Pest Management
for Greenhouse & Indoor Farms

Pests can reduce yield and productivity by damaging crops and hindering their growth. If planned correctly, greenhouse and indoor farms have great advantages of built walls and intentional interior design that allows for robust pest management.

Plant-Pest Interaction

Pest refers to "any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products" (ISPM 5)[2]

Types of Pests

- **Vertebrate (have a backbone).** Rodents, birds, reptiles
- **Invertebrate (no backbone).** Insects, nematodes, slugs
- **Disease.** Fungi, bacteria, virus
- **Weeds.** Unwanted plants

The pest triangle (Figure 1) highlights three crucial factors: the pest, the host (plant) and the environment[1]. When these elements are combined, they create conditions conducive to pest occurrence. By changing any of the factors, one can more effectively manage and control pest issues.

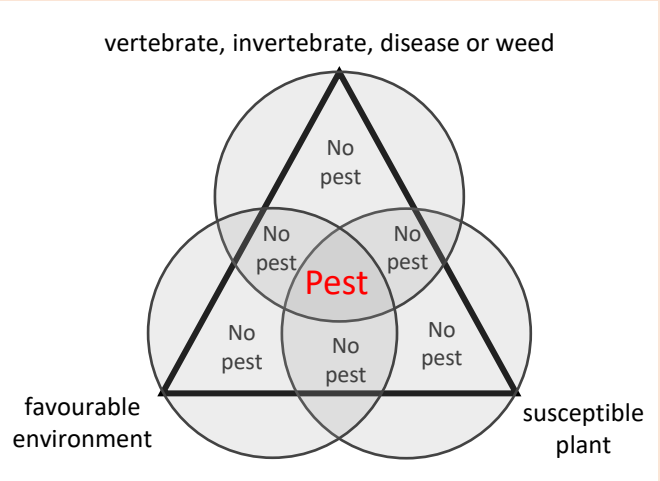

Figure 1. Pest triangle illustrating three essential factors causing pest occurrence in plants

PEST identification enables implementation of the most effective management strategies.
Look for signs of pest (e.g. larvae, frass) or symptoms (e.g. yellowing and/or wilting leaves, bite marks, speckled/mottled patterns).
Common pests in greenhouses and/or indoor farms in Singapore include:

Invertebrate

- Aphid
- Spider mite
- Diamondback moth

Disease

- *Fusarium* wilt
- Damping off
- Mildew (downy and powdery)

Aphids secrete honeydew that attracts ants. Image from CyclicalCore

Tiny red dots on underside of leaves indicate spider mites. Image from SFA

Powdery mildew. Image from Ejdzej

Fusarium wilt on tomatoes. Image from J. D. Richards.

For more detailed information on monitoring and identification, please refer to the *Guide to Integrated Pest Management (IPM) for Singapore vegetable farms* on SFA's website.

To change this factor:

- Look for ways to prevent entry into growing areas (see Page 3 for details)
- Install sticky traps above canopy of growing plants to capture pests
- Allow for beneficial insects or microbes that feed on the pests to thrive

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Plant-Pest Interaction (cont.)

SUSCEPTIBLE PLANT refers to the plant vulnerable to damage by the pest in question. This is often the plant being cultivated for production.
While it is challenging to completely change the plant itself, there are techniques that can help mitigate the damage done by pests.

To change this factor:
- Source pest-resistant seeds
- Introduce non-susceptible plant species within the growing area to disorient and hinder pests' ability to locate target plants
- Ensure appropriate amount of nutrients, light, and water is provided. Avoid insufficient or excess amounts which can stress and weaken the plants, making them more susceptible to pests.

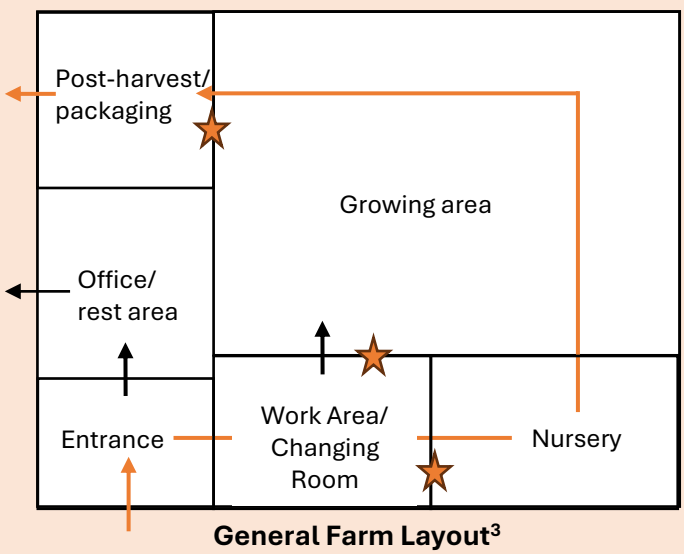
FAVOURABLE ENVIRONMENT refers to conditions that enable pest to grow, breed, and thrive. This environment often overlaps with conditions beneficial to the plant; therefore, a balance must be obtained.

To change this factor:
- Adjust the environmental conditions based on plants' preference to promote their growth. e.g., temperature, humidity and airflow.
- Remove equipment and other susceptible plants in the vicinity as these can serve as breeding grounds or shelter for pests

Pest Prevention: Creating Barrier through Structural Design

A farm could effectively manage pests through a well-conceived design. Critical considerations include the appropriate farm layout and robust environmental controls. These elements are essential for preventing pest occurrence, thereby ensuring optimal crop health and productivity.

