CUGE®

CENTRE FOR URBAN GREENERY AND ECOLOGY

LEARNER GUIDE

Plant Health Management and Disease Control (Level 2)

LNS-GNM-2014-1.1

Version	Effective Date	Changes	Author
1.0	19 March 2021	Curriculum Development	August Training and Consultancy Services
1.1	16 June 2021	Corrected plant names on pages 23 and 24	CUGE

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Course Overview

Code:	LNS-GNM-2014-1.1
Name:	Plant Health Management and Disease Control (Level 2)
Duration:	18 hours, inclusive of 2 hours of assessment

WSQ Framework

Landscape

Technical Skills and Competencies (TSC)

Plant Health Management and Disease Control

TSC Proficiency Description

Level 2

LNS-GNM-2014-1.1
Identify plant health requirements and concerns and execute steps to remediate them

Learning Outcomes

On successful completion of this unit, the participant will be able to:

1. Identify and report the presence of pest infestations and diseases
2. Identify invasive and noxious plant species
3. Identify nutrient deficiencies in plants
4. Prune infested and diseased parts of plants
5. Apply chemicals to control the growth and spread of pests, diseases and invasive species
6. Manage hazards and risks associated with plant health management

Teaching Methodologies

- Lecture
- Discussion
- Demonstration
- Practical
- Feedback

Assessment Methodologies

- Practical Exam (90 minutes)
- Oral Questioning (30 minutes)

Learning Outcome 1: Identify and Report the Presence of Pest Infestations and Diseases

Pest Infestations

Pest infestation is the presence of a large number of pests in a place, causing diseases or damages to plants. These pests will impact the plant's health in different ways, such as causing yellowing or chewed leaves, which eventually will weaken the plant and cause death.

Pests are commonly classified into two broad categories:

1. Sucking pests
2. Chewing pests

Sucking Pests

Sucking pests suck on sap and feed on plant nutrients, resulting in damages such as distorted and yellowing leaves.

<table>
<tr><th colspan="2">Common Sucking Pests</th></tr>
<tr><td>Mealybugs

<u>Characteristics</u>
• Favour new growth
• Found on the undersides of leaves or around young stems
• Attach themselves to the plant
• Secrete a powdery layer which is used for protection

<u>Impact</u>
• Cause leaves to yellow and eventually drop from the plant.</td><td> 
Fig. 1
Mealybugs
 
Secrete a powdery layer which is used for protection</td></tr>
</table>

Scale Insects

<u>Characteristics</u>

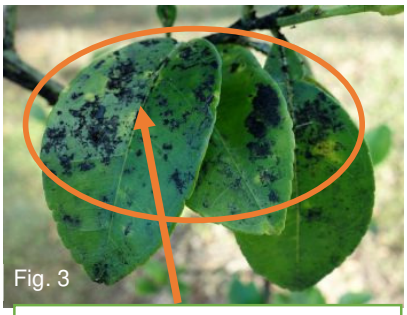
- Favour new growth
- Found on the undersides of leaves or around young stems
- Attach themselves to the plant
- Secrete a waxy covering that is smooth and shiny
- Resemble fish scales
- Can be from 1mm to 10mm in diameter and in any colour or shape

<u>Impacts</u>

- Cause leaves to yellow and eventually drop from the plant
- Excrete large amounts of honeydew, which encourages the growth of sooty mold (black-coloured fungus)

Scale Insects

Attach themselves to the plant



Black sooty mold, a black-coloured fungus

Aphids

Characteristics

- Soft, usually green insects
- Have long feelers that jab and suck nutrients from plants
- Commonly associated with the transmission of plant viruses

Impacts

Cause damages such as:

- Reduced strength
- Stunted growth
- Mottled or yellowing leaves
- Curled and wilting leaves

Aphids

Aphids attack stems of plant

Mottled or yellowing leaves

Thrips

Characteristics

- Smallest sucking insect that can be seen by the human eyes
- Have tails that point up, like a scorpion
- Feed on both leaves and flowers, puncturing the plants' cell

Impact

- Cause twisted and distorted leaves
- Puncture leaves and veins

Thrip

Feed on flower bud

Feed on leaves, puncturing the plants' cell

Whiteflies

Characteristics

- Look like small white flies with prominent wings
- Prefer to feed on new growth
- Found on the undersides of leaves, especially near the veins and are sticky to the touch
- When the plants where whiteflies are feeding are disturbed, the whiteflies will fly off in a swarm, making them easy to spot
- Cause damage by toxic saliva produced during feeding and can transmit virus

Impact

- Cause leaves to yellow, shrivel, and drop prematurely

Whiteflies

Feed on new growth, especially the veins

Mites

Characteristics

- Often referred to as spider-mites
- Too small to be seen by the eyes, usually identified by their symptoms
- Spin a silky webbing to protect the colony from predators
- Webbing is usually found on the underside of leaves

Impact

- Scattered yellowish-silvery blotchy areas on the tip and top surface of the leaf
- Cause leaves to yellow, shrivel, and drop prematurely

Spider-mites

Spin a silky webbing to protect from predators

Chewing Pests

Chewing pests chew and make holes in leaves, stems, branches, and trunks, resulting in the wilting of leaf tissue and weakening of the plant's health.

Common Chewing Pests	
Beetles <u>Characteristics</u> • Largest group of insects and the least frequently seen as most of their feeding is done at night • Identified by their front wings, which cover the second pair of wings used for flying • "Skeletonised" leaves, leaving only the leaf veins <u>Impacts</u> • Leaf tissue between veins is chewed, giving rise to lace-like appearance of leaves • Wilted leaves or stunted plants growth	 Fig. 9 Leaf damaged by Japanese Beetles  Rhinoceros Beetle  Palm damaged by Rhinoceros Beetle

Grasshoppers

Characteristics

- Feed during the day and therefore seen frequently
- Chew on grasses, leaves, and stems of plants

Impacts

- Cause ragged and chewed holes in leaves and stems

Grasshopper

Rough holes edges marked with bite and chew marks

Caterpillars

Characteristics

- Caterpillars are the larvae of butterflies and moths
- Hide in rolled leaves and can be difficult to see or manage, however their droppings on leaves and the ground below the damaged leaves are signs of the presence of caterpillars

Impacts

- Cause chewed holes on leaves, flowers, shoots, fruits and other parts of plants

Caterpillars

Hide in rolled leaves

Caterpillars and their droppings on damaged leaves

Bagworm

Characteristics

- Bagworms are the larval or caterpillar stages of moths
- Identified by the cone-shaped bag they spin from bits of host plants and other debris
- Feed on many plant species but are common on conifers such as juniper and pine

Impact

- Large populations of bagworms can strip plants of their leaves and eventually cause the plants to die

Cone-shaped bag Bagworm

Damages by Bagworm

Snails and Slugs

Characteristics

- Feed by scraping with their rasp-like tongue on a variety of living plants and on decaying plant matter
- Most active at night; hide in the day, out of heat and bright light
- Signs of their presence are their silvery trails and plant damage

Impact

- Create irregular holes with smooth edges on leaves and flowers

Leaves damaged by snails

Leaves damaged by slugs

Leaf Miners

Characteristics

- Black or grey flies with yellow stripes and translucent wings feed under surface of leaves
- The larvae create clear winding tunnels in leaves by mining through the inside of leaves, leaving a rambling track

Impact

- Cause loss of healthy leaf tissues, so the plant can't capture enough sunlight and often becomes infected with disease

Leaf Miner

Clear winding tunnels in leaves

Plant Diseases

Plant diseases are caused by plant pathogens, namely:

1. Fungus
2. Bacteria
3. Viruses

The symptoms of plant diseases may include visible changes in colour, shape and abnormal plant growth.

