
- Apply insecticides only when there are at least three leafhoppers per panicle. Check the presence of mango hopper seven days after flower induction or once flower buds are formed or have elongated.

Mango Pulp Weevil

Description:
The mango pulp weevil is a hard-bodied weevil, usually 6mm long and brownish black in color. Due to its color and habit, it cannot easily be seen in the tree. Its larvae, which feed on the mango flesh, develop inside the mango fruit.

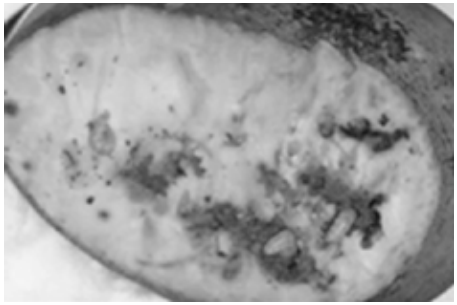
This insect is found only in Southern Palawan but because of its destructive nature, it has placed the island under quarantine. Mangoes from this area are not allowed to be transported or brought out of the province.

Damage:

The damage created by the weevil is not visible externally. But inside the fruit, tunnels and discolored pulp are formed due to larval feeding. An adult weevil does not leave the fruit until it falls to the ground and rots.

Management and Prevention:

- Prune the tree, preferably open-center pruning, to allow the sunlight to penetrate the tree canopy. Sunlight kills weevils.
- Keep the orchard clean. Remove all weeds, twigs, fallen leaves and other debris under the tree canopy.
- Dispose of infected fruits properly by burying the fruits two feet below the ground.
- Bag the fruits at 55 to 60 DAFI.



Mango Seed Borer

Description:
The adult mango seed borer moth is light brown and 16mm long. The larva is white with red inter-segmental bands.

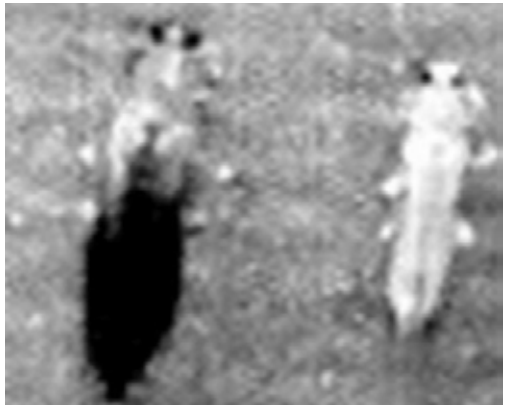
Damage:
The damage starts when the larva enters the fruit through the apex or the narrow tip area of the fruit. The growing larva feeds on the seed and flesh. Later, the damaged area collapses and the apex bursts. When the seed is totally consumed, the fruit will fall to the ground.

A single larva can consume the entire seed in a short period of time.

Management and Prevention:

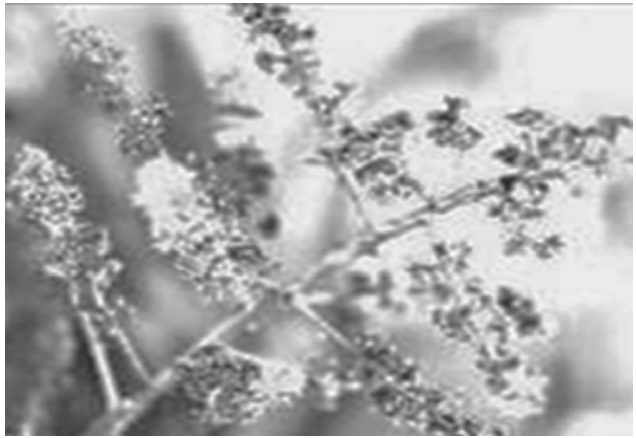
- Remove infested fruits from the tree to prevent movement of larva from one fruit to another and to minimize damage to other fruits.
- Dispose of infected fruits properly to prevent the insect from completing its life cycle. This can be done by burying the fruits two feet below the ground.
- Bag the fruits at 55 to 65 DAFI.
- Monitor infestation and when necessary, apply insecticide at 50-55 days after flower induction.

Mango Thrips



Description:
Mango thrips are minute, slender-bodied insects and about 4mm long. When fully-developed, the insects have four long, narrow fringed wings. Thrips are sensitive to light.

Damage:
Adults and nymphs attack the flowers. They suck the plant sap, which causes the flowers to wither and fall off. They can extend damage to the fruits resulting to scaby appearance locally called "chico-chico".



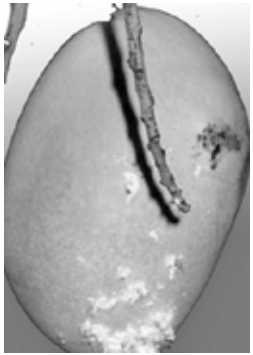
Management:
- Prune or cut off excess branches to improve aeration and to allow more light to penetrate the canopy.
- Spray registered insecticides as a fine mist to protect the upper and lower surfaces of the leaves.

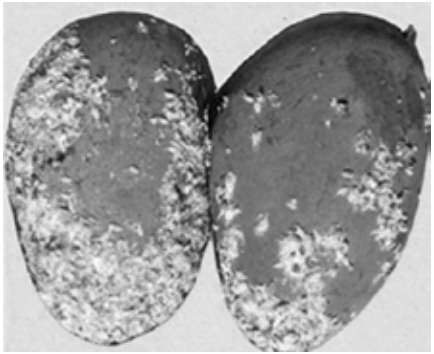
Mealy Bugs

Description:
Mealy bugs are small (2 mm long), oval-shaped, soft-bodied insects with white cottony filaments on their body. Male adult mealy bugs have two wings while females are wingless. They are usually found on flushes, flowers and fruits.

Mealy bugs have symbiotic relationship with red ants. They excrete sticky fluid called "honeydew", which serves as food for red ants. The ants protect and transport mealy bugs to the different parts of the tree.

Damage:
Mealy bugs suck vital plant sap and affects leaves, flowers and fruits. Affected parts turn yellow, dry-up and eventually, fall-off.





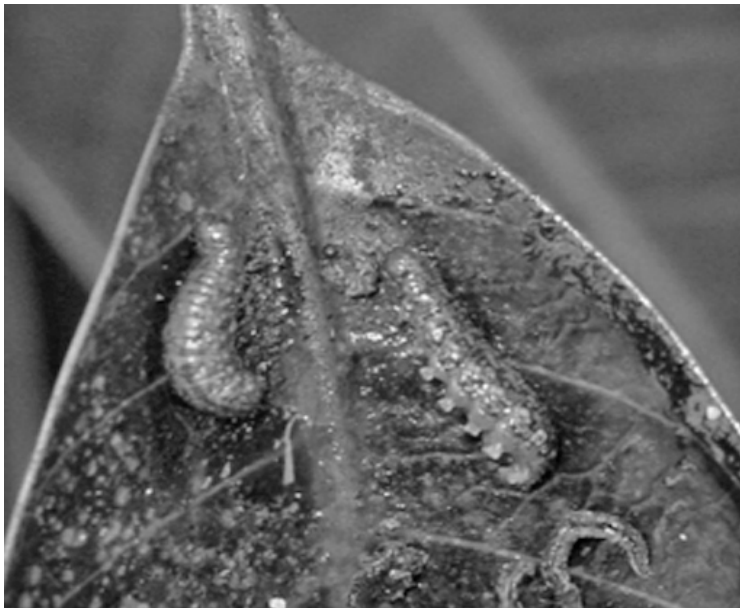
The honeydew produced by the mealy bugs promotes growth of sooty molds on leaves, which eventually affects the photosynthetic activity.

Management:
- Prune heavily infested plant parts.
- Spray registered insecticide immediately before bagging.

Mango Tip Borer

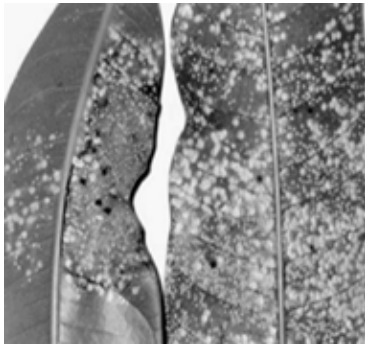
Description:
The adult mango tip borer is a grayish black moth, usually about 8mm long. Its larva can grow to as long as 10 mm and light-brown to purple in color. It is considered as a serious pest of flowers and young shoots.

Damage:
Mango tip borer destroys the flowers from bud emergence to elongation. Its larva bores into the tip of the shoots and developing flowers and feeds on the inner tissues. The affected shoots wilt and terminal parts die while the affected panicles split-open and gradually shed off the flowers.



Management:
- Prune and burn the infested parts to prevent the insects from multiplying and spreading.
- Spray registered insecticides recommended for tip borer control.

Scale Insect



Description:
Scale insects are small (1 mm long), stationary, convex and scale-like organisms.

Damage:
High population of scale insects causes the canopy to turn black due to the growth of sooty mold. Since the leaves are covered with sooty mold, photosynthetic or food production activity is reduced considerably.

Punctures created by insects on the fruit result in whitish spots which lower the fruit's market value.

Management:

- Look for scale insects on leaves, flowers and fruits. Check if infestation is widespread or occurring only in small patches. If infestation is widespread, prune heavily-affected parts before spraying registered insecticide. If it occurs in patches, remove affected parts mechanically.
- Check if there are ipil-ipil or kakawate trees nearby. These are alternate hosts of scale insects and serve as a source of infestation.
- Destroy the red ants infesting the mango tree because these facilitate the spread of scales from one tree to another.

Twig Cutter

Description:
The larva of twig cutter grows to as long as 18mm, is colored white and legless. It can be found inside the twigs where it feeds on woody tissue. It pupates inside the twig and will get out only when it has become a fully-grown beetle. The adult twig cutter is a gray-spotted long-horned beetle and around 20mm long.

This insect is very destructive during the dry season, particularly in many growing areas of Central Luzon.

Damage:
The twig cutter cuts or girdles the twig before it lays eggs. The infested twig breaks off easily at the point of incision or die. A twig cutter-infested tree is characterized by the presence of dead twigs and leaves on its canopy.

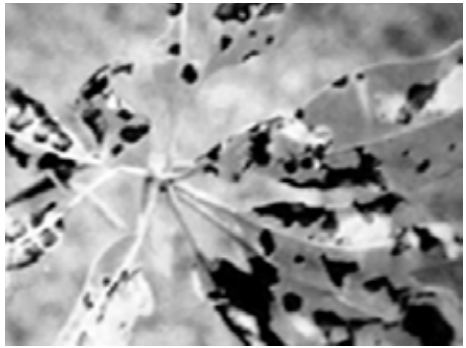
Management:
- Prune and burn infested twigs to prevent the development and spread of insects.
- Apply insecticide during flushing stage, the time when the adults lay eggs on the twigs.

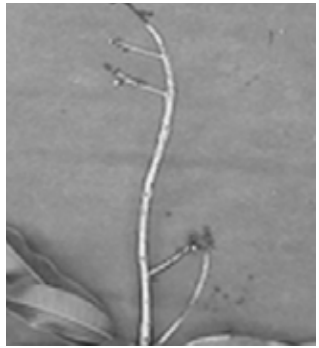
DISEASES

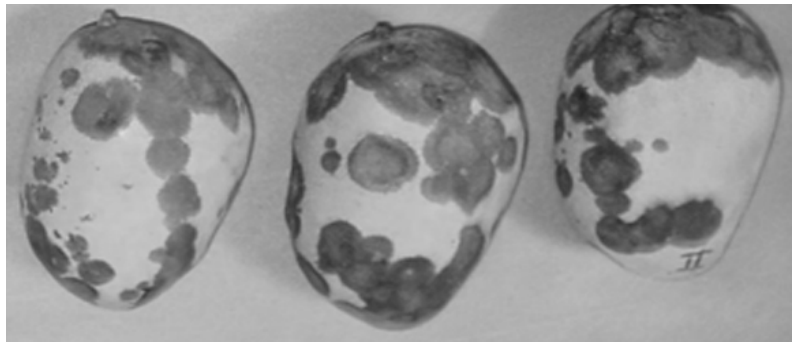
Anthracnose

Description:
Anthracnose is a major post harvest problem of mango fruits and is the most serious fungal disease of mangoes in the Philippines.

