Integrated pest management in mango - emphasizing non-insecticidal control of major insect-pests

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Mango is a major tropical fruit crop in India, known for its nutritional and commercial significance. Its production is greatly hampered by a variety of insect pests that infest at various stages of development. Over 260 insect and mite species have been documented, including hoppers, mealybugs, fruit flies, stem borer, seed weevils, and midges, which all cause significant production and quality losses. Indiscriminate pesticide use, monocropping, and climatic variations have intensified pest outbreaks, resistance, and ecological imbalance. Adoption of Integrated Pest Management (IPM) strategies integrating cultural, mechanical, biological, and need-based chemical methods offers an effective and sustainable solution. Non-insecticidal methods such as orchard cleaning, pruning, the use of biocontrol agents, entomopathogenic fungi, and pheromone or light traps can assist in reducing pest populations. IPM adoption promotes safe fruit production, environmental preservation, and long-term orchard viability.

Keywords: *Mango, Integrated pest management, Pests, Biological control, Sustainable management*

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Introduction

Mango, *Mangifera indica* L. is one of the most important and popular fruits in the world, often referred to as the king of fruits highly valued for its distinctive aroma, pleasant taste and substantial nutritional content (Mukherjee, 1997). One of the oldest and most prized fruits of human domestication, mango has roots in the Indo-Burma region. India is the leading producer of mangoes globally, accounting for nearly half of the world's total mango production and cultivated area. Mango cultivation constitutes approximately 22% of the

total area under fruit crops in the country, covering around 23.1 lakh hectares and yielding about 21.29 million tonnes annually (NHB, 2020). Among the Indian states, Uttar Pradesh ranks first in both mango production and productivity, contributing 25.76% to the national output from an area of 0.59 lakh hectares. It is followed by Andhra Pradesh, Karnataka and Bihar (GOI, 2024). It has a distinct aroma, vibrant peel colour, good taste, and significant nutritional value due to its high content of vitamin C, β-carotene, and minerals. The content of mango pulp varies depending on the cultivation region, variety, and stage of ripeness. Mango pulp has a diverse range of components, including water, carbohydrates, organic acids, lipids, minerals, pigments, tannins, vitamins, and flavour compounds. It contains essential vitamins such as C, A, E, K, and the majority of the B group (except biotin), however vitamin D is noticeably absent (Maldonado et al., 2019). In addition to this, it also includes polyphenols, carotenoids, organic acids, and natural volatiles, which not only offer medical value but also indicate the fruit's quality. As the fruit grows and matures during the period of rapid growth results in an increase in alcohol-insoluble solids, with starch accumulation being the most significant chemical alteration in pulp tissue (Tharanathan et al., 2006). Each part of the mango tree, from its leaves and flowers to its bark, pulp, peel, and seeds, holds useful nutrients.

Commercial mango cultivation is driven by area expansion, varietal changes and increased chemical use and this has significantly shifted pest dynamics. Climate change has further triggered new pest outbreaks and aided invasives (Meena et al., 2024). A variety of pests and diseases can harm mango plants at any stage of development, from immature nursery seedlings to fully grown trees. Pre-harvest attacks on fruits also frequently lower their market value and restrict their export possibilities (Fita, 2014). About 260 insect and mite species are reported as mango pests, including fruit feeders, foliage feeders, and those attacking inflorescences, buds, branches, and trunks (Veerish, 1989). The hopper, mealybug, inflorescence midge, fruit fly, scale insect, stem borer, leaf webber, and stone weevil are some of the most devastating insect pests that attack mango trees. Their impact is especially severe during flowering and fruiting, when hoppers and midges limit fruit set and sap-sucking pests like mealybugs and scales reduce plant vigour (Singh & Baradevanal, 2021). Mango cultivation in India suffers major losses from these insect pests. Fruit flies cause 5–70% yield loss, premature fruit drop, post-harvest spoilage and export restrictions (Kapoor, 2004). Seed weevils reduce seed viability and fruit quality, whereas stem borers weaken or destroy trees, causing long-term orchard loss (Patel et al., 2018). Leafhoppers limit fruit set by shedding flowers, and mealybugs destroy inflorescences and fruits while promoting sooty mould (Anant, 2016). Effective annual control measures are necessary to manage mango pests, particularly fruit flies, seed weevils, tree borers and leafhoppers, which all pose substantial challenges to fruit supply and quality (Singh et al., 2022). Together, these pests have a substantial impact on mango productivity, limiting its export potential.