Plant Diseases	
Fungus	
Leaf Spots Characteristics • The fungi can be found on dead leaves or twigs on the ground or soil; the spores can be blown onto other plants • Spots vary in size and shape • Usually brown, black, tan, or reddish in colour. Some may have a darker red or black border • As the fungi spread, these spots can deform and merge to become a larger patch Impact • Destroy leaf tissue once the fungus enters the leaves and plant becomes unable to produce food from these diseased leaves • Leaf spots can spread quickly and cause the plant to wilt or die, especially in new and less-established plants	 Leaf Spots  Spots merge to become a larger patch  Fig. 12 Spread quickly, especially in new and less-established plants

Rust

Characteristics

- Easily identified by small spots found on the underside of leaves
- Usually bright orange, becoming black with age
- Upper leaf surface will develop yellow patches and lower leaf surface, small yellow-reddish pustules

Impact

- Causes spots and blisters on leaves
- May cause cankers and galls on branches and the main stem

Rust

Gall on plant

Spots and blisters on leaves

Powdery Mildew

Characteristics

- Easiest to recognise
- White fluffy cotton-strands on both the upper and lower leaf surfaces which can cover the whole leaf
- Tends to affect plants in shady areas more than those under direct sun

Impact

- Leaf discolouration
- Cause plant to show early signs of aging, and leaf falling
- Reduce the quality and quantity of flowers and fruits

Powdery Mildew

Small white spots; powdery mildew first appears on the upper part of leaves

Soft Rot

Characteristics

- Caused by pathogens that produce substances that destroy the texture of plant tissue, resulting in the plant tissue becoming soft and watery
- Symptoms of soft rot include soft, wet, rotted, tan or cream-coloured leaves
- Rotting tissue develops a bad smell

Impact

- Degrade plant cell, eventually cause plant structure to fall apart
- Stem and leaves will eventually die off
- Rotten plants will tend to attract flies and ants as they feed on these rotten parts

Soft rot on a snake plant

Rotting leaves

Leaf base and bulb rot

Sooty Mold

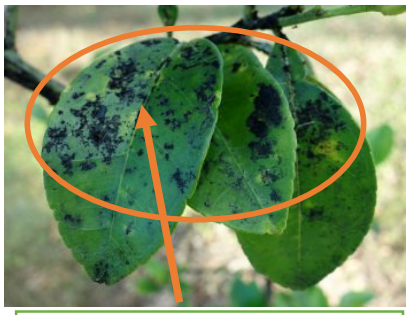
Characteristics

- Grow from the secretion of honeydew produced by aphids, whiteflies or mealybugs
- Plant's twigs, branches or leaves will be covered in a dirty, black soot

Impact

- Cause indirect damage by reducing photosynthesis leaf surface area
- In some severe cases, cause stunted growth or early leaf drop

Sooty Mold



Black sooty mold, a black-coloured fungus

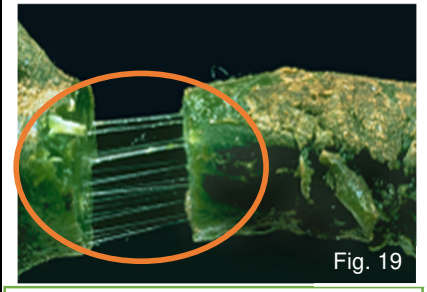
Bacteria

Characteristics

- Can multiply fast hence a plant can die quickly from a bacterial infection
- Enters plants through an opening, usually from insect damage
- Infections tend to show watery symptoms; when an infected plant part is cut, slimy bacterial will ooze out and produce a foul smell

Impact

- Once it penetrates into the plant, bacteria restrict the plant's ability to access water and nutrients. Left untreated, the plant will die.



Bacterial slime flows out from stem

Bacterial infection on an orchid plant

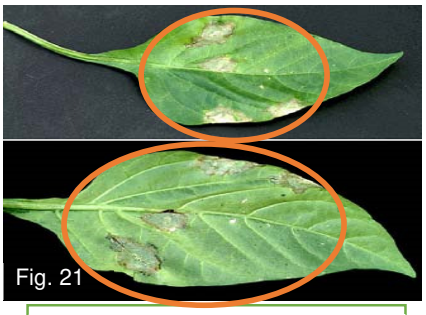
Viruses

Characteristics

- Viruses are parasites, they require a living host in order to grow and multiply
- Spread by the movement of sap infected by viruses, that can be picked up from tools such as secateurs or by sap sucking insects like aphids
- Infected leaves display different patterns (like mosaic or ringspot) of light green and dark green

Impact

- Cause leaf infections, resulting in wilted leaves



Harmful spots virus on leaves

Mosaic mottling symptom in an infected leaf

It is important to check plants regularly for pests and disease infections to take mitigation actions and precautions to prevent future occurrences.

Reporting Pests and Diseases

If pests or disease infections were observed during inspection, the plant health disorders must be reported to an appropriate person for further instructions.

The disorder can be reported using photographs and the following information should be provided:

1. Location of plants - provide landmarks, park or road name.
2. Plant's name - if you do not know the species, take photos of the leaves, flowers and fruits to help in the identification.
3. Plant disorders/abnormalities - zoom in on the signs of disorders or visible pests.
4. Surroundings - observe the area around that plants that could have caused its health problems.

Some pests or diseases are not easily identified using photographs. In such cases, a live specimen of the pest or affected diseased plant should be collected in a sample bag to show your supervisor. Further expertise may be required for testing at a diagnostic laboratory. This is to ensure the correct identification of the pest/disease so that a suitable treatment can be prescribed.

Learning Activity 1

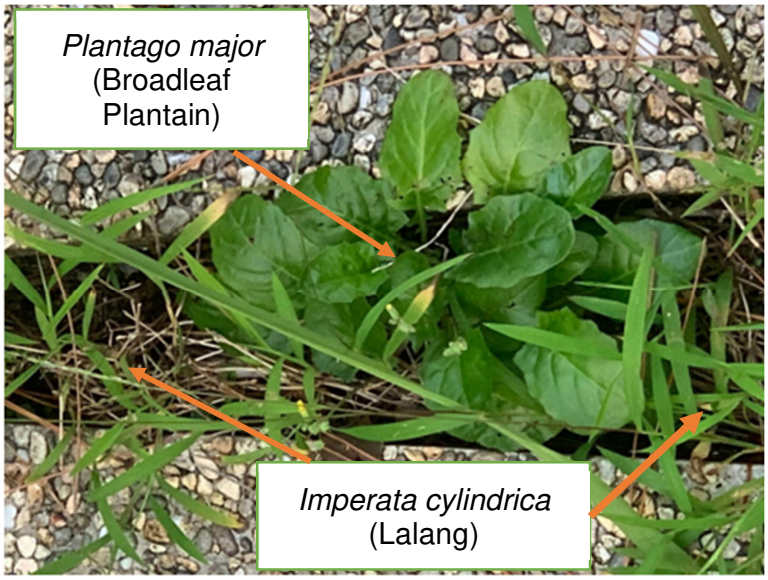
Form groups of 2 - 3. Conduct an inspection at the worksite to identify pests and diseases using this Plant Inspection Checklist. Report your group's findings to the trainer.