Damage:
Anthracnose causes irregular brown spots on young leaves while mature leaves get distorted with "shot-holes" in various shapes and sizes. It also blackens and withers the flowers and produces "blossom blight" while causing brown to black sunken spots on the fruits.







Other damage caused by anthracnose:

- reduced tree vigor
- unproductive terminal branches
- withering of flowers
- failure to set and retain fruits
- rotting of fruits
- total crop failure

Management:

a. Field Management

Follow recommended cultural practice to maintain vigorous and productive trees, which are less prone to diseases.

- Maintain good light penetration and air circulation in each mango tree.
- Collect and burn trash to reduce sources of disease.
- Bag fruits using appropriate bagging materials to reduce further field infestation.
- Fertilize and irrigate trees to improve tree vigor.
- When flushing occurs on rainy days, protect emerging flushes from leaf spots by spraying registered contact fungicides. DO NOT use systemic fungicides.

- Apply protectants/systemic fungicides to protect inflorescence against blossom blight and fruit rot infection on developing fruits.

b. Post Harvest Management

Subject newly harvested fruits in hot water treatment:

- for 10 minutes if water temperature is between 53 to 55oC, or
- for 1 minute if water temperature is between 59 to 60oC

Scab

Description:
Scab is a fungal disease which primarily infects young developing fruits. It is prominently seen in panicles and young developing fruits, particularly on the pedicel.

The surface of infected fruit has grayish brown spots with dark irregular margin. As the spots enlarge, the surface develops cracks and fissured corky tissues. Heavily infected fruits look like common scab-infected calamansi fruits.

Heavier infestations occur during the rainy season.

Damage:
Infected fruits are misshapened with unsightly looking surface, thus are downgraded and have lower market value.

Management:
- Follow the protection management used against anthracnose.
- Use the recommended cultural practice to maintain vigorous and productive trees, which are less prone to diseases.
- Maintain good light penetration and air circulation in each mango tree through

regular sanitation and pruning. Prune after harvest to increase ventilation and reduce humidity inside the canopy.

- Collect and burn trash to reduce sources of diseases.
- Bag fruits using appropriate bagging materials to reduce further field infection.
- Spray registered fungicides in scab prone areas during the young fruit stage or around 35 to 50 days after flower induction to control the disease.

Sooty Mold

Description:

Sooty mold is a fungal disease that grows and obtains nourishment from the honeydew excreted by insects such as leafhoppers, scales and mealy bugs. The disease develops on the leaf surface and on fruit as black velvety covering.

Damage:

The sooty mold on leaves interferes with the photosynthetic activities of the plant. It reduces the tree's vigor and fruit bearing capability and downgrades the fruit's market value.

Management/Prevention:

- Eradicate or manage the population of the honeydew-excreting insects.
- Bag clean fruits with appropriate bagging materials.
- Practice pruning.

Diplodia/stem-end rot

Description:

Diplodia stem-end rot is a fungal disease caused by complex fungal organisms. It is characterized by dark lesions developing at the pedicel end of the mango fruits after they are harvested. Under warm and moist conditions, the infected area extends towards the end of the fruit. The fruit turns from dark-brown to purplish black and the tissues become watery and produce unpleasant odor.

Diplodia stem-end rot produces soft rot unlike anthracnose which produces hard rot. This disease also infects inflorescence, young developing fruits and terminal branches.

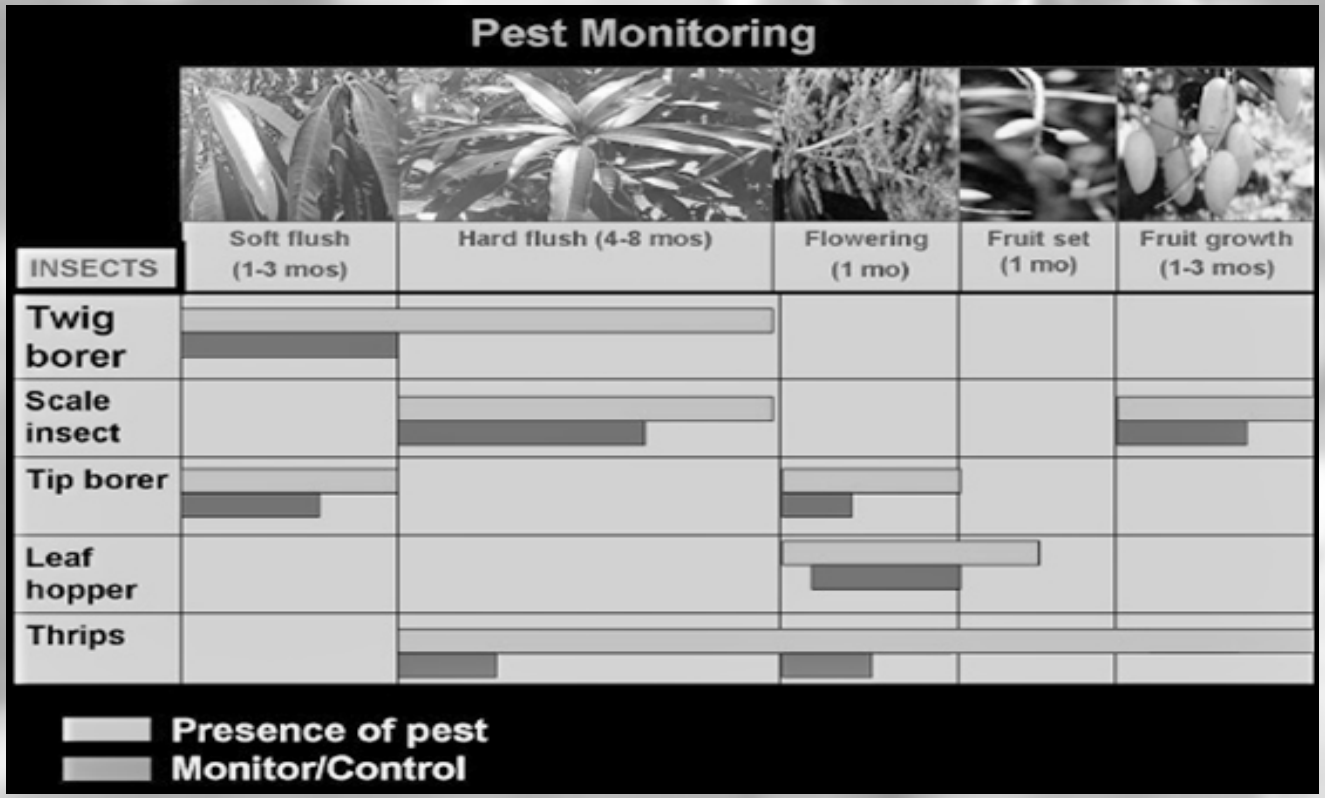
Damage:
Stem-end rot causes post-harvest losses due to rotting of fruits. It also reduces tree vigor because of severe drying of twigs and defoliation.

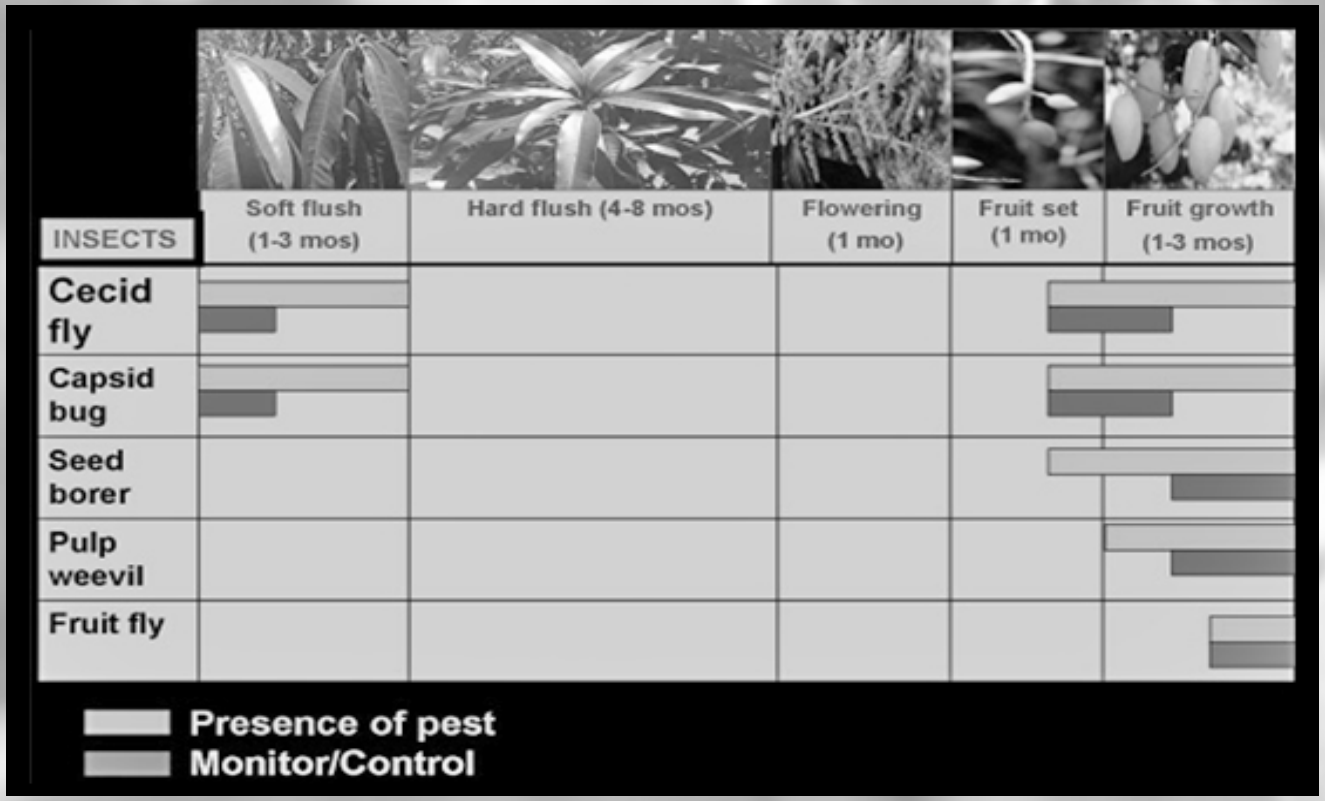
Management:

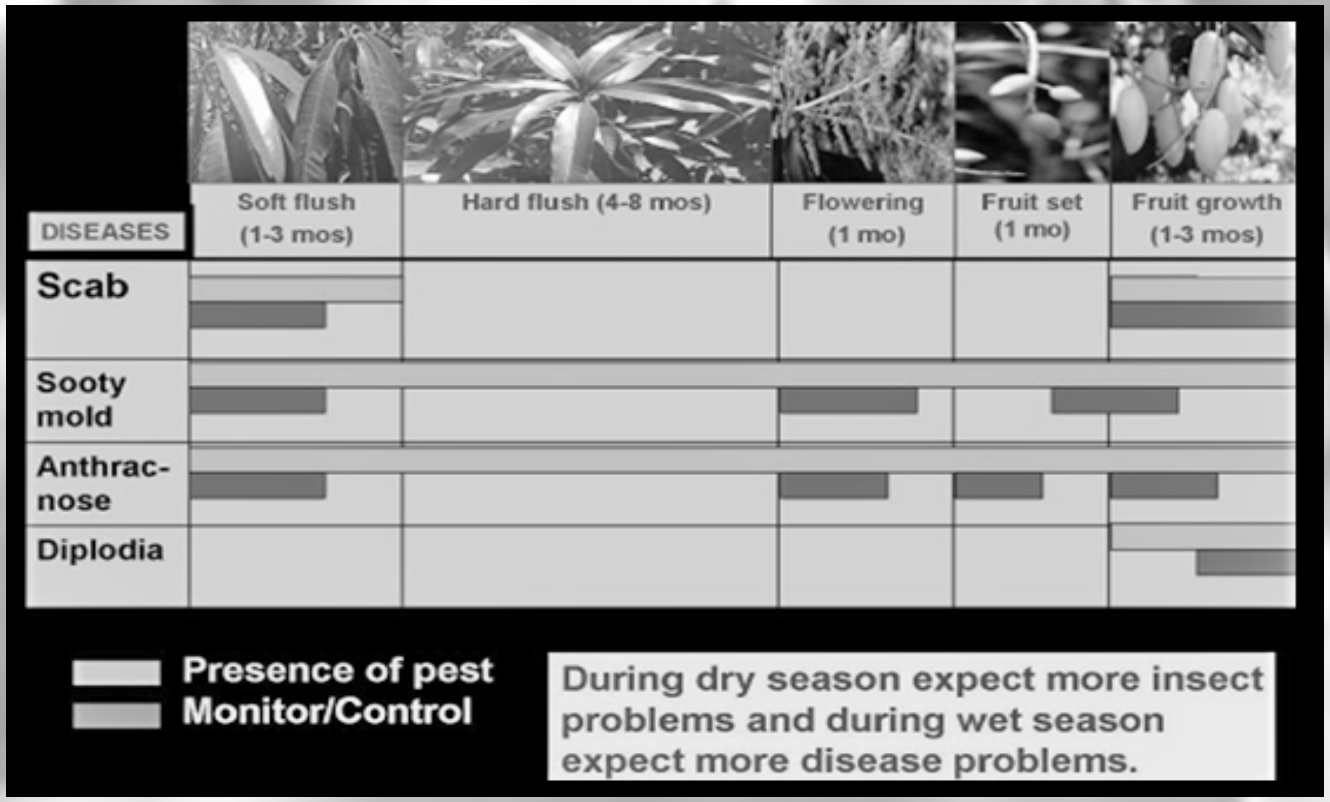
- Remove and burn primary sources of the disease such as dead twigs, barks and other trashes.
- Harvest the fruits with about 1 to 2cm of the stalk attached. It was observed that there is a high incidence of stem-end rot on fruits without stalk.
- Follow the disease management interventions developed for anthracnose. They are known to substantially reduce incidence of stem-end rot.

Pest and Weather Monitoring

The pest monitoring guide will show the kinds of pests that will attack the mango tree during each phase and the ways to prevent or manage the infestation that may attack the orchard.




INSECTS
Soft flush (1-3 mos)
Hard flush (4-8 mos)
Flowering (1 mo)
Fruit set (1 mo)
Fruit growth (1-3 mos)
Cecid fly
Capsid bug
Seed borer
Pulp weevil
Fruit fly
Presence of pest
Monitor/Control


DISEASES
Soft flush (1-3 mos)
Hard flush (4-8 mos)
Flowering (1 mo)
Fruit set (1 mo)
Fruit growth (1-3 mos)
Scab
Sooty mold
Anthrac-nose
Diplodia
Presence of pest
Monitor/Control
During dry season expect more insect problems and during wet season expect more disease problems.

Beneficial Organisms

Predators. Insects that actively search out and eat insect pests, i.e. lady beetles and spiders.

Parasitoids. Insects that prey on eggs of pests, i.e., Trichogramma sp. which are tiny wasps that kill eggs of mango seed borer.
Other beneficial organisms present in the farm are fungi and pollinators.

Entomophagous, which means "insect eating," fungus is a parasitic species or fungal pathogen that grows and develops on specific insect pests.

Pollinators are insects that helps in the fertilization. Most common pollinators are bees and blow flies.

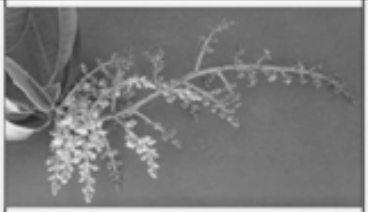
Pesticide Management

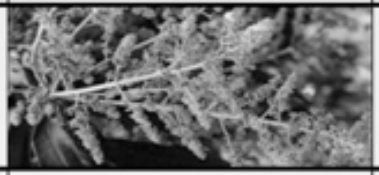
1) Apply registered insecticides during the weak links in the life cycle of the insect pests. Thus, it is important to know or identify the weak links in the insect's life cycle.
2) Apply registered insecticides only when pest monitoring results show that it is time to apply insecticides
3) Apply different types of chemical pesticides alternately to delay the development of insect resistance.
4) Apply registered insecticides at critical stages before the damage reaches economic level.
5) Apply registered fungicides at stages when the plant is vulnerable to fungi attacks. Refer to the Pest Monitoring Guide and remember that diseases are prevalent during the wet season.
6) Apply registered protectant fungicides during less critical period or before disease infection is initiated.
7) Apply registered systemic fungicides during critical periods and usually after infections have started.

Integrated Pest Management Program for Mango

Month After Harvest (MAH)	Phenology	Illustration	Target Pests	IPM Interventions
1	Dormant		Scale insects Mealybugs	Prune to improve light penetration and air circulation Fertilizer application (soil application)
2	Flushing		Cecid Fly Twig cutter Anthracnose	Spray insecticides and fungicides* to protect flush Apply growth regulator if necessary
7-9	Leaf Maturation		Twig cutter	Prune and burn infested twigs
Before flower induction			Mango leafhopper	Light trapping Field sanitation Pruning

DAFI	Phenology	Illustration	Target Pests	IPM Interventions
Flower induction O DAFI*	Mature buds and leaves		Mango Leafhopper	Start of chemical induction 1.0 – 2.5% KNO_3 with high hopper population, mix insecticide and flower inducer
1-8 DAFI	Bud break/ bud initiation		Mango leafhopper	Monitor percent flushing/ flowering Monitor for pest
9-12	Bud emergence		Mango leafhopper Tip Borer Thrips	Monitor for pest Spray insecticide if needed

DAFI	Phenology	Illustration	Target Pests	IPM Interventions
13-16	Post emergence: Bud elongation I		Mango hopper Tip borer Thrips Anthracnose	Apply foliar fertilizer Monitor for pest Spray insecticide and fungicide if needed
17-22	Post emergence: Bud elongation II		Mango hopper Tip borer Thrips Mealy bug Anthracnose	Monitor for pest Spray insecticide and fungicide if needed
23-25	Pre-anthesis		Mango hopper Tip borer Mealy bug	Apply foliar fertilizer Monitor for pest Spray in insecticide and fungicide if needed

DAFI	Phenology	Illustration	Target Pests	IPM Interventions
26-30	Full bloom		Blossom blight	No insecticide spraying to encourage pollinators Shaking of branches
31-35	Fruitset (mongo size)		Mango hopper Tip borer Mealy bug Anthracnose Scab	Monitor for pests Spray insecticide and fungicide if needed
36-42	Fruit development (corn size)		Mango leafhopper Tip borer Mealy bug Anthracnose Scab	Monitor for pests
43-50	Fruit development (marble size)		Tip borer Mealy bug Cecid fly Anthracnose Scab	Spray insecticide and fungicide if needed Early bagging for cecid fly control (optional)

DAFI	Phenology	Illustration	Target Pests	IPM Interventions
51-60	Fruit enlargement (chicken-egg-size)		Mango seed borer *Helopeltis* sp. Mealybug Scale insect Mango pulp weevil Anthracnose Scab	Field sanitation Before fruit bagging apply foliar fertilizer Spray insecticide and fungicide if needed
61-90	Fruit enlargement		Mango seed borer *Helopeltis* sp. Mealy bug Scale insect Anthracnose Scab	Monitor for fruit pests Collection and proper disposal of fruit drops In not bagged spray insecticide and fungicide

DAFI	Phenology	Illustration	Target Pests	IPM Interventions
91-109	Start of maturation		Fruit fly Mealy bug Scale insect Anthracnose Scab	Monitor for fruit pests Collection and proper disposal of fruit drops Spray insecticide and fungicide if needed
110-120	Full maturity		Fruit fly Stem-end rot Anthracnose	Harvesting of fruits based on maturity indices Hot Water Treatment (HWT)- Dip newly harvested fruits in hot water (52 to 55°C) for 10 min. Rinse in cool running water for 10 min., air dry and pack. Modified HWT, 60 °C for 1 minute, no hydro cooling.

CHAPTER 3:
Pesticide Management

Objectives:

At the end of this chapter, the participants must be able to:

1. Define pesticide management;
2. Discuss the basic information and classification of pesticides;
3. Explain the importance of maintaining the maximum residue limit; and
4. Discuss how good agricultural practice (GAP) can be implemented in pesticide management.

Pesticide Management is the judicious use of pesticides. It focuses on maximizing the benefits of the chemical while minimizing its harmful effects.

Pests are organisms whose existence conflicts with people's profit, convenience, or welfare it includes insects, nematodes, fungi, weeds, birds, rodents, or any terrestrial or aquatic plant or animal life, or virus, bacteria and other organisms.

Pesticides are any substance or product, or mixture thereof, including active ingredients, adjuvants, and inert ingredients, intended to control, prevent, destroy or repel pests.

Research and Development

- it takes at least 10 years, from discovery to commercialization, before a pesticide product is allowed to be used by the consumer
- it involves screening of more than 10,000 molecules
- a company spends at least US$ 100 million before a single product is developed, registered, and commercialized

PESTICIDES	MAJOR PESTS CONTROLLED
Fungicides	Fungi/Fungal diseases (ex. anthracnose)
Herbicides	Weeds (ex. cogon grass)
Insecticides	Insects (ex. leafhoppers, tip borers)
Rodenticides	Rodents/Rat

One reason for this:

"the stringent regulatory requirements which include biological efficacy, physico-chemical properties, toxicological, residue, ecotoxicological and environmental studies"
- includes insecticides, fungicides, acaricides, bactericides, nematicides, herbicides, molluscicides, avicides, and rodenticides

Classification of Pesticides

1. Classification based on formulation types

a. Sprayables are pesticides that are normally mixed with water and sprayed on the crop.
Specific types:
- emulsifiable concentrates -mixtures of active ingredients, solvents, and emulsifiers
- flowable concentrates - consists of finely ground active ingredients in liquid suspension
- soluble concentrates
- wettable powders - consists of active ingredient (AI) mixed with a carrier and wetting agent
- micro encapsulated formulations
- others (soluble liquid, soluble powder, oil dispersible concentrate, emulsion in water, ultra-low volume concentrate)

b. Granules and pellets are solid formulations applied as is, normally in the soil.

c. Fumigants are used in gaseous form.

2. Classification based on mode of action

a. Stomach poisons are ingested or absorbed in the digestive tract.
b. Contact poisons penetrate the insect body or plant pathogen upon contact directly with the pesticide or with the treated area.
c. Systemic poisons are taken into the plant through the roots or leaves and translocated via the vascular system to the different parts of the plant. Sucking, boring and mining insects and pathogens are affected when they attack the treated plant.