- **Separate nursery, growing racks, post-harvest and office areas** with physical barriers (e.g. walls, strip curtains) to prevent cross-contamination
- **Design movement** of people and goods in a one-direction flow to prevent cross-contamination. See orange arrows
- **Section the growing area** with physical barriers, where possible, to control spread should pest and/or disease be introduced inside



General Farm Layout[3]

Orange arrows indicate one-direction flow

Optimal position of double doors, strip curtains or air curtains

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Prevention: Best Practices

There are **four primary pathways** that pests enter farming environments. Understanding these modes is essential for implementing effective preventative measures.

PEOPLE

Pests can inadvertently enter growing areas via human vectors, often without the individual's knowledge. Common transmission points include hair, shoe soles, clothing, and hands.

- **Access Control.** Limit entry into growing area. Consider viewing windows for visitors to observe without entering. Prohibit access for personnel if they have recently been in the vicinity or in contact with plants outside the growing area (e.g., other farms, parks).
- **Designated Apparel.** Change into designated working apparel right before entry into the growing area. This should include shoes, overcoat, pants (where possible) and hairnet or cap. Remove work apparel upon exit, and launder regularly. See Layout (Page 2) for optimal changing area location.
- **Hygiene.** Wash hands with soap prior to entry into growing area and handling any equipment or plant materials.
- **Cross-contamination prevention.** Quarantine contaminated plants. After handling infested or infected plants, wash hands thoroughly before handling healthy plants to avoid spread.

PLANT MATERIALS

Plant materials include but are not limited to substrates, seeds and seedlings. These have a high potential for containing pests, as they are often exposed to environments with high pest possibility (e.g., seed breeding facilities, farm supply warehouses).

- **Origin.** Check the sources of your plant materials and substrate to ensure pest introduction is limited.
- **Seeds and Seedlings.** Healthy seed tests can be done by the water test (soak seeds in water for 15 min, the ones that sink are viable), small batch of germination before full production and visual inspection for damage and discolouring. Dispose unhealthy seeds and seedlings, as unhealthy plants are more susceptible to pests.

AIR MOVEMENT

Air currents can carry small-bodied pests from outside into the growing area. Pests, such as spider mites and fungal spores, make use of air movement to move themselves to new areas.

- **Entry/Exit Management.** Minimize duration of open access points as extended openings allow air exchange with outside environment bringing in pests.
- **Physical Barriers.** Where possible, have more than one layer of physical barrier, especially at entries/exits. Examples include double doors (only one door open at once) or strip curtains.
- **Air Flow Control.** Install air showers or air curtains where the air is blown away from entry way. A standing fan is a good substitute. This is best placed right before entry into the growing area. See Layout (Page 2) for ideal placement.

EQUIPMENT

Equipment, ranging from small tools to large machinery, can serve as vectors for pests, potentially entering and spreading within the growing area. Growing systems are also possible sources of contamination.

- **Containment.** Where possible, keep equipment within the growing area to avoid cross-contamination when exposed to environment outside the growing area.
- **Sanitation.** Wash and sanitize any equipment after use or in-between different growing area or crop type. This includes the growing systems (e.g., sump tanks, racks).
- **Surface maintenance.** Regularly clean surfaces and floors to eliminate dust, which can harbour pests.
- **Storage.** Maintain storage areas for equipment and machinery that are away from growing area to reduce cross-contamination risks.

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Integrated Pest Management: A Toolbox of Strategies

Pest management must be managed using multi-pronged approach. The strategies are divided into four tools, which should be used concurrently.

Cultural: altering farming practices (e.g. alter growing practices, habitat manipulation)

Biological: using biological elements (e.g. beneficial organisms, pheromone traps)

Mechanical: using physical structures, often to prevent entry

Chemical: using chemicals. This should be LAST resort.

Sample: Management Plan for Diamondback Moth (*Plutella xylostella*) in Greenhouse

HOST PLANTS: *Brassicas spp.* or cruciferous crops (e.g., baicai, caixin, cabbage)

MONITORING
- Place yellow sticky traps above the canopy of the susceptible plants. Check weekly and change traps every 30 days.
- Scout leaves for signs of larvae (caterpillar) and holes weekly.
- Take photos of any suspected pest damage for easy comparison to reference photos online.

CONTROL

Cultural
- Plant non-Brassicas spp. for at least 30 days to disrupt cycle of diamondback.

Mechanical
- Install barriers, like plastic netting (with no holes). Check and repair regularly for any holes and tears.
- Gently spray water overhead to force larvae to fall off the plants (this can be aided via rainfall or overhead irrigation).

Biological
- Reduce pesticide spraying to encourage beneficial insects (e.g., *Cotesia plutellae* wasps) that prey on the diamondback moth larvae.
- Install pheromone traps to capture flying adults.

Chemical
- Use active ingredients, such as *Bacillus thuringiensis* (Bt) and chlorantraniliprole, according to pesticide instructions. Rotate use of pesticides to prevent pesticide-resistance.

Diamondback moth – larvae. Image from Merle Shepard, Gerald R. Carner and P.A.C Ooi

Diamondback moth – pupa. Image from Russ Ottens

Diamondback moth – adult. Image from CSIRO

Bites from diamondback moth larvae. Image from Institute of Tropical Agriculture

Let us know your thoughts

About the Author

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