Previously minor pests like scales, mealybugs, thrips, mites, leaf webbers and stem borers have now become major threats. In response, farmers often rely heavily on chemical pesticides, resulting in environmental pollution, ecological imbalance, pest resistance, resurgence, and harmful residues in the produce (Reddy et al., 2018). Excessive pesticide use in fruit crops leaves harmful residues in the fruits, posing major health risks to customers, while also exposing farm workers and labourers to hazards from incorrect handling and pesticide poisoning. Many synthetic pesticides, including organochlorines, organophosphates, carbamates, and organophthalides, have been banned or restricted due to their environmental hazards and high toxicity to non-target organisms such as beneficial insects, amphibians, fishes, birds, and even humans (Usha et al., 2019). To address these challenges, integrated pest management (IPM) strategies should be adopted, using chemical control only as a last resort. A number of insect pests are documented infesting mango along with their respective yield loss, as mentioned in Table 1. These major pests can be effectively, safely and sustainably managed by using non-chemical approaches as a first option. Relying on natural and

environmentally friendly methods allows growers to produce healthier fruits, use fewer chemicals and save the environment. By encouraging these practices through IPM, orchard health is maintained over time and also provide better outcomes for both farmers and consumers.

Table 1. Major insect pests of mango and their respective per cent yield loss

Insect pests	Scientific names	Yield loss (%)	References
Mango Hoppers	*Amritodus atkinsoni* *Idioscopus nitidulus* *Idioscopus clypealis*	20–100	Kaushik et al., 2014
Mango Mealy Bug	*Drosicha mangiferae*	up to 80	Reddy et al., 2018
Bark Eating Caterpillar	*Indarbela quadrinotata*	20–80	Gupta et al., 2014
Inflorescence Midge	*Erosomyia mangiferae*	75–80	Singh et al., 2022
Mango fruit fly	*Bactrocera dorsalis*	5–70	Verghese et al., 2002
Mango stem borer	*Batocera rufomaculata*	40–50	Rai et al., 2019
Mango Seed / Stone Weevil	*Sternochaetus mangiferae*	15–45	Bhattacharyya et al., 2016
Mango Leaf Webber	*Orthaga exvinacea*	25–100	Shrestha et al., 2022
Termite	*Odontotermis* spp.	20–40	Paul et al., 2017
Mango Scale	*Chloropulvinaria polygonata*, *Aspidiotus destructor*,	25–30	Reddy et al., 2018
Mango Thrips	*Caliothrips indicus, Rhipiphorothris cruentatus, Scirtothrips dorsalis,*	up to 80	Bana et al., 2018
Mango bud mite	*Aceria mangiferae*	10–30	Reddy, 2017

Damage symptoms of major insects-pests and their non-insecticidal management approach

1. Mango hoppers

- Nymphs and adults suck the sap from the inflorescence, young branches, and sensitive plant sections, which reduces vigour, kills the inflorescence and causes fruitlet drop (NHB, 2020).
- Infested tissues curl and desiccate as a result of continuous sap extraction. Honeydew excretion promotes the growth of sooty mould, which reduces photosynthetic efficiency (Figure 1(a)).