Plant Inspection Checklist			
Name of team members:		Location:	Date:
S/N	Item	Observation	
1	Identify the affected plant • Species of plant • Size and height of plant If you do not know the species, take photos of the leaves, flowers and fruits to help in the identification.		
2	What are the observed abnormalities? (Refer to Pages 2 to 18) E.g. what are your observations of the leaves in terms of • colour, size and thickness • shape i.e. twisted or curled? • evidence of pest feeding		
3	What are the possible pests or diseases that might have caused the abnormalities you had observed?		

Learning Outcome 2: Identify Invasive and Noxious Plant Species

Invasive and Noxious Plant Species

Invasive and noxious plant species, commonly referred to as weeds, are unwanted and harmful plants that compete for nutrients and water with other plants.



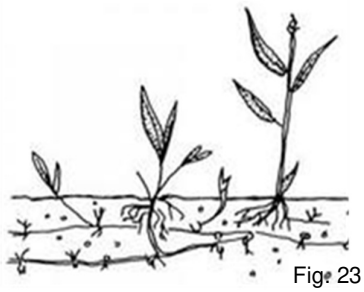
Invasive and Noxious Plant Species

Characteristics of Invasive and Noxious Plant Species

Weeds have the following distinct characteristics:

- Tend to grow fast under harsh environment
- Extensive roots system that spread above or underground
- Fight for growth space and nutrient from surrounding plants

Common Invasive and Noxious Plant Species

Invasive and Noxious Plants	Spread Method
 *Mimosa pudica* (Touch-me-not or Shame Plant)	 Fig. 23 Rhizomes
 *Imperata cylindrica* (Lalang)	
 *Paspalum conjugatum* (Buffalo Grass)	

Plantago major
(Broadleaf Plantain)

Tridax procumbens
(Coat Button)

Euphorbia hirta
(Hairy Spurge, Snake Weed)

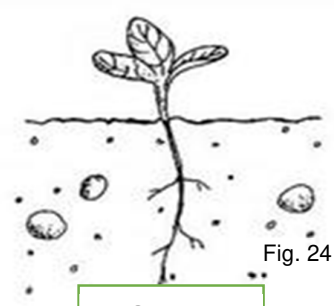


Fig. 24

Seeds

Cyperus javanicus
(Javanese Flatsedge)

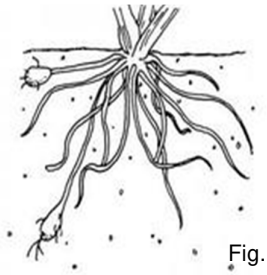


Fig. 25

Tubers

Chrysopogon aciculatus
(Love Grass)

Fig. 26

Stolons

Remediation Measures

The best remediation method is prevention and early identification and elimination of weed species. Once invasive weeds are identified, it is important to ensure that they do not spread to other areas.

There are four main weed control methods:

1. Prevention
2. Cultural
3. Mechanical/Physical
4. Chemical

The extent of the spread of invasive species will determine the remediation method. Small affected areas can be overcome by manual weeding or pruning, whereas larger areas may require the use of chemical and machineries.

Prevention Control

The prevention control method is aimed at not allowing weeds to become established.

- Do not spread fertilisers or dried grass contaminated with weed seeds on amenity grass.
- Clean machinery to avoid the transportation of weed seed, rhizomes, tubers, and roots.
- If “new” or unfamiliar weed appear, have them identified quickly and take appropriate control measures if necessary.
- Kill “new” weeds that appear.

Cultural Control

- Use ground covers or canopies to shade out weed species.
- Include re-planting, irrigating, or fertilising to encourage the establishment of a healthy ground to control invasive plants.

Mechanical/Physical Control

- Mulching – prevents the germination of weed seeds
- Weeding – manual removal of weeds
- Mowing – mow turf to cut off the weeds' reproductive structures and/or reduce food storage and nutrients supply
- Tillage – disrupt vegetative and seed reproduction
- Rotary hoeing – kill emerged weeds

Fig. 27

Use mulch as a natural weed barrier to prevent weeds seeds from germinating.

Mowing turf

Chemical Control

Herbicides are used to cut-off or kill weeds. It is important to use the correct herbicides at the correct application rate and application timing.

The use of pesticides, which include herbicides, in the cultivation of plants must be supervised by a pesticide operator certified by the Director-General under the Control of Plants Act.

Fig.: 28

Use of herbicide to cut-off or kill weeds

Learning Activity 2

Form groups of 2-3 at the worksite to:

1. Identify two types of weeds
2. Suggest the appropriate remediation measures based on the extent of spread

Learning Outcome 3: Identify Nutrient Deficiencies in Plants

Nutrient Deficiencies in Plants

Nutrient deficiency happens when a plant does not have the necessary nutrients required to grow. Plants lacking in nutrients will not grow well and will show different signs to indicate the deficiencies.

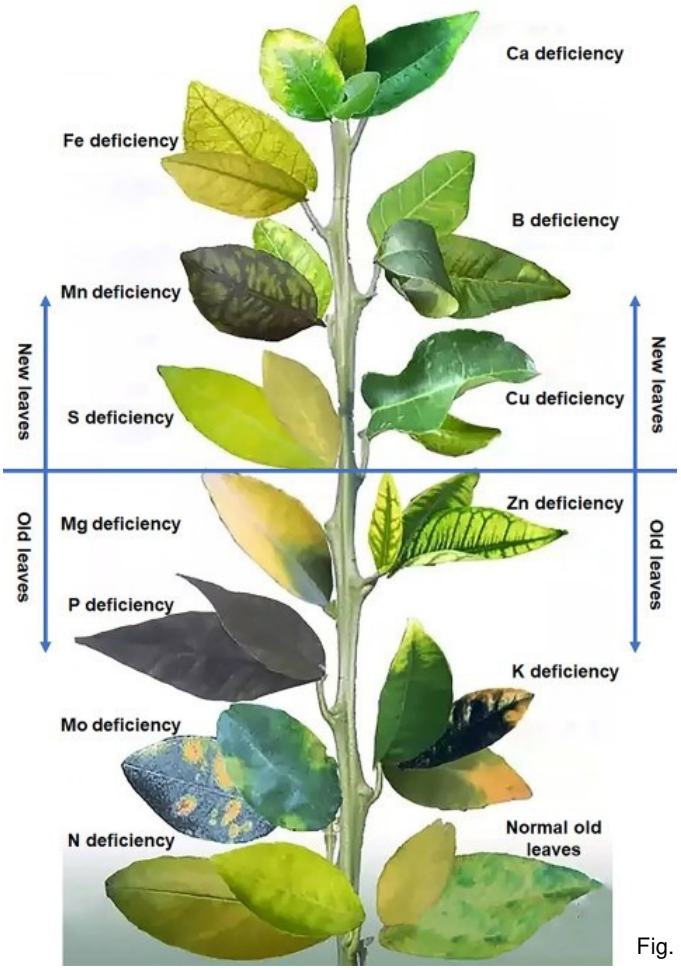


Fig. 29

Plant Nutrient Deficiencies

Essential Nutrients

Plants require the following essential nutrients for healthy growth:

Macronutrients Plants require a relatively large amount of these	**Micronutrients** Plants require minimum quantities of these
Nitrogen (N)	Boron (B)
Potassium (K)	Copper (Cu)
Phosphorus (P)	Iron (Fe)
Calcium (Ca)	Manganese (Mn)
Sulphur (S)	Molybdenum (Mo)
Magnesium (Mg)	Zinc (Zn)

All these nutrients are taken in through the roots. Water is the transportation media for nutrients from the soil to the plant roots, hence water is very important for plant nutrition.