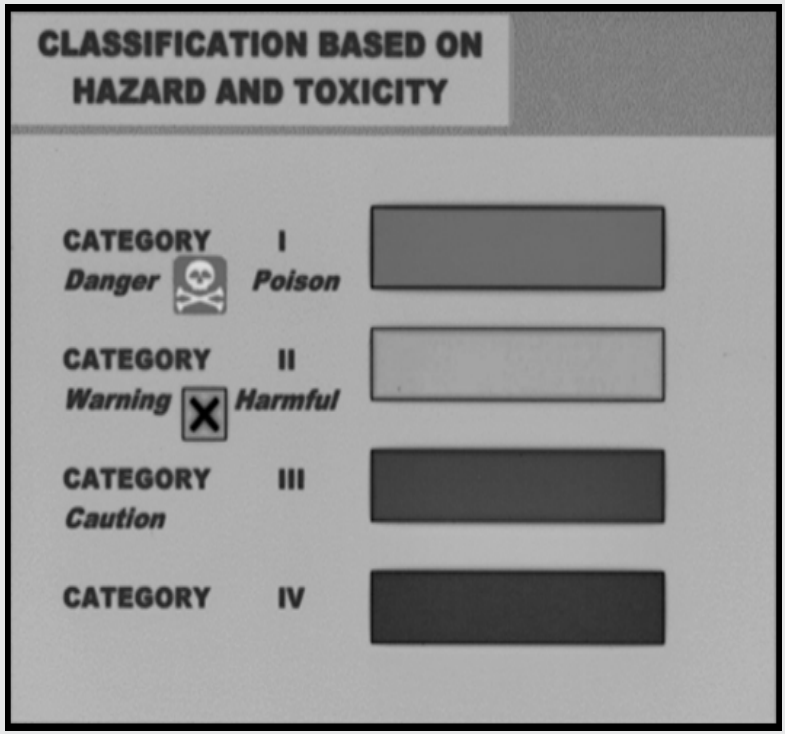
3. **Classification based on formulation toxicity**

Toxicity is the physiological or biological property which determines the capacity of the chemical to do harm or produce injury.

Hazard refers to the inherent toxicity of a compound to produce harm.

Under the Fertilizer and Pesticide Authority (FPA) guidelines:
"pesticide products or formulations are categorized as highly toxic, moderately toxic, slightly toxic and relatively non-toxic"

They color-coded as follows:
Category I - highly toxic (red band)
Category II - moderately toxic (yellow band)
Category III - slightly toxic (blue band)
Category IV - relatively non-toxic (green band)



Acute toxicity

- the adverse effect of a pesticide on animals and humans after a single exposure
- it can be measured based on the median lethal dose (LD50) or the dose or concentration needed to produce a 50% mortality in test organisms over a given period of time.
  *** Pesticides with lower LD50 values are more toxic than those with higher LD50 values.

Chronic toxicity

- the effect of a pesticide after small, repeated doses over a period of time

How pesticides enter the human body?

Oral exposure – pesticide can be ingested by an individual.

Dermal exposure – pesticide gets in contact with the skin of a person, particularly during mixing and spraying. In most cases, residues in the hand after mixing pesticides can be greater than the total body residue.

Eye exposure – pesticide enters the body through the eye tissues. Some products are severe eye irritants.

Inhalation – pesticides enters the body of a person through breathing.

Implementing Good Agricultural Practice (GAP) in Pesticide Management

1. **Use registered pesticides.**
2. **Read and follow the label instructions.**
3. **Practice Integrated Pest Management (IPM).**

1. Use registered pesticides

Apply pesticides which have been approved by the FPA.

However, there are chemicals which are not considered as pesticides but are nevertheless used in mango and are also regulated by FPA as "other chemicals". These include products like formulations of mango flower inducer and paclobutrazol.

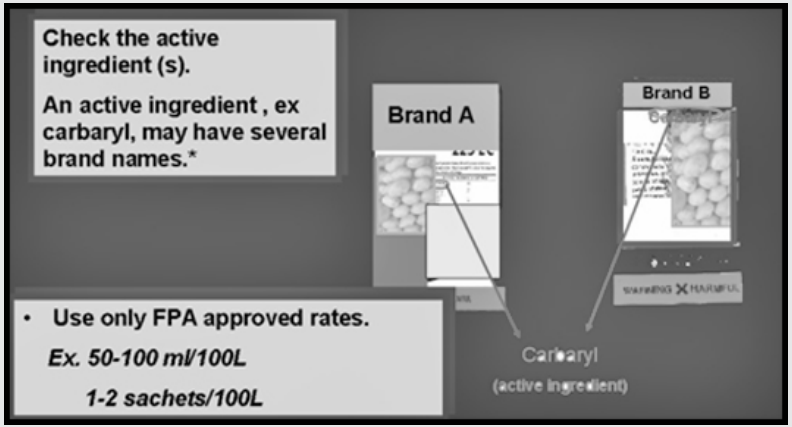
2. Read and follow the label instructions.

It is important to always read and understand the pesticide label to be able to use the product properly.

The following information are contained in the label:

A) Product Information

- Check active ingredient(s)
- Check toxicity category of the product



It is important to always read and understand the pesticide label to be able to use the product properly. The following information are contained in the label:

B) Directions for use

- Crops
- Target Pests
- Dosage
- Pre-harvest Interval
- Compatibility
- Storage and Disposal
- Emergency Contact Number

Pre-Harvest Interval

Refers to the number of days between the last spraying and harvest. It is derived from a supervised pesticide residue trial where the pesticide is applied at the recommended rates and the residue level is analyzed. Each pesticide active ingredient or AI has its own PHI.

In the example, the PHI (seven days) is indicated in the last column:

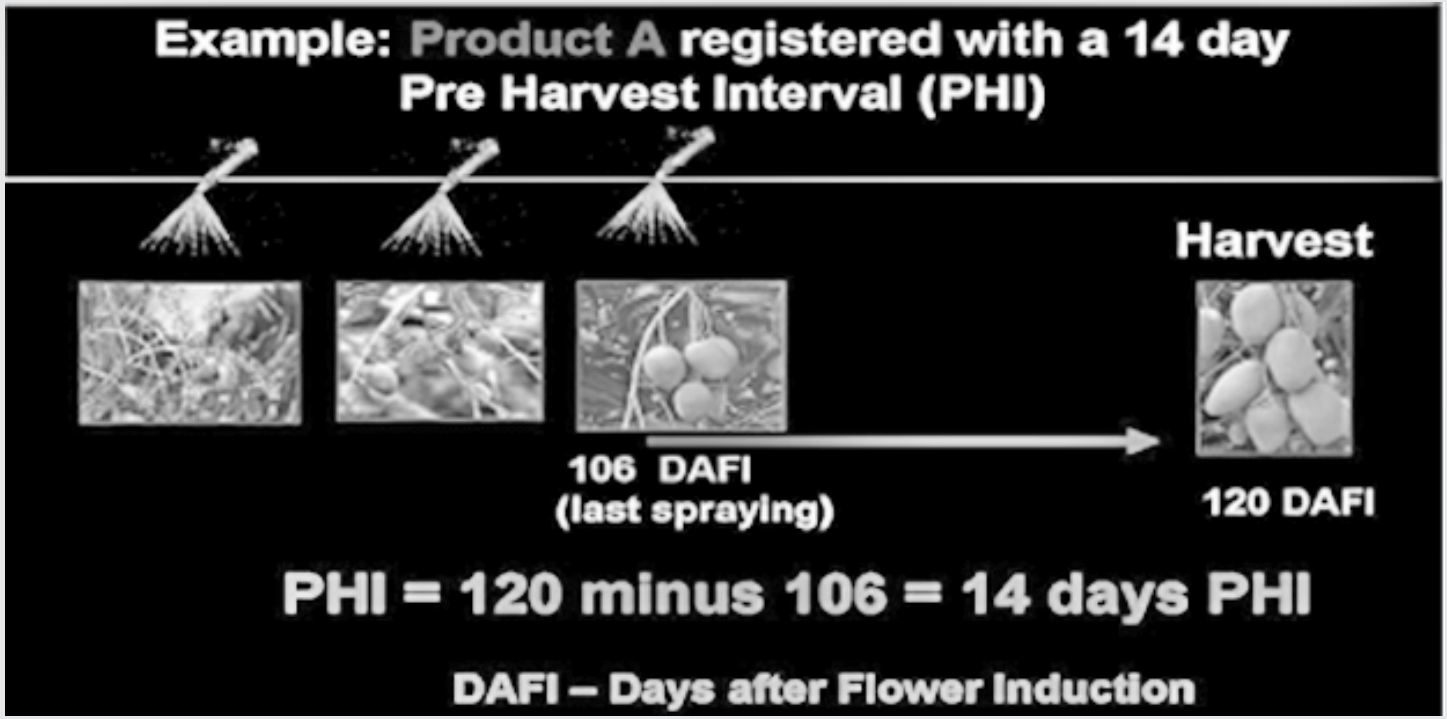
In this case, PHI indicates the last application timing of the pesticide product in mango.

DIRECTIONS FOR USE:

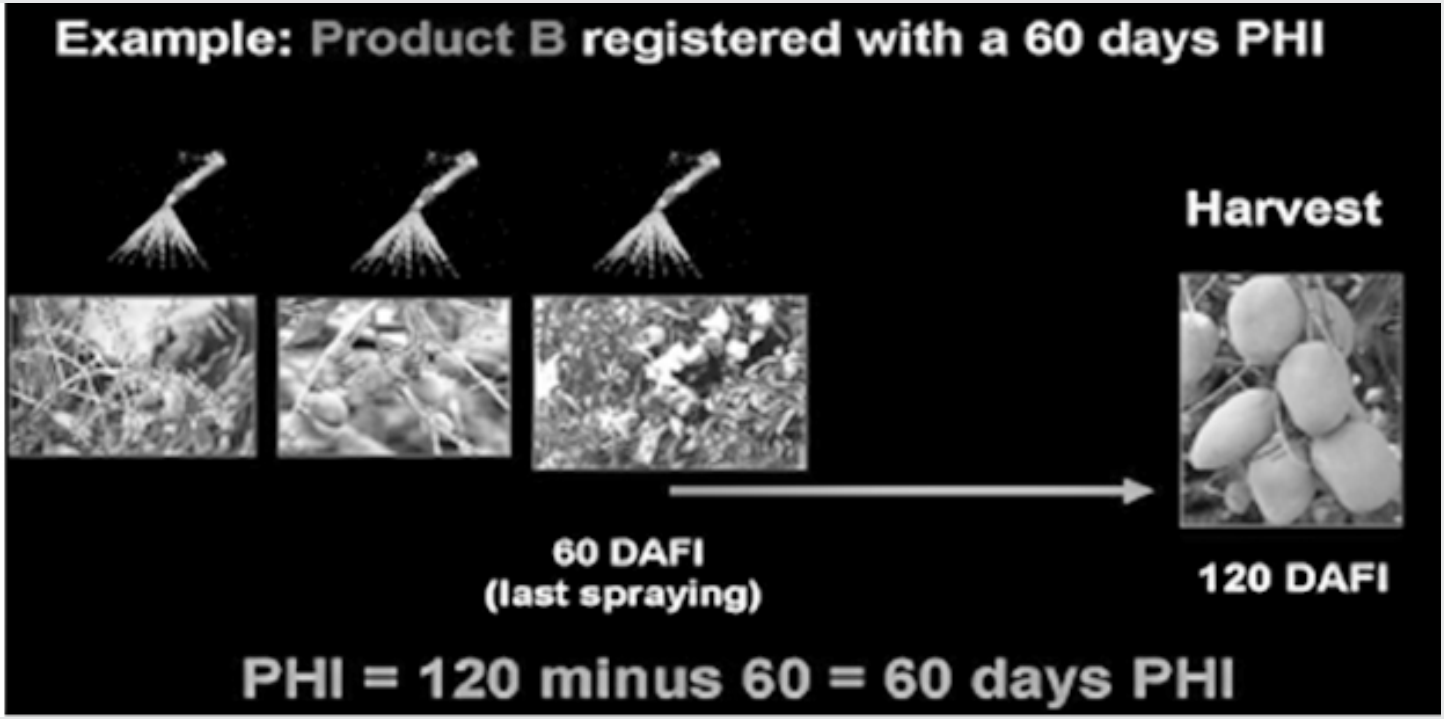
CROP	DISEASES	ml/16L	ml/100L	ml/200L	Last application to harvest–Days
Mango	Anthracnose and Scab	8 to 10	50–60 (1/2 cup)	100 (1 cup)	7

Other examples:

1. Product A registered with a 14 days PHI



2. Product B registered with a 60 days PHI



Maximum Residue Limit (MRL)

Pesticide residues may be detected in mango fruits. However, this does not necessarily mean that the crop is not safe to be consumed.