Management

- Maintain orchard hygiene by ensuring proper spacing (10×10 m or 12×12 m), reducing inputs to control vegetative flushes along with pruning, and removing weeds and alternate hosts like hibiscus, custard apple, mango, and guava (Srivastava, 1997).
- Preservation of biocontrol agents such as the predators *Mallada boninensis, Chrysopa lacciperda, Isyndus heros* and parasitoids *Pipunculus annulifemur, Halictophagus indicus, Polynema* spp.
- Apply *Metarhizium anisopliae* or *Beauveria bassiana* (1×10^8 cfu/ml) once during the off-season and again during flowering at 7-day intervals, combined with 0.2% Nimbicidin or Azadirachtin (3000 ppm @ 2 ml/L) at initial stages of hopper infestation (Rahman et al., 2019).
- Apply imidacloprid 17.8 SL at 0.3 ml/l, thiamethoxam at 0.5 g/l, or lambda-cyhalothrin at 0.5 ml/l during the panicle initiation stage if the number of hoppers per panicle is more than four. To protect pollinators, however, spraying should be avoided during full bloom (Verghese and Devi Thangam, 2011).

2. Mango mealy bug

- Both adults and nymphs feed by sucking sap from the inflorescence, tender leaves, young shoots, and developing fruits, thereby impairing fruit set as shown in Figure. 1(b).
- Excretion of honeydew promotes the growth of sooty mould, which obstructs photosynthesis. Extensive infestations cause the plant to become devitalised, which results in smaller and early dropping of fruits (Ishaq et al., 2004).

Management

- Ploughing in the month of November and December (exposes eggs and pupae to sunlight and natural enemies) and clearing weeds like *Clerodendrum infortunatum* help minimise pest infestation and flooding orchards in October kills eggs (DPPQS, 2022).
- Since the newly hatched crawlers climb to tree and start infestation, we can prevent and kill the crawlers by banding of tree trunk in the month of November or December with 25cm wide, 400-gauge alkathene sheets 30 cm above the ground with the help of sulti along with mud plastering (Figure 2(a)).
- The aggregated mealy bugs at the bottom of the alkathene sheets can be killed by using any of the entomopathogenic fungus like *Beauveria bassiana* or any of the insecticides below preventing further damage.
- Flooding an orchard in October helps to eliminate mealybug eggs.
- Install glue traps around the mango trunk at a height of 1 foot from the ground and replace them every 10 days (Kour et al., 2022).
- In the first week of December, transplant 5-6 lemongrass seedlings around the tree trunk (Kour et al., 2022).
- Apply entomopathogenic fungi such as *Beauveria bassiana* (2 g/L at 1×10^7 spores/ml) or 5% NSKE in the second week of December (Jabunnaher et al., 2025; Reddy et al., 2018).
- Release 10 to 15 *Cryptolaemus montrouzieri* grubs per tree and preserve predators such as *Menochilus sexmaculatus*, *Rodolia fumida* and *Sumnius renardi* (Haseeb & Srivastava, 2003).
- Apply need-based, label-claim insecticides such as Dimethoate 30% EC, Malathion 50% EC or Spirotetramat 11.01 % + Imidacloprid 11.01 % w/w SC.

3. Bark eating caterpillar

- The caterpillars attack the young trees, boring into the trunk and create zigzag galleries composed of silk and frass as in Figure 1(c) (Reddy et al., 2018).
- During the day, they stay concealed in the tunnel and at night, they emerge to feed on the bark. In cases of severe infestation, fruit development is significantly decreased, plant growth is halted and sap flow is impeded (Butani, 1977).

Management

- For effective control, collect and burn afflicted branches, as well as set up light traps to attract adult moths.
- Caterpillars can be killed by placing an iron spike into their tunnels and implementing control measures during egg hatching and early larval stages (Srivastava, 1964).