Signs of Nutrient Deficiencies

The signs of common nutrient deficiencies in plants are:

Nutrient	**Signs of Deficiency**
Nitrogen (N) For vegetative growth and production of lush foliage	• Leaves turn yellow • The plant has poor or stunted growth  Fig. 30 Nitrogen Deficiency

Phosphorus (P) • For stronger roots • Promotes flowering • Increases stem strength	Purple or bronze discolouration in the upper and lower sides of older leaves.  Fig. 31 Phosphorus Deficiency
Potassium (K) • For larger fruit growth • Increase resistance to diseases	Browning or yellowing on leaf edges of newly matured leaves.  Fig. 32 Potassium Deficiency
Magnesium (Mg) Helps plant absorb sunlight for photosynthesis	Older leaves yellowing or whitening between their leaf veins (pale leaves with dark green veins).  Fig.33 Magnesium Deficiency

Types of Fertilisers

Fertilisers are added to plants to:

- Increase the amount of nutrients in the soil
- Help counter soil fertility problems
- Enhance plant growth

There are two broad types of fertilisers:

Organic Fertilisers

Organic fertilisers are made from decaying plants or animal matter. They release nutrients as they break down, improving the condition of the soil and its ability to hold water and nutrients. Given time, they make soil and plants healthier and hardier. Organic fertilisers are renewable and biodegradable, therefore, sustainable and environmentally friendly.

Compost

Bone meal

Seaweed

Chicken manure

Blood meal

Soybean meal

Inorganic Fertilisers

Inorganic fertilisers are manufactured artificially from minerals or synthetic chemicals. They provide fast and exact doses of nutrients to meet the specific needs of plants.

Urea

Magnesium Sulphate

Super Phosphate

Potassium Chloride

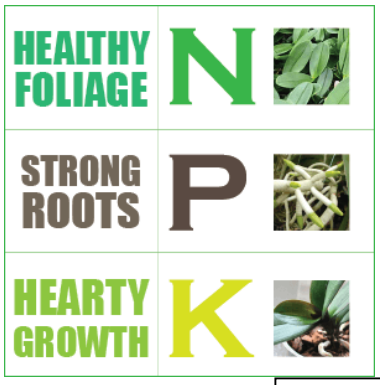


Fig. 34

- **N – Nitrogen -** for better growth of leaves
- **P – Phosphorous** - for strong roots
- **K – Potassium** - for healthy growth, flowers and fruits

N.P.K.'s Usage

15 parts **N** - Nitrogen
15 parts **P** – Phosphorus
15 parts **K** - Potassium

Granule N.P.K.

Fig. 35

Liquid N.P.K.

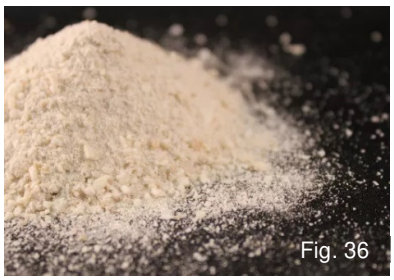


Fig. 36

Powder N.P.K.

Learning Activity 3

At the worksite, form groups of 2 - 3 to:

1. Identify two plants with nutrient deficiencies
2. Suggest the type of fertilisers that would be appropriate to feed the unhealthy plants

Learning Outcome 4: Prune Infested and Diseased Parts of Plants

Incorporating Learning Outcome 6: Manage Hazards and Risks associated with Plant Health Management

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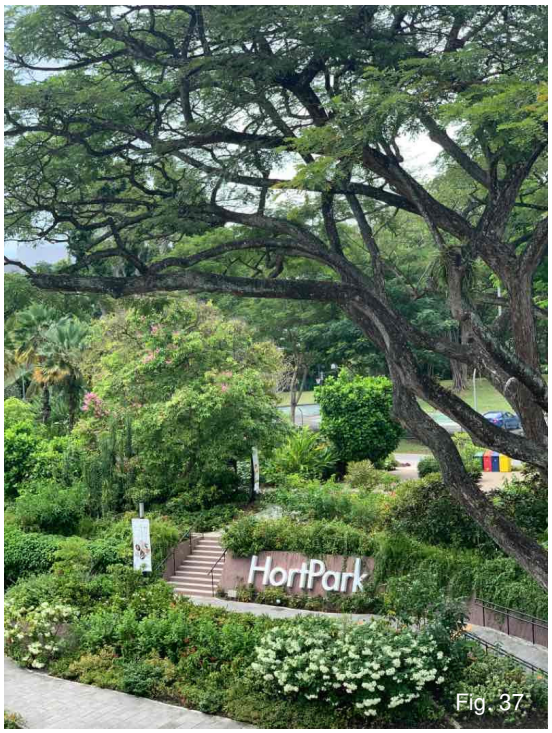
Plant Spacing

It is important to provide enough spacing between plants for the plants to spread out and grow healthily.

Plants should be spaced:

- According to their expected width at maturity
- To allow for the plant to develop a well-established root system
- To allow for the plant to receive enough sunlight and not by shaded by other plants that are too close

The preferred spacing is usually a range, such as 15 - 30 cm apart for small-sized shrubs, 30 – 45 cm for medium-sized shrubs.



Healthy plant growth at HortPark

Prune Plants to Remove Infested and Diseased Parts

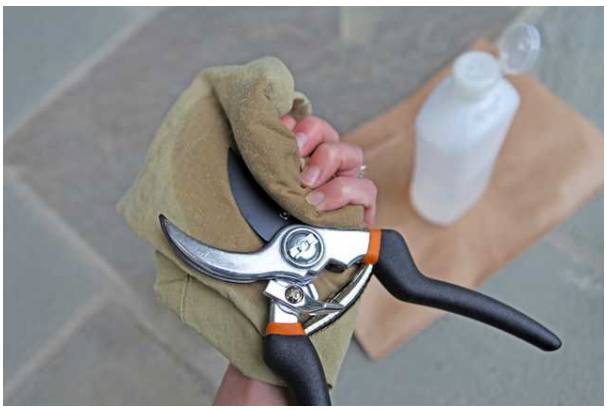
This course will cover the pruning techniques to remove diseased and infested parts of shrubs.