To verify this, the pesticide residue level detected must be compared with the Maximum Residue Limit (MRL) of that pesticide in the crop. If the food crop has residue below or at the MRL, it can be consumed.

PHI is one of the critical factors affecting pesticide residues. If we follow the PHI, residue levels at harvests can either be less than or equal to the MRL. If we shorten the PHI, the residue level at harvest will be above the MRL.

Eating food with residues below or at MRL will not lead to health concerns.

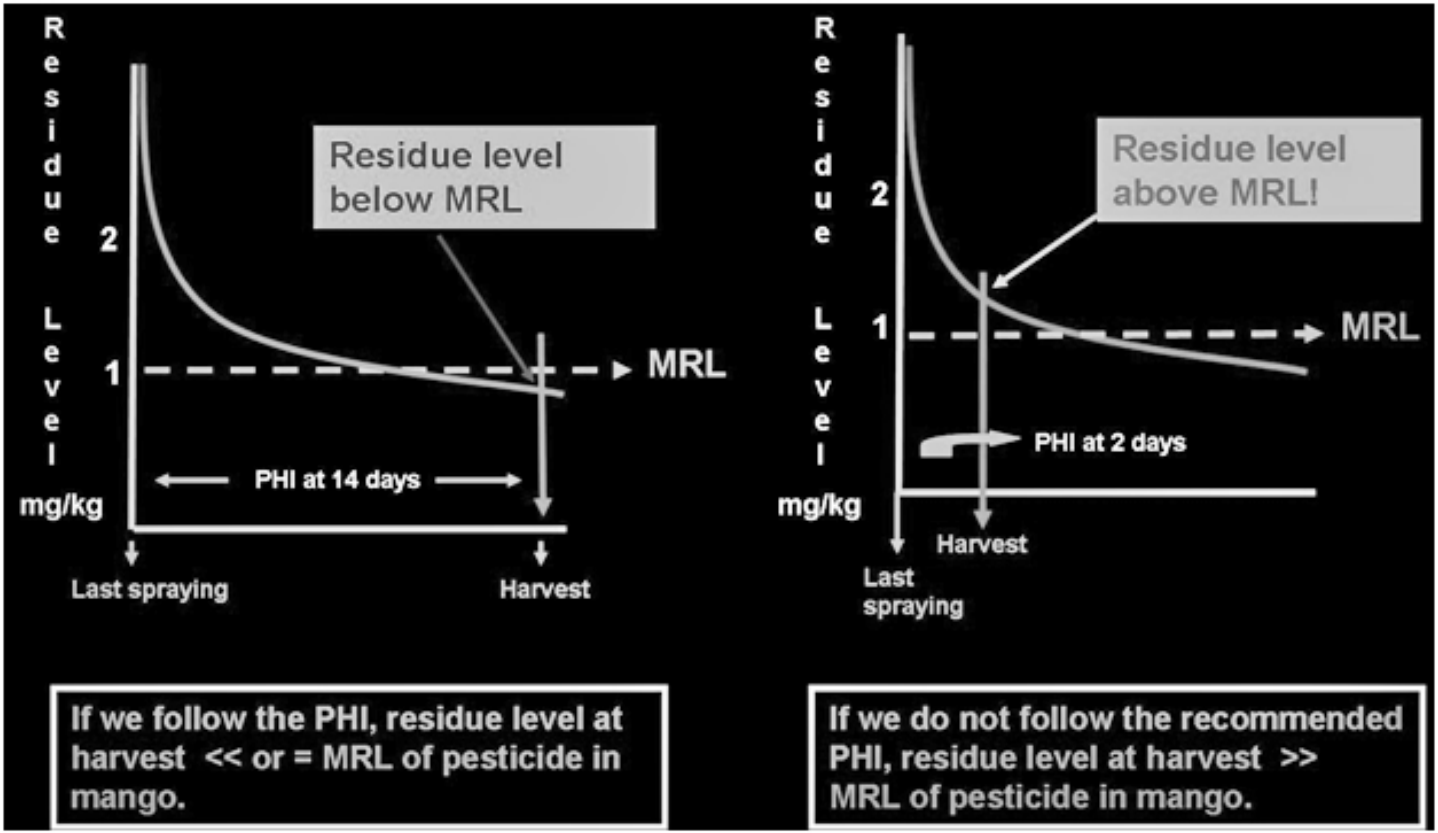
MRL is the maximum residue level of a pesticide legally permitted in food, agricultural commodity or animal feed resulting from the use of a pesticide according to Good Agricultural Practice.

It is expressed as milligram of the pesticide active ingredient per kilogram of the commodity (mg/kg).

If we comply strictly with the guidelines on using pesticides and make sure it is consistent with Good Agricultural Practice (GAP), then we can help reduce pesticide residues in food commodities.

If we apply pesticides following the recommended PHI, pesticide residues might be present even if GAP is practiced, but this will be below the MRL, and therefore residues resulting from GAP at harvest are acceptable. The commodity can likewise be traded both in domestic and international markets.

What will happen to the pesticide residue level at harvest?



What happens if MRL levels are exceeded?

Rejection of our mango exports!

MANGO EXPORT SHIPMENTS REJECTED BY JAPAN*

DATE	COMPOUND	MRL	Residue detected
Sept. 2004	Chlorpyrifos	0.05 ppm	> 0.05 ppm
Dec. 2004	Chlorpyrifos		> 0.05 ppm
June 2005	Chlorpyrifos		0.07 ppm
Aug. 2006	Cypermethrin	0.03 ppm	0.04 ppm
Aug. 2006 (2 samples)	Cypermethrin		0.09 ppm 0.08 ppm

*BPI-NPAL Report

Implementing Good Agricultural Practice (GAP) in Pesticide Management

It is important to always read and understand the pesticide label to be able to use the product properly.

The following information are contained in the label:

C) Proper use and handling

Before mixing:

1. Keep spraying equipment in good condition. Check sprayer for defects.
2. Check and repair leaks. Do not use faulty or leaky sprayers, they cause unnecessary waste and hazards.
3. Clean the nozzles with water or soft-probing device. Never blow into a clogged nozzle.
4. For appropriate personal protective equipment (PPEs) to be used, READ THE PRODUCT LABEL.

PPE - *protective clothing and other paraphernalia such as gloves (preferably neoprene or nitrile when mixing concentrates), masks/respirators (used to handle powders and volatile liquids), goggles/safety glasses, boots, coverall, apron.*

During mixing:

Mixing pesticides involves the following:

1. Opening and closing the containers;
2. Measuring the concentrated/formulated product;
3. Transferring the measured amount; and
4. Dissolving it in water in the mixing tank (200L plastic drum).

To minimize dermal exposure:

1. Use appropriate gloves.
2. In case of spillage, remove gloves immediately, and wash hands.

Safety measures:

1. Use a measuring cup or graduated cylinder in measuring the concentrated formulated pesticide, with care to avoid spillage or hand contamination.

2. Use clean water for mixing pesticides to avoid microbial contamination of the mango fruits.
3. When the contents of the pesticide bottle are used up, rinse the bottle 3 times with water and pour into the last sprayer tank load.
4. Never use your bare hands for mixing.

TRIPLE RINSE LOGO

During application:

Follow the following the guidelines:

1. Pesticide residues are highest in the face area, including the neck and shoulders, so wear the necessary protection.
2. Do not spray against the wind.
3. Spray inner canopy first before spraying the outer canopy.
4. Use a power sprayer with an extended boom, such as a bamboo pole, to reduce contact with the spray mist.

To minimize exposure during spraying:

- Wear protective headgear.
- Cover your nose and mouth while spraying.
- Wear long-sleeved shirts and long pants.
- Change your shirt and headgear when they get wet with perspiration or spray solution.
- Remove gloves last.
- Do not rub face or other body parts with contaminated hands.
- Do not smoke and eat if your hands are not washed clean after spraying.
  Pesticide residues in your hands could transfer to your mouth and could lead to poisoning.

After spraying:

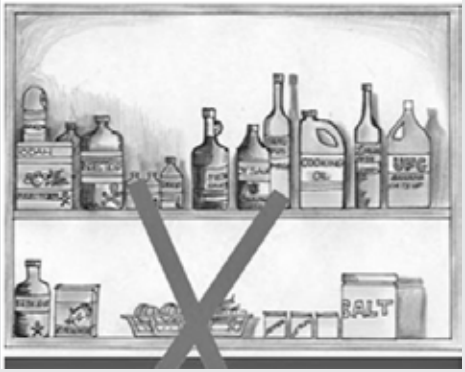
Consider the following safety measures:

1. Clean spray equipment by flushing the remaining pesticide solution using detergent and clean water.
2. Do not dispose contaminated water or rinsate into waterways.
3. Change clothes immediately after spraying.
4. Remove gloves last.
5. Wash your hands with soap and water.
6. Do not go home in your working clothes (used in spraying) because the pesticides in the fabric can be absorbed by the skin.
7. Do not hang used clothes to dry for reuse the following day.
8. Soak clothes in water and detergent.

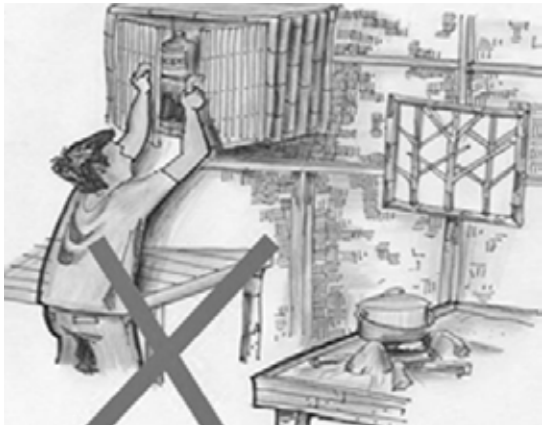
9. Dispose of rinse water properly, taking care not to contaminate water and food sources.
10. Launder working clothes separately from uncontaminated clothes.

D) Storage and disposal

1. Store pesticides in their original labeled containers.
2. Keep pesticides locked in storeroom and out of children's reach.
3. Keep pesticides out of the kitchen.
4. Do not place pesticide bottles beside bottles of vinegar, oil and soy sauce.
5. Do not place pesticide powders near salt or sugar.



6. Keep pesticides away from fire or open flame, stove or lamps. Liquid formulations may have flammable solvents which can be a fire hazard.
7. Partially used pesticide bottles must be placed inside a thick plastic bag to avoid hand contamination.
8. Do not recycle used bottles as containers for oil, vinegar, soy sauce, and for any other food and feed stuff.