- Inject the mixture of ethylene glycol and kerosene (1:3 ratio) into the tunnel using a syringe, followed by sealing the opening with mud (DPPQS Technical Bulletin, 2022).
- Place a piece of cotton into the tunnel dipped in fumigant like petrol or kerosene, then cover the aperture with mud or clay.
- Install light traps (1 per hectare) to attract adult moths; control is most successful when eggs hatch and caterpillars are little.
- Rynaxypyr 25 SC (0.2 mL/L), Lambda-cyhalothrin 5 EC (1.0 mL/L), Deltamethrin 2.8 EC (0.5 mL/L), or Indoxacarb 15.8 SC (0.3 mL/L) can be injected into active caterpillar holes containing frass, excreta, or gummy exudates (Satyanarayana et al., 2017).

4. Inflorescence midge

- The maggots consume the internal organs of the bud, which eventually take on an oval or conical shape before turning brown and falling off (Rai et al., 2019).
- Infestation leads to bending, drying, and stunted growth of inflorescences (Figure 1(d)).
- Young maggots attack tender fruits, causing yellowing and premature drop.

Management

- In November, deep-plough the orchard to expose pupae and diapausing larvae to the sun and their natural enemies.
- Conserve parasitoids like *Euplemus* sp., *Tetrastichus* sp., *Pirens* sp. and predators such as *Formica* sp., *Oecophylla* spp., *Camponotus* spp. (Grover, 1986)
- Collection and destruction of infected panicle twigs and leaves.
- Spraying 0.045% Dimethoate during the bud burst stage of the inflorescence effectively controls insect populations.

5. Mango fruit fly

- The females deposit their eggs in clusters inside the mesocarp after puncturing immature/mature fruits with a pointed ovipositor (Vayssières et al., 2009).
- Oozing occurs from the oviposition punctures.
- Larvae feed on the pulp, leading to fruit rotting and premature drop (Figure 1(e)).
- Infested fruits, which frequently have a high maggot count, become unmarketable.

Management

- Installation of methyl-eugenol-based male attractant traps at 4–5 traps per acre for monitoring 10 traps per acre for mass trapping, replaced at 3–4 weeks. The following traps must be installed during fruit setting till fruit harvesting as in Figure 2(c).
- Regular collection and destruction of fallen and infested fruits by dumping them in pit (1 m deep) away from the orchard (Choudhary et al., 2022).
- Raking of top 40–60 cm soil under trees for exposing of soil-hibernating pupae of fruit flies (NIPHM, 2014b).

- Paper bagging is an effective technique in mango cultivation to reduce pest infestation and improve fruit quality, enhancing the suitability of fruits for export (Figure 2(b)) (Raza, 2019).
- Hot water treatment of fruits at 48 ± 5°C for 60 min kills different development stages of fruit fly (Verghese et al., 2011).
- Mangoes for export to Korea must undergo Vapor Heat Treatment (47.5°C for 20 min) or Hot Water Treatment (over 48°C for 60 min, for fruits <500 g) in registered facilities under quarantine supervision as per official guidelines.
- Mango varieties such as Alphonso, Kesar, Benganpalli and Totapuri are treated with irradiation in the range of 400–1000 Greys for export to USA and Australia, with packaging in ventilated thermocol boxes covered by mesh (≤1.6 mm).
- Application of poison bait may be prepared by adding 100g of jaggery and 2ml of Deltamethrin 2.8EC in 1 lit of water and sprayed on the tree trunks at weekly interval. The bait could be sprayed on the nearby hedges and vegetation (Chandana et al., 2023)

6. Mango stem borer

- Females lay eggs beneath the wooden bark of the branches and the trunk from where the grub emerges and bore into the tree branches.
- Grubs damage stems as well as roots (NHB, 2020).
- They make irregular cavities and feed on bark after hatching (Figure 1(f)).
- They dig tunnels frequently burrowing upward, which causes the branches to dry.