Tools and Equipment required for Pruning

Types of Pruning Tools and their Functions	
Secateurs For pruning small branches and stems of up to 2cm thick	
Lopper Strong secateurs with long handles to cut thicker branches of up to about 4cm in diameter	

It is important to choose good quality pruning tools and to keep them in good condition by:

- Keep pruning tools sharp by sharpening them at least at least once a year.
- Clean and oil tools after use to keep them free from rust.
- Disinfect tools using alcohol after use on diseased plants.
- Store your tools in a dry and protected area, preferably by hanging them on a wall.



Disinfect tool using alcohol

Personal Protective Equipment (PPE) for Pruning

Head Protection – Safety Helmet
Protect the head from falling branches when working in area with trees.

Eye Protection – Safety Glasses
Protect the eyes from flying branches/clippings when pruning.

Body Protection – Safety Reflective Vest
Increase visibility when working near roadside or in places with human traffic.

Hand Protection – Cotton Gloves
Protect the hands from cuts by plants, tools and equipment when pruning.

Foot Protection – Safety Boots with steel toe caps
Protect the feet from injury caused by dropping tools and equipment.

Set up a Safe Work Zone

Before commencing work, check that the worksite is cleared of obstacles, obstructions and hazards, which may include:

- Poor accessibility or physical obstructions blocking access to the plant.
- Too close to the public pathway which may cause danger to public onlookers or result in disturbance by onlookers.
- Presence of dangerous insects' hives or nests (e.g. beehive, ant nest) or animal (e.g. snake hiding in the shrub/hedges). If so,
  - Inform your supervisor
  - Do not disturb the dangerous animal or insect
  - Move away from the worksite

After you have finished checking the worksite, place barricades around it to prevent members of the public from entering. Put up safety and warning signages to warn the public to stay away from the worksite.

Red-White Tape

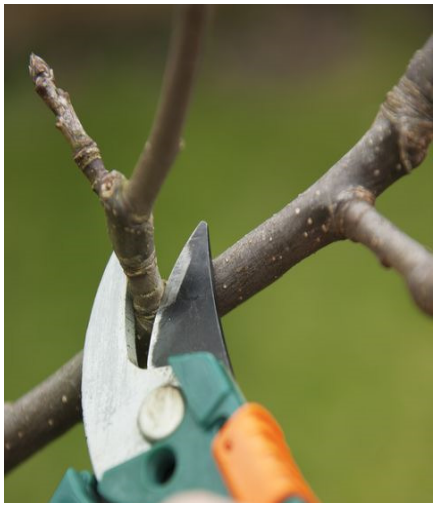
Safety Cone

Warning Signages

Perform Pruning to Remove Diseased and Infested Parts of Plants

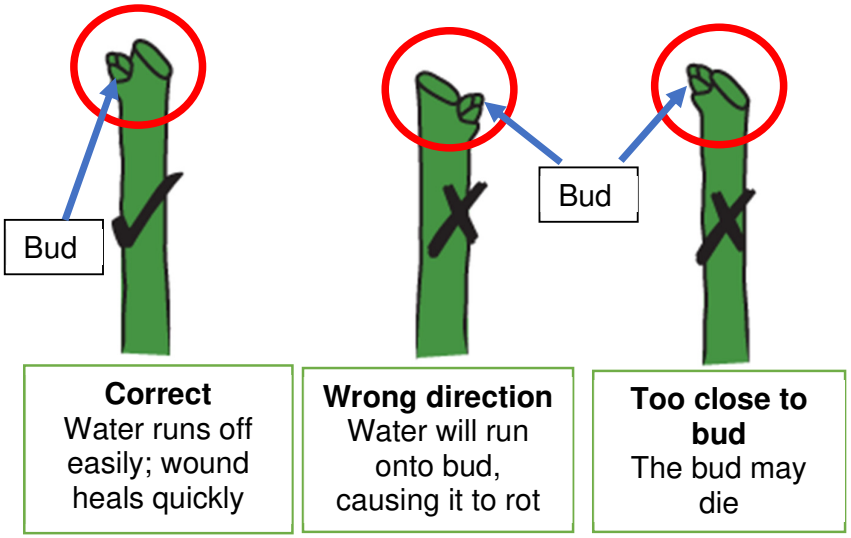
Before you start pruning, you need to know what to prune and remove from the plant. Look out for dead, dying or diseased parts of the plant. Prune and remove these to avoid contamination to other parts of the plant. Do not over-prune as this may damage plants or stunt their growth.

Cut off diseased or infested parts of the plant



Make a clean cut to remove infested parts

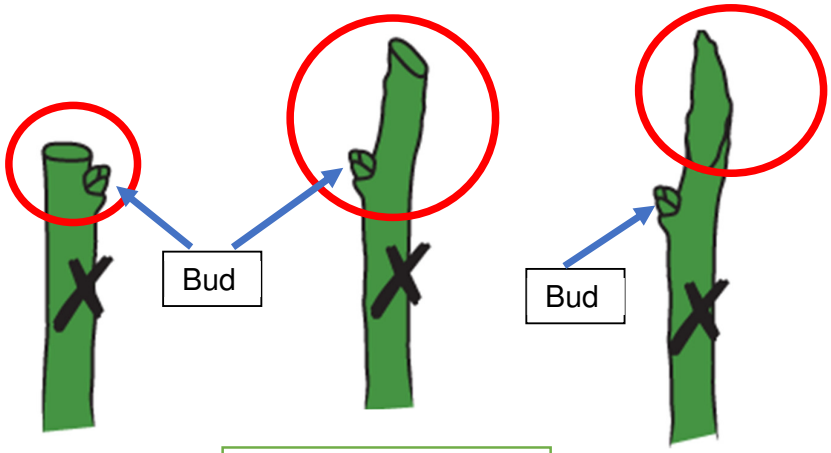
Techniques of Cutting Stems and Branches



Correct
Water runs off easily; wound heals quickly

Wrong direction
Water will run onto bud, causing it to rot

Too close to bud
The bud may die



Too flat
Holds water which can cause the bud to rot

Too much stub
Die back occurs as wound does not heal easily; infection can occur

Too large a wound
Infection enters wound easily

Proper Disposal of Diseased Plant Waste

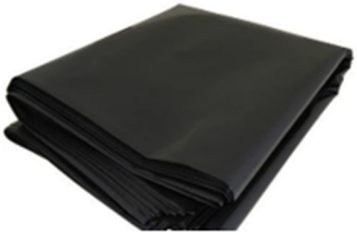
Pest infested or diseased plant waste must be disposed of properly to avoid contamination.

Sweep plant waste and place them in disposal bags. Tie the bags to secure them when they are full or when moving to another location to prevent the diseased plant waste from falling out. Do not mix diseased plant waste with other horticultural waste to avoid cross-contamination.

All diseased plants waste in disposal bags will be collected and dispose of at a Waste-To-Energy Incineration Plant for processing.

