Comprehensive Guide to Citrus Diseases, Pests, and Disorders in India

Introduction

Citrus (including sweet oranges, mandarins, lemons, and limes) is a vital fruit crop for Indian farmers, especially in states like Telangana, Andhra Pradesh, Maharashtra, and the Northeast. Citrus trees, however, are vulnerable to a wide array of **diseases, pests, nutrient deficiencies, and physiological disorders**. These issues can severely impact yield – for example, **Huanglongbing (citrus greening)** alone can cause up to *30–100% yield loss* in affected orchards[1]. This guide provides an **in-depth, field-ready reference** on **all major citrus health problems in India**, with research-backed information and farmer-friendly advice. It covers fungal, bacterial, viral, and phytoplasmal diseases; insect and mite pests; nematodes; nutritional deficiencies; and physiological disorders, including those noted in sample surveys (such as **citrus canker, greening, sooty mold, citrus variegated chlorosis, melanose, mite damage, stem borers, dieback, leaf miner**, etc.). Each issue is detailed with **symptoms, causes, spread, distribution, economic impact, and integrated management** (cultural, organic, and chemical control). We also include a **master table of diseases**, a **visual symptom diagnosis chart**, comparative symptom tables, and seasonal occurrence insights for Indian regions. The language is kept straightforward for farmers, while maintaining scientific accuracy (including English and scientific names for pathogens/pests). This comprehensive guide aims to help farmers and extension workers **identify problems early, take preventive measures, manage outbreaks effectively with IPM, and know when to seek expert help** – thereby safeguarding orchard health and productivity in India.

Major Fungal Diseases of Citrus in India

Fungal pathogens thrive in humid, warm conditions and often cause characteristic spots, rots, molds, or blights on citrus. They spread via **airborne spores, rain-splash, and infected plant debris**. Many fungal diseases intensify during the monsoon and can cause fruit drop, blemishes, or tree decline. Below we detail key fungal diseases.

Citrus Scab (*Elsinoë fawcettii*)

Category: Fungal disease (leaf/fruit scab)
Description: Citrus scab (also called **sour orange scab or verrucosis**) is caused by a fungus *Elsinoë fawcettii*. It primarily affects leaves, twigs, and fruit surfaces, causing **raised, corky**

lesions. Scab is especially severe on **rainy-season flushes** in young orchards. Mandarins, lemons, and rangpur lime are very susceptible, whereas sweet oranges and acid lime are relatively resistant[2][3].

Citrus scab on a rough lemon fruit, showing raised corky scab lesions. This fungal disease (caused by Elsinoë *spp.) creates wart-like pustules on citrus leaves and fruits, especially in moist rainy weather.*

Symptoms: On young leaves, small, pale orange or gray spots form and develop into **wart-like, conical protuberances** (often on the underside of leaves with a corresponding sunken area on the top). Leaves may become distorted with **hollow, cone-shaped outgrowths** at lesion sites[4]. On fruit, scabby, irregular lesions form on the rind, which can be unsightly and cause fruit distortion. Unlike canker, **scab lesions lack a yellow halo and do not cause leaf yellowing** (and leaves are often distorted by scab, whereas canker lesions do not distort leaves)[5]. Twigs can also get scab pustules, potentially girdling young shoots.

- *Early-stage:* Small pinpoint orange flecks on new leaves and fruitlets during wet weather. Lesions enlarge into **slightly raised, soft corky spots**.
- *Advanced-stage:* Lesions turn **brown or gray, raised and wart-like**, merging into rough scabs. Older scabs become hard, cracked, and may drop out, leaving scars. Severe leaf infection causes distortion and **premature leaf drop**; fruit infections cause misshapen fruit and cracking if severe.

Causes & Spread: The scab fungus overwinters on infected twigs and old lesions. With spring/monsoon rains, it produces spores that spread via **rain-splash and wind-driven rain** onto new growth. **Humid, wet conditions (20–30°C)** favor infection. Young tissue (leaves/fruit under 6–8 weeks old) is most vulnerable[2]. Spread can also occur via movement of infected nursery stock.

Geographic Distribution: Scab is present in most Indian citrus-growing regions, especially where rain or high humidity coincides with flush growth (e.g. Northeast India, parts of South India during monsoon). It is commonly seen in nurseries and young orchards during rainy months. Lemons and mandarins in high-rainfall areas (Assam, Meghalaya, Western Ghats) often report scab outbreaks.