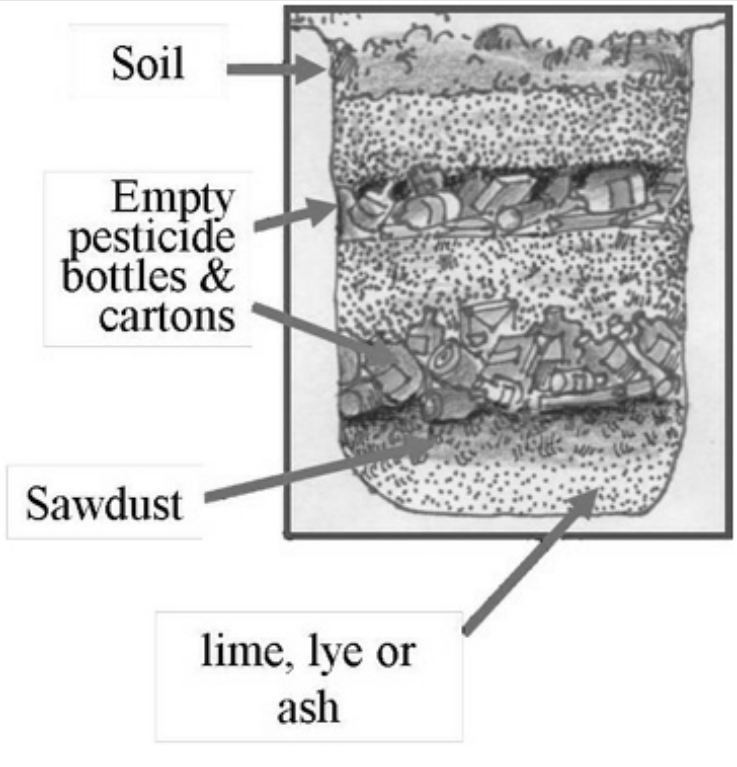
Dispose empty pesticide containers as follows:

1. Dispose of empty pesticide bottles and cartons into a pesticide disposal pit.

2. Dig disposal pit in an area away from people and animals and far from water sources.

3. Do not burn pesticide containers.

   The temperature in the burning pile is not high enough to destroy the pesticide left in the containers. It will only spread faster through the hot air generated while burning. This will lead to inhalation problems and in some cases, phytotoxicity in standing crops.



Practice Integrated Pest Management (IPM)

At some point, pesticide resistance develops in insects, plant pathogens, and other organisms. These happen when the:

1. Same pesticide or pesticides of same chemical group such as pyrethroids, carbamates, organophosphates are continuously used;

2. Improper amount of pesticide was applied (underdosing and overdosing).

Pesticide resistance problems can be avoided by following these measures:

1. Practice Integrated Pest Management (IPM) by applying other control methods, such as cultural methods, which include among others:
   a. Pruning – removal of crowded branches to allow light and air movement inside canopy, thus creating an environment unfavorable for the development of insect pests and diseases
   b. Proper fertilization – healthy plants can recover better from pest damage or infection
   c. Sanitation – removal of sources of plant pathogens and insect pest
   d. Intercropping – changes visual and chemical cues for insects which reduce mango visibility. Intercrops: vegetables, legumes, rice and corn
   e. Removal of secondary or alternate host

plants, such as weeds – less food/ oviposition sites for pests

f. Bagging – prevents insects from laying eggs on fruits

2. Choose pesticides which conserve and do not harm pollinators (bees) and natural enemies.
3. Use products according to recommended doses. Underdosing quickly affects insect populations with average levels of tolerance, while over dosing kills most of the insect population leaving only those which are tolerant or resistant. This leads to the development of a new generation of insects which are difficult to kill.
4. Use appropriate, well-maintained equipment to apply insecticides/ fungicides.
   Use recommended water volume and spray pressure in order to obtain optimal coverage of the canopy. Avoid spraying to run-off.
5. Target the pests at their vulnerable stage, (young instars, larvae) where possible, because these are easier to control than older instars/larvae.
6. Use appropriate economic thresholds and spray intervals (based on label recommendation).
7. Use alternately products of different modes of action or from different chemical groups such as pyrethroids, carbamates, organophosphates and new generation compounds.
8. If the efficacy of the product is no longer good, do not reapply the same insecticide /fungicide but change the class to one having a different mode of action.
9. Mix different pesticides. This may offer a short-term solution to resistance problem. However, remember that each product used in the mixture should belong to a different class or mode of action, and is used at the recommended dose.

CHAPTER 4:
Insecticide Resistance Management (IRM)

Here are the concepts related to insecticide resistance:

Susceptibility is the sensitivity of an insect pest to an insecticide application. Therefore, if an insect is exposed to a spray treatment and it dies, it is said to be SUSCEPTIBLE. On the other hand, if an insect shows no effects and does not die as a result of exposure to the treatment, it is NOT SUSCEPTIBLE or is RESISTANT.

This now leads us to RESISTANCE which is defined as the heritable change label recommendation.

Under normal farmer field situations, resistance development in a population, most commonly, results from the selection of forms or biotypes of the pest.

This population eventually evolves into one with many individual insects RESISTANT to that particular insecticide.

Different insects within a population normally can also experience varying degrees of susceptibility to the same treatment.

FACTORS THAT AFFECT DEVELOPMENT OF INSECTICIDE RESISTANCE

First is the TARGET ORGANISM.

Exposed to the stress of pesticide treatments, there are "high risk" species that like the diamond backed moth, mango leafhoppers and thrips which adopt quickly. Within the same pest species, there are differences in capability to the stress brought about by natural genetic variability.

Second is the PRODUCT.

Each chemical has its own insecticidal activity which dictates what pests are susceptible or resistant to it. The chemical nature and formulation of the product determines the effective period within which it continues to be effective against the target pest. This is also known as residual control.

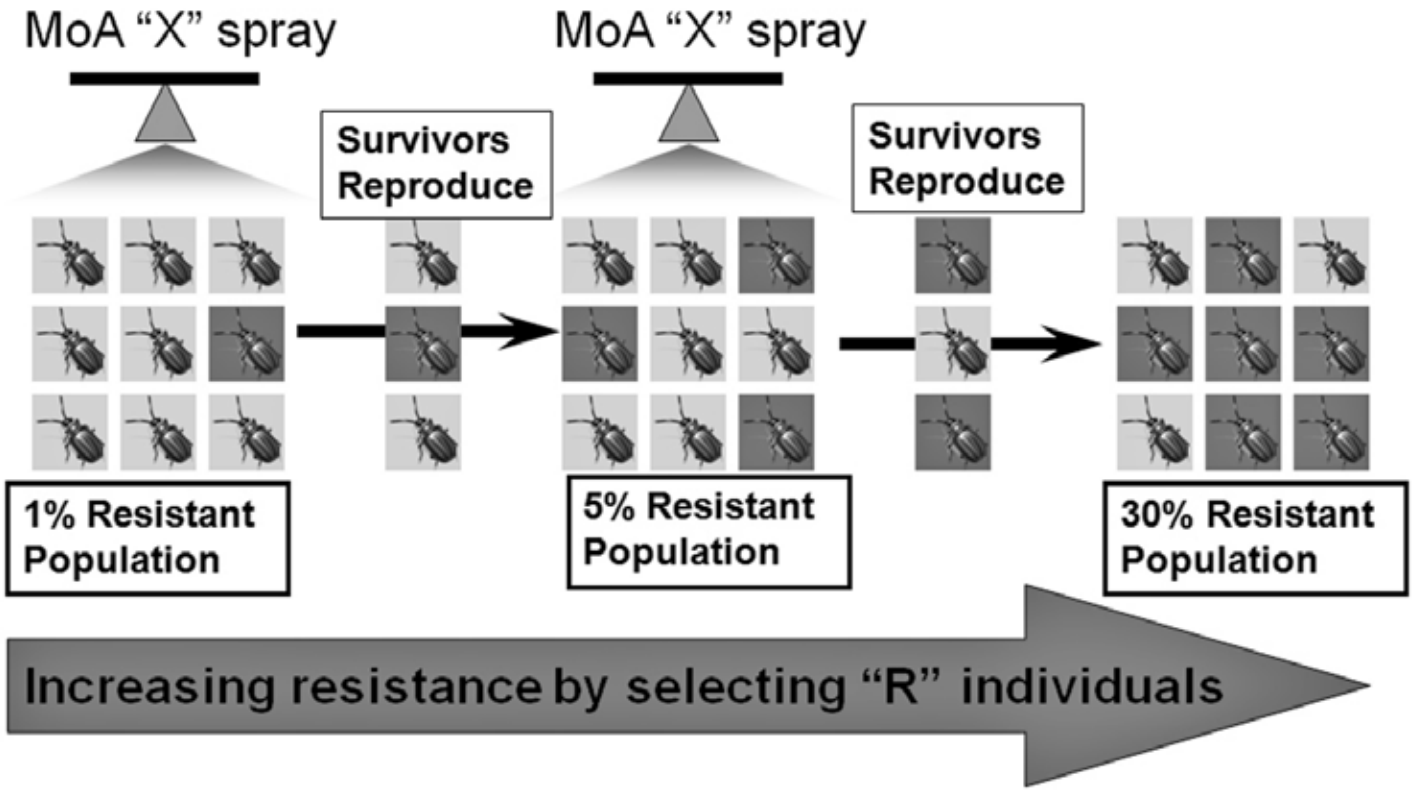
Third is INTENSITY OF USE.

Under this, we have:

- Over-dependence on a single mode of action.
- Number of applications per crop cycle and also per year.
- The rate used per application and interval between sprays.
- Different product brands from companies belonging to the same mode of action.
- Farmers not knowing much about the development of insecticide resistance.

Target Organism and product are factors that cannot be controlled at our end. However, the way we use these pest management products is where we can have the best opportunity to prevent --or delay -- the development of resistance!

How Resistance Develops in a Population



HOW RESISTANCE DEVELOPS IN A POPULATION

Insecticide Resistance develops when the susceptibility of the population to insecticide treatment changes from "generally susceptible" at the initial treatment of that chemical to a situation where many insects already survive the same rate and frequency of application using the same chemical or chemicals belonging to the same mode of action.

Every time the spraying of the same product is done, more resistant insects are selected to reproduce.

Under natural field conditions, a pest population is composed of several kinds of insects.

In terms of susceptibility to a particular pesticide, they can be grouped into three types:

- The SUSCEPTIBLE individuals which are usually killed by the optimum rate of the product.
- The MODERATELY RESISTANT which are killed like the susceptible insects but some survive when some conditions stated on the label of the pesticide are not followed, and
- The RESISTANT insects which will require the highest rate on the pesticide label to provide commercially acceptable control.

To illustrate how insecticide resistance development happens, the following scenario in the farmer's field has been created.

For purposes of simplification and easier understanding, only the Susceptible Insects and Resistant Insects are shown. Moderately resistant insects continue to coexist with these insects in the natural field situation.

Upon initial exposure to the treatment, the original population shows the mortality of all exposed susceptible and moderately susceptible insects and the survival of resistant insects.

Given the many factors that affect the performance of the insecticide in the field, let's say, 25% of the population survive. It is expected that ALL the resistant individuals survive while much less of the susceptible insects remain.

Since forces of nature continue to take place, insects that survive reproduce.

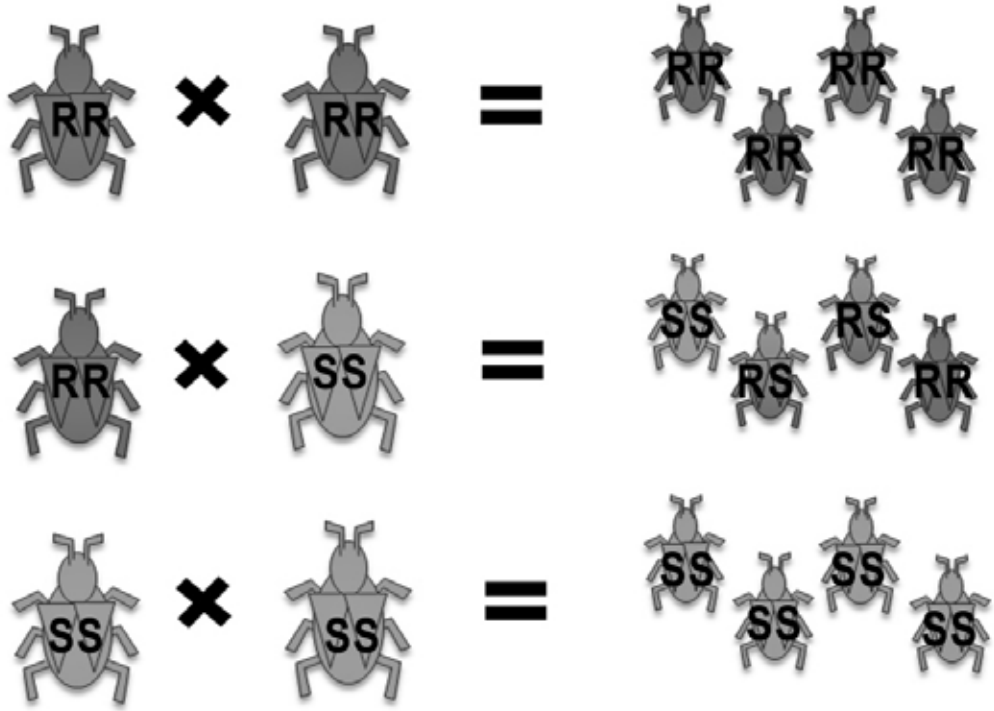
Assuming we only look at what happens to the Resistant and Susceptible insects that get involved in the population's reproductive process, the resulting offspring of the combinations will be as illustrated:

Resistant by Resistant will give all Resistant offspring

Resistant by Susceptible will give a mix of Resistant

Susceptible by Susceptible will give all Susceptible offspring

Remaining Insects Reproduce According to the following:



All Resistant (RR) offspring

Mix of Resistant (RR), Moderately Resistant (RS) and Susceptible (SS) offspring

All Susceptible (SS) offspring

Going back to the population resulting from the survivors of the first spraying done, we can expect more Resistant individuals compared to the first population treated.