The tools for post-pruning housekeeping include:

Rake



Disposal bag

Learning Activity 4

At the allocated worksite, work individually to prune and remove infested parts of plants using the following tools:

1. Secateurs
2. Lopper

Learning Outcome 5: Apply Chemicals to Control the Growth and Spread of Pests, Diseases and Invasive Species

Incorporating Learning Outcome 6: Manage Hazards and Risks associated with Plant Health Management

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Chemicals (pesticides) are commonly a last option to control the growth and spread of pests, diseases and invasive species when all other methods were not effective.

Types of Horticultural Chemicals

The types of chemicals used in landscape maintenance include:

1. Contact Chemicals

- Chemicals that kill pest directly upon contact.
- Example of contact chemicals are *fungicides*, which inhibits the growth of fungi and *insecticides*, which treat insect infestations.

2. Systemic Chemicals

- Chemicals that are absorbed by a plant when applied to the seeds, soil, or leaves.
- The chemical then circulates through the plant's tissue, killing the insects that feed on them.
- Example of a systemic chemical is *herbicides*, which are translocated into the plant system to kill weeds.

Types of Herbicide:

Types of Herbicides for Treating Invasive Species	
Selective Herbicide	Herbicide that targets specific weed species
Non-selective Herbicide	Herbicide that kills all plants when comes into contact

Commonly used Horticultural Chemicals	
 White Summer Oil Kills aphids, mealybugs, scales, whiteflies	 Diazinon Treat leaf spots
 Malathion Kills aphids, mealybugs, mites	 Captan Treat leaf spots, fruit rots

Safety Data Sheet (SDS)

All chemicals sold or supplied must come with a safety data sheet (SDS). The SDS contains information on the chemical that will allow for proper preventive measures to be developed for the handling, application, storage and disposal of the chemicals.

Rules for the Use of Pesticides

The Control of Plants Act Chapter 57A states the rules relating to the protection of plant and plant products against pests and diseases, the control of the introduction of pests into Singapore and the use of pesticides.

Pesticide Label Requirements

The containers of any pesticide sold or supplied for use in the cultivation of plants must have labels stating the following information in English:

a. trade name or brand name
b. pesticide composition and chemical name
c. formulation type
d. type of crop which the pesticide may be used
e. use directions with safety measures to be taken during application
f. recommended interval from last application to harvest of the crop
g. relevant hazard and caution statements and graphic symbols recommended by WHO/FAO Hazard Classification Code
h. antidote to the pesticides, if any, and first aid instructions in case of poisoning by the pesticide
i. net weight and volume of the pesticide
j. name and address of the registered Singapore manufacturer, importer, distributor, supplier or seller

Read labelled information on chemical bottle before mixing

Use of Pictograms

A pictogram is a symbol which conveys a message without the use of words, with the aim of communicating key safety information to users in different countries, and with varied levels of literacy.

The Globally Harmonised System of Classification and Labelling of Chemicals (GHS) pictograms are the most commonly used on pesticide labels.

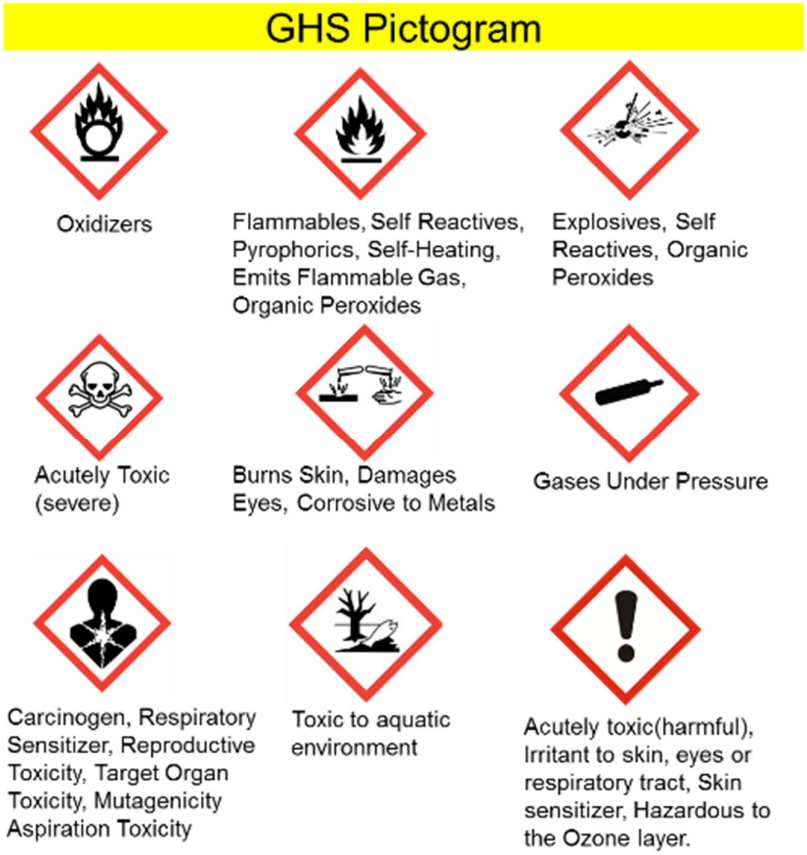


Fig. 38

GHS pictogram definition

Pesticide Container Requirements

The containers of any pesticide sold or supplied for use in the cultivation of plants should not allow the pesticide to pass through and sufficiently strong to prevent leakage from ordinary risks of handling.

Storage of Pesticides

Chemicals, including pesticides, must be stored appropriately as required by WSH regulations, which include:

- Refer to the Safety Data Sheet (SDS) of the chemicals for proper storage and handling
- Store in dry and well-ventilated areas, away from heat and direct sunlight
- Containers should be properly labelled and covered when not in use
- Safety equipment such as fire extinguishers and washing facilities and PPE should be provided in the vicinity of the storage area
- Chemicals should be stored under lock and key, with access given to authorised personnel only

Fig. 39

Storage for horticultural chemicals

The use of pesticides in the cultivation of plants must be supervised by a pesticide operator certified by the Director-General under the Control of Plants Act.

Chemical Application Guidelines

Weather Considerations

When spraying chemicals to plants, please take note of the following:

- Spray during the cooler part of the day.
- Do not apply chemicals during hot sunny weather to reduce the risk of plants getting burnt.
- Do not apply chemicals before the rain. The rain will wash off the applied pesticides, wasting them. In addition, the possibility of the chemicals flowing into drains or surrounding ground areas can cause environmental damage.

Off-Target Chemical Spraying

Chemicals may drift during spraying, causing off-target spray drift issues which can cause damages or injuries to plants, the environment and also affect human health.

To minimise the impacts of off-target spraying:

- Read and understand the manufacturers' labelled instructions and safety precautions before carrying out any chemical spraying. Product labels provide contact details of the manufacturer who can provide reliable technical advice to assist you if necessary.

- Be careful of surrounding areas – check around area where you intended to spray. If possible, maintain a buffer zone between areas of application and areas where there is a risk of damage from spray drift e.g., other flora and fauna

- Use the right equipment – select applicators and nozzles that will give you the correct droplet size to minimise drift and maximise efficiency. Make sure the equipment you are using is in working condition. Always use equipment as recommended by the manufactures.

- Check weather conditions – If there is a change in wind direction during spraying, stop and monitor the situation before continuing.