Management

- Infested shoots should be clipped-off and destroyed (Baradevanal et al., 2021).
- Clean holes and pour it with neem seed kernel extract (5%) into the hole and plug the hole with cotton/wool and paste mud (NIPHM, 2014a).
- Kill different life stages of stem borer by putting iron hook or wire inside the bored stem (Venkata et al., 2018).
- Covering of mango stem with nylon mesh during the month of May-August helps to capture newly emerged adult beetle and their killing them prevents further damage (Venkata et al., 2018).
- ARKA Borer Control (ABC) developed by IIHR application act as preventive and curative measures for borer control. It prevents egg laying and further damage by the grubs by applying this paste before rainy season at 2.5-3ft above the ground level as in Figure 2(e) (Chavan et al., 2025).
- Use chlorpyrifos 20 EC at 3 ml/l, imidacloprid 17.8 SL at 1 ml/l, or thiamethoxam at 1 g/l to spray the trunk section five times at weekly intervals to prevent infestation (Venkata et al., 2018).

7. Mango seed/Stone weevil

- Female lays eggs under the rind of developing fruits or on the epicarp of partially grown fruits (Carrillo et al., 2017).
- Grubs damage the cotyledons after feeding on the seed coat and pupation takes place inside the seed (Figure 1(g)).
- Fruits with infestations frequently exhibit discolouration of the surrounding pulp and affect the processing and exporting sectors.

Management

- Collection and destruction of infested mango fruits, as like for fruit flies (Bhattacharyya and Khound, 1995).
- Conservational biological control strategies like intercropping with sorghum, maize, bajra, blackgram, groundnut, etc., for population buildup of ants (*Camponatus* sp., *Monomorium* sp., and *Oecophylla smaragdina*). Microbial biocontrol agents such as *Aspergillus* sp., *Beauveria bassiana* are also proved to be effective, following the application rate as mentioned for mango hoppers (NIPHM, 2014a).
- Because of their hidden life phases, mango weevils have few natural predators; but adults can be preyed on by ants, rats, lizards, and birds (Hansen, 1993).
- Use a powerful broom to vigorously clean stem and branch joints, which will disturb resting mango weevils.
- Applying sticky bands to the top end of the tree trunk will stop weevils from migrating to branches in February to lay their eggs on fruits.
- Obtain mango stones for raising seedlings (root stocks) from healthy/un-infested plants.
- Apply 0.0025 percent deltamethrin six weeks following fruit set.

8. Mango leaf webber

- Young caterpillars feed gregariously and scratch the surfaces of leaves.
- Later, they web tender shoots and leaves together, feeding from within in groups.
- Affected trees appear sickly from a distance due to brown, dry webbed leaf clusters caused by severe feeding as shown in Figure 1(h) (Reddy et al., 2018).

Management

- Mechanical pruning of overcrowding, overlapping, and non-bearing dense branches in cultivation under leaf webber infested areas.
- In symptoms of webbed branches are observed, cut them down and destroy them (DPPQS, 2022).
- Spray lambda-cyhalothrin at 1ml/litre intervals for 15 days.

9. Termite

- Termites travel upward through tunnels and consume roots (Singh & Singh, 2003).
- On tree trunks, they create mud galleries and consume the bark under their protection.

Management

- Orchards should be kept clean and free of all.
- Do not injure the plants, as this may provide easy entry routes for termites.
- Ensure plants are not sick or water stressed (Verma et al., 1980)
- Whitewash the trunks with milk of lime.
- Get rid of affected plants and destroy the termites (Srivastava and Butani, 1987)
- Avoid making heaps of pruned materials or dead trees in the orchard.
- Apply Chlorpyrifos 20 EC @ 1 kg a.i./ha

10. Mango scale insects

- By sucking sap from leaves and tender parts nymphs and adult scales weaken the plants (Rai et al., 2019).
- Honeydew, which they exude, encourages the growth of sooty mould (Figure 1(j)).
- Severe infestations hamper the ability of mango trees to bear fruit.