In the second season spraying of the same insecticide, we can expect more Resistant individuals compared to the first and second season population treated.

During the third season spraying of the same insecticide, the selection - and retention-- of more Resistant individuals is encouraged every time the spraying of the same insecticide or products from the same mode of action is done.

The selection for Resistant insect continues even if rates are increased. Eventually, the farmer notices that the same insect pest population no longer dies. He then complains that the product he relied upon and was initially effective, has now been replaced with a non-effective --or substandard – product.

GENERAL INSECTICIDE RESISTANCE MANAGEMENT MANUAL

To manage the development of insecticide resistance, we have general guidelines to understand, remember and implement:

Principle #1 Practice Integrated Pest Management (IPM) principles.

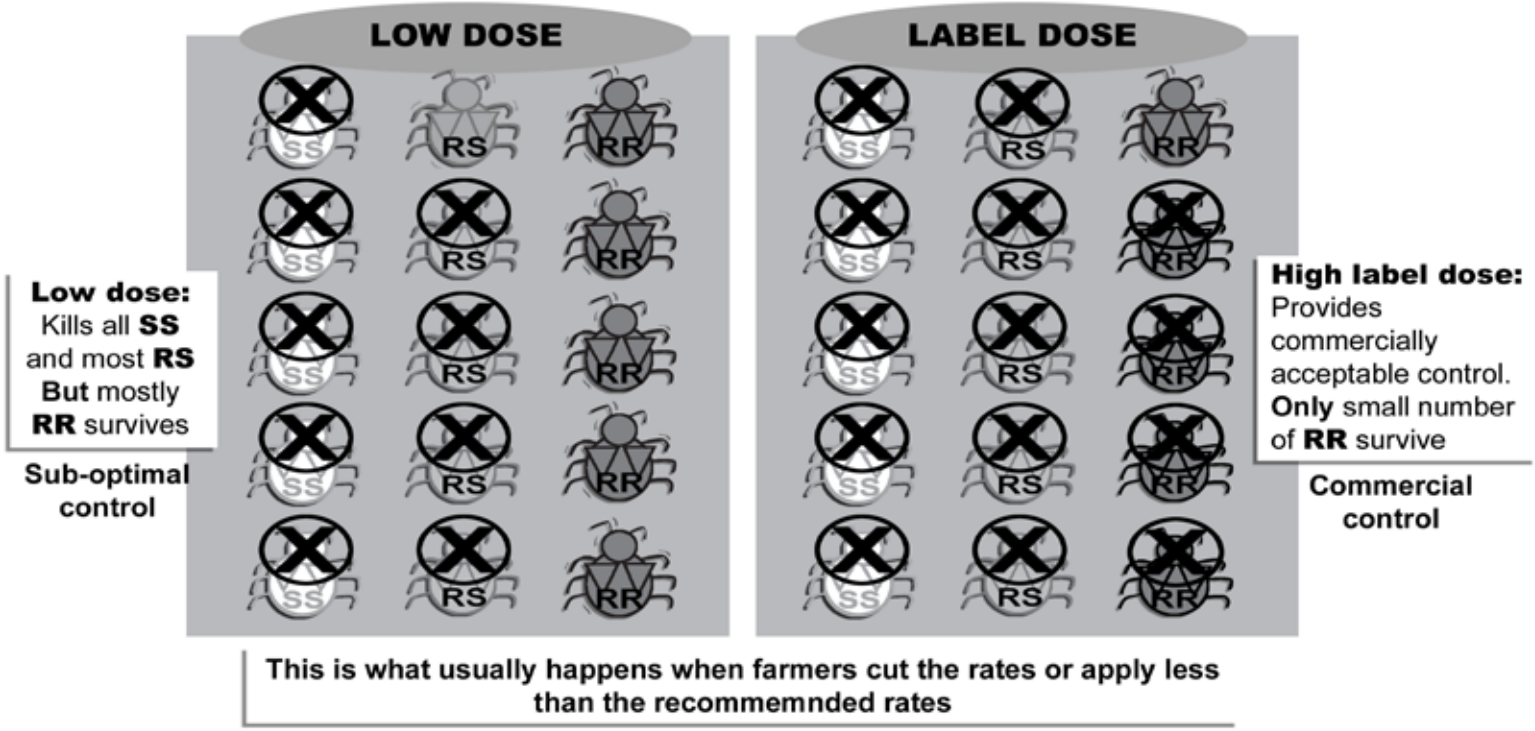
The farmer should:

- Keep in mind that prevention of pest outbreaks is still the best strategy and is done by incorporating appropriate pest control mechanisms even before planting.
- Select insecticides with care (as much as possible, it should not be harmful to beneficials).
- Seek advise from true experts such as trained extension workers and company representatives.
- Be familiar with the pests and monitor their population during the growing season, and
- Practice clean culture

Principle #2. Follow Label Recommendations.

In the farmer's field, the natural insect population has a mix of dominant and recessive genes that determine resistance. Depending on what constitutes the insect's genetic make-up, a pest will express different degrees of susceptibility to a particular chemical or product. An insect pest is either Susceptible (SS), Moderately Resistant (RS) or Resistant (RR).