Prepare for Chemical Spraying

Personal Protective Equipment for Chemical Spraying

Put on the appropriate PPE to prevent the chemical from coming into contact with your eyes and skin.

Set-up a Safe Work Zone

As chemicals pose a certain degree of toxicity, it is advisable to cordon off a larger area around the infested plants to prevent members of the public from going near the worksite.

Safety zone requirements:

Tools and Equipment for Mixing and Applying Chemicals			
			
Hand held sprayer	Measuring jar	Pail	Horticultural chemical

Steps of Chemical Spraying

Steps for Chemical Spraying	
1. Wear appropriate PPE at all times during application of chemicals. 2. Check all equipment are safe for the task	 Check all equipment
3. Inspect the plants: • Identify the symptom of the weeds, pests and diseases on the plants • Identify the location of weeds within workzone • Assess the plants' surrounding environment, e.g., poor drainage and compaction of ground, signs of yellow or brown leaves of plants	
4. Make sure the sprayer is in working condition • Pour some water into the sprayer • Pump and test that the sprayer is working • Do not use the sprayer if it faulty, inform supervisor of the faulty equipment	

5. Prepare (mix) the chemical
   - Use a measuring jug/cup to measure out the required amount of chemical as per labelled instructions.
   - Dilute the chemical with appropriate amount water, as per labelled instructions, and pour the mixture into the sprayer
   - Always check with your supervisor if you need clarification on the chemical types and dosages

Tighten the cap of the sprayer after filling it with the chemical mixture

6. Pump the sprayer 10 to 15 time before you start spraying. To ensure uniform coverage, pump the handle again every 5 seconds to ensure constant pressure.

7. Spray evenly from waist height at the affected/designated area. Do not spray off-target.

8. After you have finished spraying, do not walk on the areas that you had sprayed as you will carry the chemical on your shoes to other areas.

9. Rinse the sprayers after each use.
   - Do not pour the rinsed water into sinks, drains or hard surfaces.
   - Pour the rinsed water and leftover chemical into a designated pail.
   - All chemical waste will be sent to NEA (National Environment Agency) designated waste collection centre.

Pour leftover chemical into designated containers

10. Wash hands thoroughly with soap.

Biological Pest and Disease Control

Biological control, or biocontrol, is a method of controlling pests and diseases using other organisms. It can be used in situations when pesticides cannot, for example, on plants that may be scorched by chemicals.

The natural enemies, or predators (e.g. birds, dragonflies, spiders, ants, ladybugs) of a pest species can be introduced into the environment to consume or attack the pests, resulting in a population decrease to a level where the pest is no longer a problem. Pathogens (e.g. fungi, bacteria, viruses) and other micro-organisms can also be used to control or prevent the development of disease in plants.

Advantages of Biological Control

- Environmentally friendly and safe for the applicator
- Leave no residues
- Lasting; no need for continuous reapplication, as is necessary with pesticides
- Host specific
- Unlike chemical methods, pests do not become resistant to biological control agents

Disadvantages of Biological Control

- Slow acting
- Do not completely eliminate pests, as doing so would mean the predators would also die
- Possibility of feeding on other plants or insects (non-target species)
- Can be costly, e.g. research needs to be done prior to the implementation of the biocontrol strategy

Learning Activity 5

At the worksite, work individually to:

1. Apply chemicals to treat plants for pests and diseases
2. Dispose of used chemicals properly
3. Clean up equipment after use

Other Hazards and Risks associated with Plant Health Management

Working at Roadside

Working at the roadside can be dangerous. Safe work practices in high traffic work area include:

- Rotating and/or flashing lamps need to be placed at regular intervals along work zone on roadside
- Use larger direction sign
- Use Truck Mounted Attenuator (TMA) when working on expressways and roads with a speed limit above 70km/h.

Working on expressway

Truck Mounted Attenuator (TMA) - mount blinking beacon lights on the top and warning signs at the rear of vehicles

The following control measures in LTA's Code of Practice must be adhered to while working along the roadside:

- Cordon off the work area
- Re-direct traffic flow
- Install TMA (for expressway) and placement of warning lights and signages
- Workers must wear luminous vests to enhance their visibility
- Establish the work zone and its removal, especially near fast lanes, expressways, and major roads

Heat Stress

It is important to protect yourself from extreme heat and solar radiation by:

- Drinking plenty of water
- Wearing cooling and protective clothing
- Wear soft hat and sunglasses to block out direct sunlight contact
- Monitoring yourself and your co-workers for symptoms of dehydration or heat exhaustion

Chemical Exposure

The improper handling or application of chemicals can cause irritation, burns and even affect internal organs.

It is important to observe the following when handling chemicals:

- Read the chemical label and follow manufacturers' instruction on usage, quantity, storage and disposal.
- Put on the appropriate PPE, especially when working with liquid chemicals.
- Ensure there is a first aid box available at the worksite.

Assessment Information

The assessment methodology for this course is Practical Exam and Oral Questioning.

Practical Exam

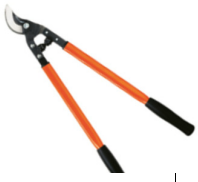
For the Practical Exam, you will be given **90 minutes** to perform the following tasks to demonstrate your competence for the learning outcomes:

a. Identify and report one pest infestation or disease.
b. Identify one invasive species, assess the extent of spread and recommend an appropriate remediation method.
c. Identify one plant with nutrient deficiency; suggest the possible nutrient that is lacking.
d. Put on the appropriate PPE, set up a safe worksite and select the appropriate tools, equipment for plant pruning and chemical application.
e. Perform plant pruning and chemical application.
f. Reinstate the worksite and dispose of horticultural waste and leftover chemical.
g. Clean and store tools and equipment properly.

Oral Questioning

For Oral Questioning, you will be given **30 minutes** to answer 10 questions that check your knowledge in accordance to the learning outcomes.

Appendix 1 – Tools, Equipment and Material Checklist

Personal Protective Equipment			
 Safety Helmet ☐	 Safety Glasses ☐	 Face Shield ☐	 Dust Mask ☐
 Safety Vest ☐	 Raincoat ☐	 Cotton Gloves ☐	 Rubber Gloves ☐
 Safety Boots ☐			
Work Zone Requirements			
 Red/White Tape ☐	 Safety Cones ☐	 Warning Signs ☐	
Tools, Equipment and Machinery			
 Secateurs ☐	 Lopper ☐		

 Measuring Jar	 Handheld Sprayer	 Pail	
Horticultural Products			
 Horticultural Chemical	 Fertiliser		
Housekeeping Items			
 Rake	 Dustpan	 Disposal Bag	 Cloth

Reference Material

Tropical Gardeners' Guide to Healthy Plants
By Pim Sanderson, Fong Yok King and Daniel Burcham

WSH Council, Workplace Safety and Health Guidelines, Landscape and Horticulture Management, Singapore, Second revision:2018

Control of Plant Act (Chapter 57A), 1994 Revision Edition 2000

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Fig 1. Mealybugs
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Fig.2 Scale Insects https://cdn.britannica.com/34/124734-004-BA50D02A/Cottony-cushion-scale.jpg Accessed on 08 Mar 2021