Management

- Pruning of infested branches and burn them.
- Pruning should be done (branches and twigs) preferably during summer (Reddy et al., 2018).
- These should be placed in a pit constructed on one corner of the orchard. Allow branches and twigs to dry until the parasites escape.
- Burn the remaining debris.
- Removal of attendant ants may permit natural enemies to control the insect.
- Dimethoate (0.05%) and Malathion (0.075%) are often used to control scale insects, however sprays are only effective during the crawler stage (Raza et al., 2023).

11. Mango thrips

- Thrips damage young leaves, buds, inflorescences, flowers and developing fruits by lacerating and sucking sap (Verghese et al., 1988).
- This results in wilting of inflorescences, curling of the leaves, and silvery or brown spots (Figure 1(i)).
- In severe cases, affected fruits develop a rusty appearance.

Management

- Monitor for thrip infestation by placing sticky traps (Blue/yellow) at regular intervals as in Figure 2(d) (Reddy et al., 2018).
- Promoting natural enemies that include predatory thrips, predatory mites (e.g. *Amblyseius* spp.) anthocorid bugs or minute pirate bugs (*Orius* spp.), ground beetles, lacewings, hoverflies, and spiders (NIPHM, 2014a).
- Neem seed kernel extract (5%) and neem oil (2%) efficiently reduce thrips by focussing on nymphs and lowering adult egg-laying.
- For severe infestations, spray with pesticides such as thiamethoxam 25% WG (0.3 g/liter) or imidacloprid 17.8% SL (0.3 mL/liter).

12. Mango bud mite

- Mango malformation disease which is prevalent in North India is caused by mite infestation (Reddy et al., 2022).
- It targets axillary and internal buds, inhibiting their development.
- The infestation causes closely developed lateral buds to become crowded and deformed.

Management

- Removing and destroying infested plant parts, like dead or severely affected branches, helps reduce mite populations.
- Choosing tolerant or resistant mango varieties, such as Neelam or Humayudin, can minimize mite damage.
- Maintaining adequate spacing between plants allows for better air circulation, reducing humidity and mite proliferation.
- Introducing or conserving natural enemies of the bud mite, like certain predatory mites (*Amblyseius swirskii)*, can help keep populations in check (DPPQS, 2022).
- Encouraging the presence of beneficial insects like ladybugs and lacewings, which can feed on mites, is also helpful.

Table 2. Insecticides recommended by CIB&RC for the management of major pests in mango

Insecticide	Common name of the pest	Dosage/ha			Waiting period (days)
		a.i (gm)	Formulation (gm/ml)	Dilution in water (Liter)	
Buprofezin 25 % SC	Mango Hoppers	0.025% - 0.05%	1-2 ml/liter of water	5-15 liter per tree	20
Deltamethrin 02.80 % EC	Mango Hoppers	0.03 – 0.05 %	0.33-0.5 ml/lit	As per spray field requirement	01
Flonicamid 50 % WG	Mango Hoppers	200	400	1000	15
Imidacloprid 17.80 % SL	Mango Hopper	0.40 - 0.80g/tree	2-4ml/tree	10 litre	45
Lambda-cyhalothrin 05 % EC	Mango Hoppers	0.0025-0.005%	0.5-1.0 ml/l of water	-	07
Lambda cyhalothrin 24% w/w WDG	Mango Hopper	72.0	300.0	1500	7
Oxydemeton-methyl 25 % EC	Mango Hoppers	0.025%	1500-2000	1500- 2000	-
Pymetrozine 50 % WG	Mango Hoppers	150	300	1000	36
Thiamethoxam 25 % WG	Mango Hoppers	25	100	1000	30
Tolfenpyrad 15 % EC	Mango Hoppers, Thrips	150.0	1000	500	7
Triflumezopyrim 10% w/w SC	Mango Hoppers	25	23.6 ml/100 L water	1000	30
Spirotetramat 11.01 % + Imidacloprid 11.01 % w/w SC	Mealy bug	0.018%	0.075%	As per required	15