Follow Label Recommendations

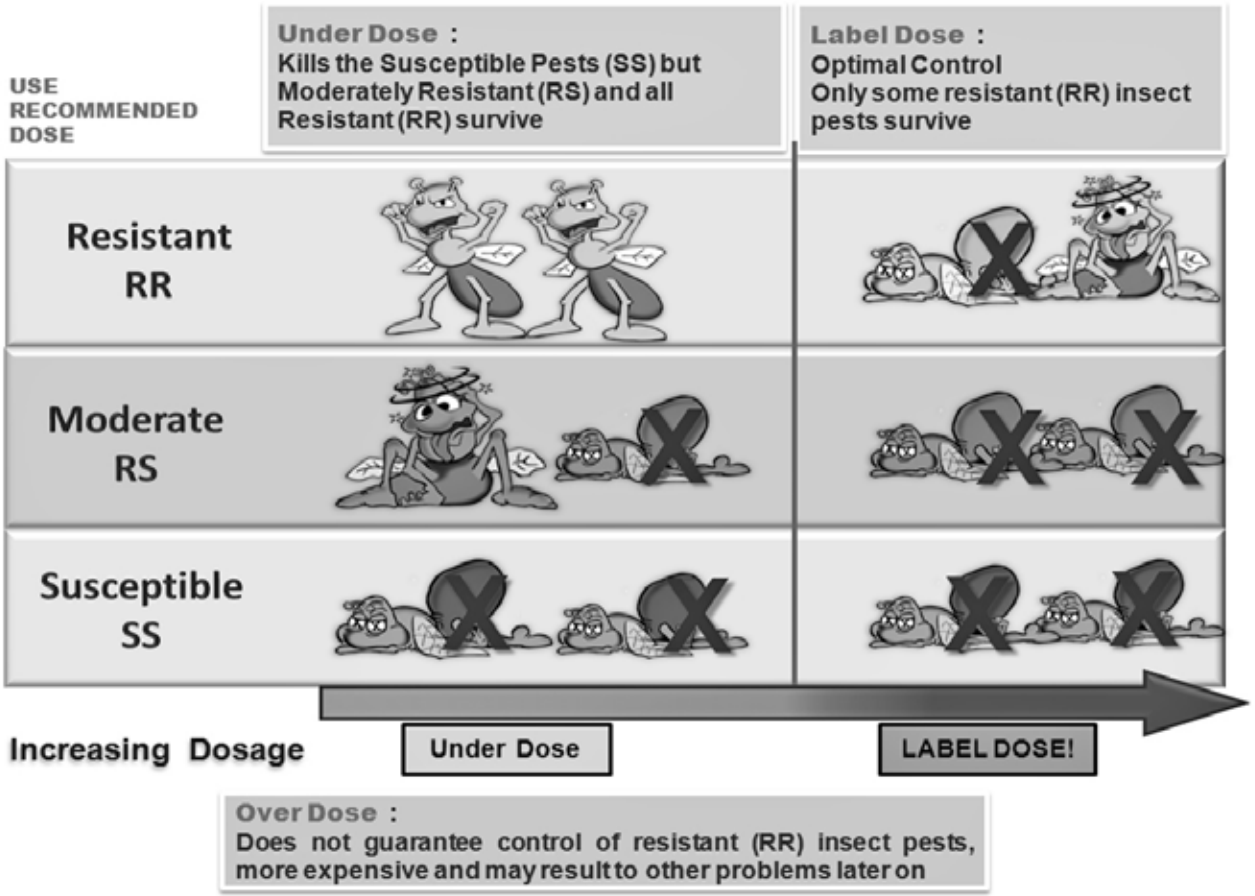


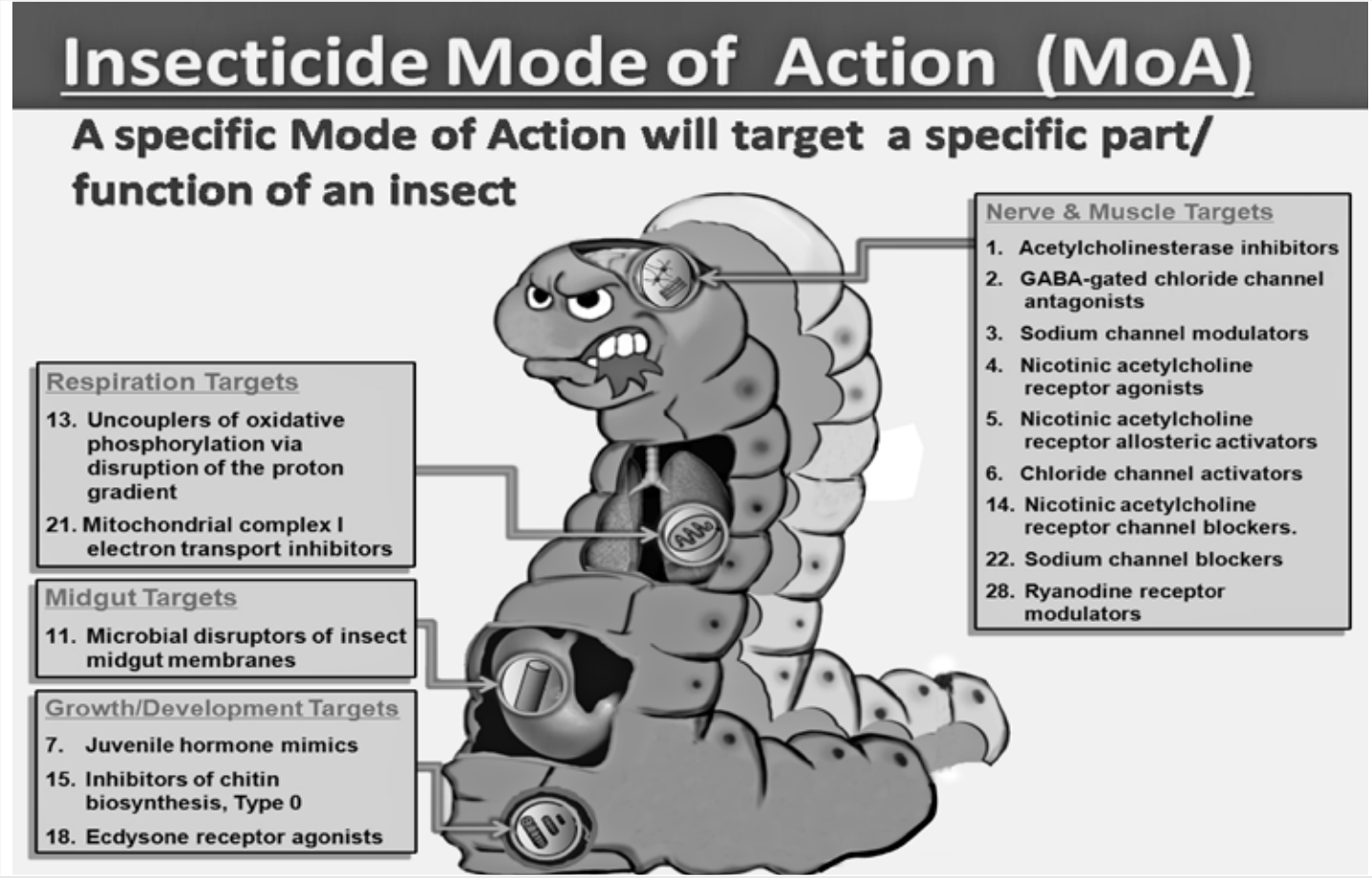
In development and registration of crop protection products, minimum and maximum rates that provide commercially acceptable control (some 70-90% control of the resistant population) are determined and placed as the optimum rate on the label as basis for judicious use by farmers.

There is a recommended rate placed on the label. However, some farmers tend to play with the rates depending on how they perceive the situation in the field to be.

Some apply UNDER DOSE when they see few insects, not knowing that this only kills the Susceptible and some of the Moderately Resistant insects, but ALL the resistant insects survive.

Applying the LABEL DOSE results to optimal control of most target insects with only some resistant insect pests surviving. But when insecticide resistance has developed and there is difficulty in controlling the pest, applying OVER DOSE does not guarantee control of the target insects. The pest control becomes more expensive and increasing the rate may result to other problems later on.


USE RECOMMENDED DOSE
Under Dose :
Kills the Susceptible Pests (SS) but Moderately Resistant (RS) and all Resistant (RR) survive
Label Dose :
Optimal Control
Only some resistant (RR) insect pests survive
Resistant
RR
Moderate
RS
Susceptible
SS
Increasing Dosage
Under Dose
LABEL DOSE!
Over Dose :
Does not guarantee control of resistant (RR) insect pests, more expensive and may result to other problems later on


Insecticide Mode of Action (MoA)
A specific Mode of Action will target a specific part/ function of an insect
Nerve & Muscle Targets
1. Acetylcholinesterase inhibitors
2. GABA-gated chloride channel antagonists
3. Sodium channel modulators
4. Nicotinic acetylcholine receptor agonists
5. Nicotinic acetylcholine receptor allosteric activators
6. Chloride channel activators
14. Nicotinic acetylcholine receptor channel blockers.
22. Sodium channel blockers
28. Ryanodine receptor modulators
Respiration Targets
13. Uncouplers of oxidative phosphorylation via disruption of the proton gradient
21. Mitochondrial complex I electron transport inhibitors
Midgut Targets
11. Microbial disruptors of insect midgut membranes
Growth/Development Targets
7. Juvenile hormone mimics
15. Inhibitors of chitin biosynthesis, Type 0
18. Ecdysone receptor agonists

Resistance Management Principle #3. Know the Product Mode of Action (MoA)

As of July 2017, the IRAC MoA Classification Version 8.3 contains 29 specific groups and 1 group of unclassified chemicals. But as far as Lepidopteran insect pests are concerned, the IRAC broadly clusters them under

- Nerve and Muscle Targets under which there are 9 MoA groups
- Respiration Targets under which there are 2 groups
- Midgut Targets with 1 group, and
- Growth/Development Targets with 3 groups

To show that alternating different active ingredients, the table of pesticides registered and commonly used vegetables in this table showed that there are several insecticide active ingredients that belong to the same Mode of Action Class.

For example, in the Pyrethroids, there are more than 150 brands currently being marketed all over the country. Imagine the difficulty for the farmers to check and follow this recommendation if there is no active information campaign and additional guides are given to help them like placing the MoA number of pesticide labels.

Knowing what MoA covers the specific product we have used, we can now look for other products that belong to other MoA for use as alternate product during the cropping season.

In the case of diamondbacked moth, for example, the MoAs that can be alternated are from the groups

5 , 11 , 13 , 22A and 28 . These products have FPA registration for the target pests.

A critical need in the effort to educate farmers on the management of insecticide resistance development is a farmer-friendly guide that can be recognized even by farmers who will have difficulty reading and understanding written letters.

Teaching them how to choose alternation partners by looking at MoA numbers on the label (which will hopefully be approved soon) will be a big help. Companies promoting the use of their products can help by providing technical brochures that list products or MoAs that can be used as alternates with their product.

What's in it for companies which have several products having different active ingredients but belong to the same MoA? Why should they promote alternation with products that belong to a different MoA from other companies?

There is such a thing called CROSS RESISTANCE.

This is because:

- Resistance at the insect's target site not only renders... share a common Mode of Action
- Resistance that results from insect metabolic processes may be cross resistant... (degree of cross-resistance may vary).

Thus, any type of insect resistance... making them LESS EFFECTIVE or ineffective as well.

Principle #4. Rotate by Insecticide MoA.

Now that we know that different products belong to different Modes of Action, what should we do then? We should use the understanding as basis for Rotating or Alternating different products during the cropping season.

Why alternate or rotate? The basic principle is that FREQUENCY OF GENES FOR RESISTANCE TO AN INSECTICIDE WILL DECLINE DURING THE APPLICATION OF ALTERNATIVE INSECTICIDE BELONGING TO DIFFERENT MODE OF ACTION.

This alternation prevents the selection for resistant individual thereby prolonging the effective longevity of the product.

In rotating insecticide modes of action, there are several principles that we need to follow in order for our resistance management efforts to succeed.

First, avoid the exclusive use of one MoA throughout a crop cycle for a pest species with multiple generations.

The second principle in rotating insecticide MoA is to Alternate “windows” or “Blocks” with different modes of Action.

This is where spray applications are arranged into MoA spray Windows of blocks.

What is an ACTIVE WINDOW?

It is approximately the duration of one generation of the target pest. This is about 25-40 days for most major pests. Thus, 30 days is a good average.

Considering that the duration of the residual activity provided by a single or sequence of applications possibly exceeds this length of time, it is best to switch to the next block of insecticide MoAs to control the insects that survive the previous treatment window.

After forming spray "windows" or "blocks", the third principle of Rotating MoAs is to practice the Rotation of "Active" and Alternative MoA "windows" or "Blocks".

In situations where the crop cycle period is more than 50 days and one generation of the target insect is 30 days, ROTATING or ALTERNATING MoA WINDOWS or BLOCKS is one of the better ways of managing insecticide resistance development.

In cases where residual activity provided by a SINGLE application is longer than a single generation of the target pest, the product should be restricted to a single application.

In situations where the crop cycle period is more than 50 days and the target insect generation is 30 days, we need to use "Treatment Windows" and rotate with different Insecticide Mode of Action (MOA) groups to minimize exposure of successive pest generations to the same MOA.

(4) Rotate by Insecticide MoA

(4.c) General Example: Rotation of "Active" and Alternative MoA "Windows" or "Blocks"			
Crop Cycle Period > 50 days and an insect generation is 30 days			
Active Window of a Single MoA (30 days)	Alternative MoA Window (30 days)	Active Window of a Single MoA (30 days)	Alternative MoA Window (30 days)
Single or Sequential application of MOA (Group A)	Single or Sequential application (s) of MoA (Group B)	Single or Sequential application (s) of MoA (Group A)	Single or Sequential application (s) of MoA (Group B)

Note. If residual activity provided by a single application is longer than a single generation of the target pest, restrict use to a single application.

In case of repeated cultivation of short cycle crops (less than 50 days) do not treat consecutive crops at the same farm location, but alternate with different mode of actions.

As another principle, consider the duration of the crop cycle as a "treatment window".

- Maintaining insect susceptibility greatly depends on rotation of insecticides with effective products from a different MOA that eliminate resistant individuals.
- Rotation with products that provide poor or no control of the target pest increases the risk of developing resistance to that particular insecticide.
- Positioning schemes and how they impact insecticide resistance development are as follows:
- Scheme 1 No Alternation/Rotation where no rotation of products belonging to different MoA is used across cropping seasons and years of farming. Here, selection pressure is high and the population of the susceptible does not recover in number.
- Scheme 2 Rotation within generation alternates two MoAs within the same generation across crop seasons. Since consecutive generations of the target pest are exposed to the same MoAs, selection pressure doesn't change between generations. The drawback is that there is risk of resistance development for both AIs.

(4) Rotate by Insecticide MoA

General Product Positioning Guidelines

IRM guidelines below show least to best product rotaton recommendations

1

Year 1		Year 2		Year 3		Year 4	
1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen
MoA1	MoA1	MoA1	MoA1	MoA1	MoA1	MoA1	MoA1

No alternation/rotation

High selection pressure

No recovery of sensitive population.

2

Year 1		Year 2		Year 3		Year 4	
1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen
MoA1 MoA2	MoA1 MoA2	MoA1 MoA2	MoA1 MoA2	MoA1 MoA2	MoA1 MoA2	MoA1 MoA2	MoA1 MoA2

Rotation within generation

Consecutive generations exposed to same MoA. Selection pressure doesn't change between generations. Risk of resistance development for both ai's

3

Year 1		Year 2		Year 3		Year 4	
1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen
MoA1	MoA2	MoA1	MoA2	MoA1	MoA2	MoA1	MoA2

Rotation among generations

Following generations are not exposed to same MoA. Selection pressure doesn't increase within the generation. Recovery of susceptible population.

4

Year 1		Year 2		Year 3		Year 4	
1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen	1st Gen	2nd Gen
MoA1MoA2	MoA3 MoA4	MoA1MoA2	MoA3 MoA4	MoA1MoA2	MoA3 MoA4	MoA1MoA2	MoA3 MoA4

Rotation within and between

Ideal situation (very low risk) Not alway applicable with good efficacy.

- Scheme 3 Rotation among generations does not expose the succeeding generations to the same MoA. Hence, the selection pressure within each generation does not increase. Also, the population susceptible to the previous MoA is allowed to recover.
- Scheme 4 Rotation within and between generations and across seasons is the ideal situation because of the very low risk of insecticide resistance development. However, it is not always applicable with good efficacy.

Since the farmer will need to rotate MoA in the best way possible given his own situation, it is also better to do it on a bigger scale or area from field to area-wide pest management.

This can be done by synchronizing area-wide spray programs to minimize the movement of resistant individuals and maximize the advantage of rotating products with different MoA.

It should be noted, however, that spraying only small strips or portions of a farm results in a mosaic pattern of pest exposure that dilutes the advantage of rotating MoA.

It is emphasized that it is ideal to rotate as large an area as possible according to the MoA rotation strategy.

ACKNOWLEDGEMENT

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