Fig. 3 Black sooty mold, a black-coloured fungus https://irontreeservice.com/wp-content/uploads/2016/06/Sooty-Mold-350x0-c-default.jpg Accessed on 08 Mar 2021

Fig. 4: Aphids attack stems of plant https://gardenerspath.com/wp-content/uploads/2019/03/How-to-control-aphids-FB.jpg Accessed on 08 Mar 2021

Fig. 5: Thrip https://dh1muyqdu88ie.cloudfront.net/wp-content/uploads/2017/12/11144316/FEATURED-Thrips.jpg Accessed on 08 Mar 2021

Fig: 6: Feed on leaves, puncturing the plants' cell https://www.nature-and-garden.com/wp-content/uploads/2020/01/thrips-leaf-damage-320x320.jpg Accessed on 26 Feb 2021

Fig. 7: Feed on new growth especially veins
https://www.almanac.com/sites/default/files/image_nodes/whiteflies_d-kucharski-k-kucharska_ss.jpg Accessed on 26 Feb 2021

Fig. 8: Spider-mites https://i0.wp.com/hydrodionne.com/wp-content/uploads/2017/05/Phytoseiulus-persimilis-on-leaf2.jpg?fit=480%2C480&ssl=1 Accessed on 08 Mar 2021

Fig. 9: Leaf damaged by Japanese Beetles https://www.amdro.com/-/media/Images/Amdro2-NA/US/signs-of-pests/Leaf-

Damage/leafdamage_japanesebeetles.jpg?h=508&la=en&w=1086&hash=D65DF0F15E25C79E7E0891A9AB325D4E99CFAD5D Accessed on 08 Feb 2021

Fig. 10 Caterpillar https://www.nature-and-garden.com/wp-content/uploads/sites/4/2018/10/organic-treatment-caterpillar.jpg Accessed on 08 Mar 2021

Fig. 11: Cone-shaped bag Bagworm https://extension.umd.edu/sites/default/files/_images/programs/hgic/Insects/Bagworms/0717013-PPT.jpg Accessed on 26 Feb 2021

Fig. 12: Spread quickly, especially in new and less-established plants https://cdn.domyown.com/images/content/leaf_spot_on_potted_terracotta_plant.jpg Accessed on 26 Feb 2021

Fig. 13: Rust https://dta0yqvfnusiq.cloudfront.net/growingearth/2013/07/download-160913-57d82de7e5d6e.jpg Accessed on 08 Feb 2021

Fig.14: Gall on plant https://www.walterreeves.com/wr2020/wp-content/uploads/2020/03/oakgall2.jpg Accessed on 21 Feb 2021

Fig. 15: Small white spots; powdery mildew first appears on the upper part of leaves https://www.almanac.com/sites/default/files/users/AlmanacStaffArchive/powdery-mildew-identification_full_width.jpg Accessed on 26 Feb 2021

Fig. 17: Rotting leaves https://www.researchgate.net/profile/Iris-Yedidia/publication/229590513/figure/fig1/AS:279033154686998@1443538096253/Calla-lily-showing-bacterial-soft-rot-symptoms-in-the-greenhouse-a-discoloration-of.png Accessed on 26 Feb 2021

Fig. 18: Leaf base and bulb rot https://www.researchgate.net/profile/Iris-Yedidia/publication/229590513/figure/fig1/AS:279033154686998@1443538096253/Calla-lily-showing-bacterial-soft-rot-symptoms-in-the-greenhouse-a-discoloration-of.png Accessed on 26 Feb 2021

Fig. 19: Bacterial slime flows out from stem https://ohioline.osu.edu/sites/ohioline/files/01-31-hyg-fact-PP401_06.pdf.pdf-1_13.jpg Accessed on 08 Feb 2021

Fig. 20: Leaf spot with yellow ring https://morningchores.com/wp-content/uploads/2020/03/bacterial-blight-damage.jpg Accessed on 26 Feb 2021

Fig. 21: Harmful spots virus on leaves https://ohioline.osu.edu/sites/ohioline/files/01-31-hyg-fact-PP401_05.pdf.pdf-1_13.jpg Accessed on 26 Feb 2021

Fig. 22: Mosaic mottling symptom in an infected leaf https://media.springernature.com/lw785/springer-static/image/chp%3A10.1007%2F978-1-0716-0334-5_2/MediaObjects/465409_1_En_2_Fig3_HTML.png Accessed on 26 Feb 2021

Fig. 23: Rhizomes https://content.ces.ncsu.edu/media/images/18-weed_spread.jpg Accessed on 08 Feb 2021

Fig. 24: Seeds https://content.ces.ncsu.edu/media/images/18-weed_spread.jpg Accessed on 08 Feb 2021

Fig. 25: Tubers https://content.ces.ncsu.edu/media/images/18-weed_spread.jpg Accessed on 08 Feb 2021

Fig. 26: Stolens https://content.ces.ncsu.edu/media/images/18-weed_spread.jpg Accessed on 08 Feb 2021

Fig. 27: Use mulch as a natural weed barrier to keep weeds seeds from germinating. https://www.scotts.com/sites/g/files/oydgjc106/files/styles/scotts_marquee_large/public/asset_images/US/article/Lawns/batch5_51-55/SoilMulch_165_328x190.jpg?itok=pfITyFkg Accessed on 14 Feb 2021

Fig. 29: Plants Nutrient Deficiencies https://www.smart-fertilizer.com/wp-content/uploads/2020/10/111.jpg Accessed on 08 Feb 2021

Fig. 30 - 33: Nitrogen / Phosphorus / Potassium / Magnesium Deficiency Identifying Nutrient Deficiency in Plants (nparks.gov.sg) Accessed on 14 May 2021

Fig 34: N.P.K.'s usage https://www.dayliliesinaustralia.com.au/wp-content/uploads/2013/09/NPK-Dose-for-Daylilies-Fertilisers-Nitrogen-Phosphorus-Potassium.jpg Accessed 08 Feb 2021

Fig. 35 Liquid N.P.K http://biofertilizer.biz/product/wp-content/uploads/2018/08/042-copy.png Accessed on 09 Mar 2021

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Fig. 37: Optimum healthy plants growth at HortPark to Henderson Waves to Mt. Faber Peak https://pacer-note-images.pacer.cc/233710648_AA7882DA-CF88-4442-92ED-27E32F6EAAF7_1574482354.jpg Accessed on 27 Feb 2021

Fig 38: GHS pictogram definition https://www.chemsafetypro.com/Topics/GHS/GHS_Pictogram.png Accessed on 09 Mar 2021

Fig. 39: Storage for chemical https://www.ehs.gatech.edu/sites/default/files/images/offices/chemical/flammable_storage_cabinet.jpg Accessed 08 Feb 2021

Fig. 40: Working on expressway http://www.pioneertrainingcentre.com/wp-content/uploads/2017/06/BTCC-8.jpg Accessed on 17 Feb 2021

Fig. 41: Truck Mounted Attenuator (TMA) - mount blinking beacon lights on the top and warning signs rear of vehicles https://www.singhenghoe.com/assets/Services/3960cf1964/machinery-truck-mounted-attenuator.jpg Accessed on 17 Feb 2021