Source: DPPQS(GOI), 2024

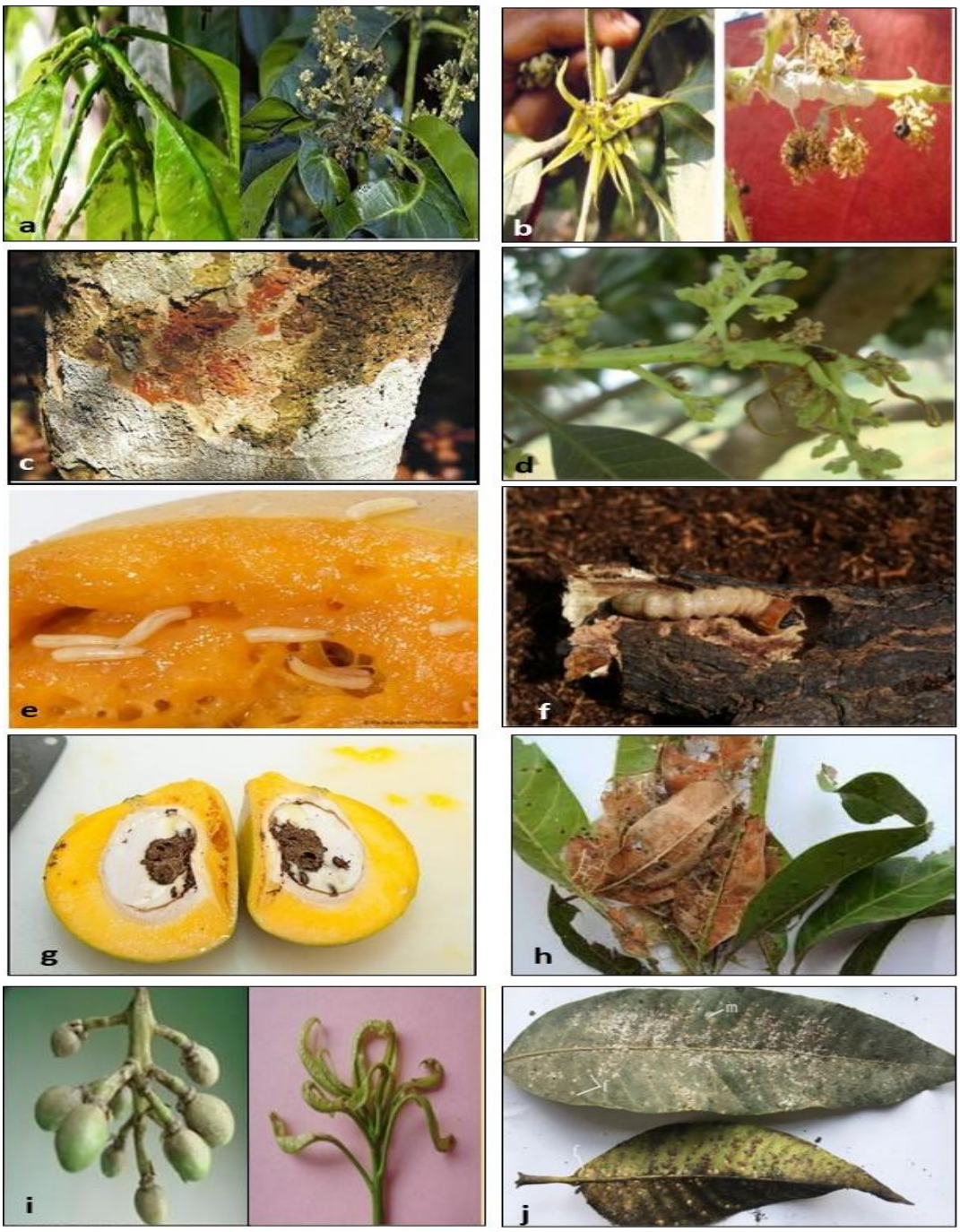

Figure 1. Damage caused by major insect-pests in mango

a) Mango hopper infestation on leaf and inflorescence (Munj et al., 2025), b) mealy bug attack on different plant parts (Singh & Baradevanal, 2021), c) damage caused by bark eating caterpillar on mango trunk (Garg, 2012), d) Affected panicle due to inflorescence midge (Reddy et al., 2018), e) fruit fly larvae on infested mango, f) mango stem borer infestation in trunk (Munj et al., 2025), g) stone weevil infestation in cotyledons (Kurmi & Upadhyay, 2023), h) mango leaf webber damage (Ibrahim et al., 2023), i) thrips attack on fruits and shoots ((Munj et al., 2025), j) Scale symptom on leaf (Hashim, 2021)

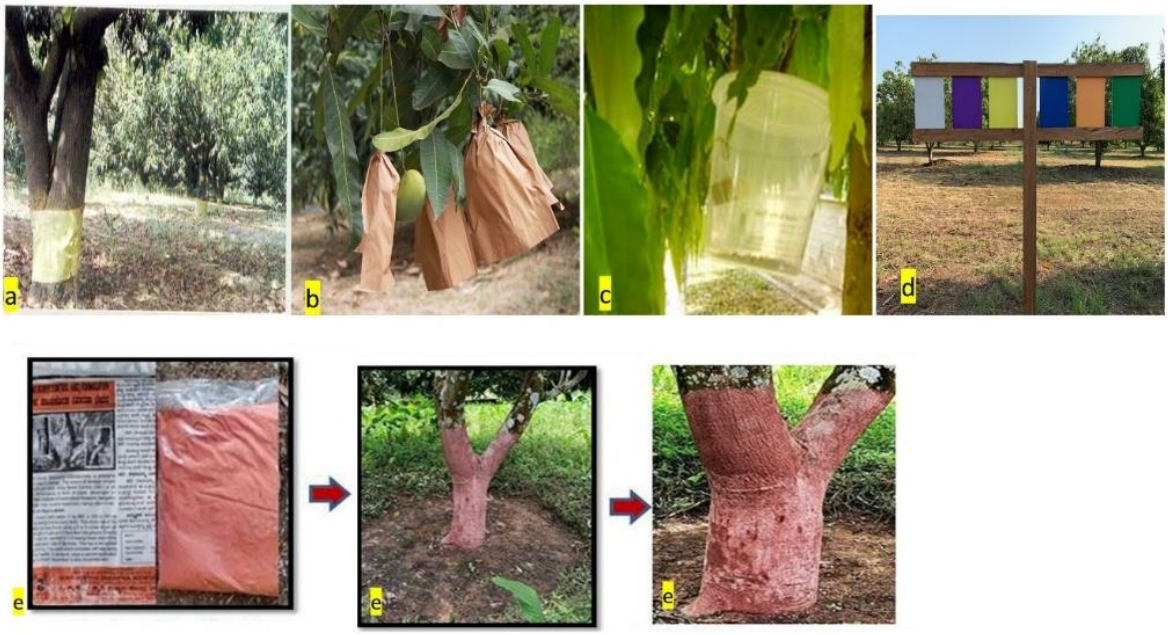

Figure 2. Management practices for some major insect- pests

a) Alkathene band for preventing mealy bug migration (IPM schedule for mango pests NHM ,2012), b) Paper bagging of fruits against mango fruit fly (Islam et al., 2023), c) Methyl eugenol traps, d) colored sticky traps in the mango orchard to attract thrips (Carrillo et al., 2022), e) Arka borer control slurry application on mango trunk (Chavan et al., 2025)

Conclusion

Effective management of mango pests requires integrating eco-friendly and sustainable approaches within an IPM framework. Emphasizing biological control, cultural practices, and minimal pesticide use can maintain orchard health, reduce environmental hazards, and ensure safer fruit production, supporting long-term productivity and sustainability in mango cultivation.

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