Economic Impact: While scab doesn't usually kill trees, it causes **cosmetic damage** and fruit drop, reducing marketable yield. Infections can result in 10–30% of fruit being unmarketable due to blemishes. For export fruits, even minor scab makes fruit unacceptable. Severe leaf infection can stunt young trees, delaying bearing.

Risks & Yield Loss: If unmanaged in susceptible cultivars (e.g. *Kagzi* acid lime, certain mandarins), scab can cause significant cull rates of fruit and reduce tree vigor. Yield losses of around 20% are common in badly infected orchards[6][7], and higher in young plantings if defoliation occurs. Scab also increases costs due to the need for protective sprays in nurseries and orchards.

Prevention: Use **scab-resistant rootstocks/varieties** when possible (sweet orange rootstock is tolerant[2]). Ensure **good air circulation** in the canopy by pruning, to reduce humidity. Avoid overhead irrigation in nurseries/orchards during new flush periods. Timely application of

fungicides in wet season new growth can prevent initial infections (see IPM). Nursery seedlings should be monitored and treated, as they can be a source of spread.

Integrated Pest Management (IPM): Cultural control includes pruning out and destroying infected twigs after harvest, and timing new flushes (through pruning or "bahar" regulation in acid lime) to avoid peak wet periods if possible. **Protective fungicide sprays** at key times are essential in susceptible varieties: - **Chemical protection**: Copper-based fungicides (Bordeaux mixture or copper oxychloride) or broad-spectrum fungicides like mancozeb can be sprayed just before rainy flush and repeated during wet weather[8]. For example, spray **Carbendazim 0.1%** or **Copper oxychloride 0.3%** at bud break and again 15–20 days later[8]. In areas with heavy scab pressure, 2–3 sprays in the monsoon flush may be needed. - **Organic options**: Use of lime sulfur or Bordeaux mixture (allowed in organic systems) can reduce scab. Also, **biofungicide** treatments with antagonists like *Trichoderma* on leaf surfaces may offer partial control. Ensure orchard sanitation – remove and bury fallen infected leaves and fruit to reduce spore load. - **Resistant rootstock or interstock**: As noted, using tolerant rootstocks (e.g. *Rangpur lime* or *trifoliate orange hybrids* for mandarins) can reduce scab severity[2]. - **Monitoring**: During wet weather, inspect new flushes for first signs of scab. Implement fungicide sprays promptly at first symptom appearance to arrest spread.

Chemical Control & Dosage: In India, recommended chemical controls for scab include spraying **Carbendazim @ 1 g/L** or **Copper oxychloride 50% WP @ 2–3 g/L** on new flushes. A typical schedule is to spray at **flush emergence**, then **repeat 2–3 times at 20-day intervals** during the rainy season[8]. Alternatively, **wettable sulfur 0.2–0.3%** can suppress scab and powdery mildew concurrently. Always follow label rates and pre-harvest intervals. Rotate fungicide classes to prevent resistance. (Note: In organic systems, use Bordeaux mixture 1% just after flowering and repeat after 2–3 weeks.)

When to Escalate: If **scab persists** despite sprays, or if you observe **new symptoms during dry weather** (suggesting it might be a different issue like canker or nutrient burn), consult an agricultural expert or plant pathologist. Also, if the disease is affecting a large percentage of young fruit (risking heavy crop loss), expert advice on spray programs or use of systemic fungicides may be needed.

Field Diagnosis Checklist: For citrus scab, use this quick field checklist: - Do young leaves or fruits have **raised, wart-like corky bumps** (especially on underside of leaves)? - Are lesions grayish or pink-orange and **irregularly shaped**, with adjacent tissue distorted (on leaves)? - Is there an absence of yellow halos (unlike canker) and presence of leaf **deformation**? - Did symptoms appear after wet/humid weather on new growth? - Are similar scabby lesions seen on nearby rough lemon or grapefruit (which are very susceptible, indicating scab presence)? If **yes** to the above, scab is likely. Confirm by noting that scraping the bump reveals corky tissue (and not bacterial ooze or hole). Use a hand lens to see fungal structures on old lesions if possible.

QR-Code Summary: *Citrus Scab – Fungal disease causing raised corky warts on leaves/fruit in wet weather. Symptoms: wart-like scabs on young leaves (leaf distortion) and fruit rind. Cause:* Elsinoë *fungus, spread by rain-splash in monsoon. Impact: cosmetic fruit damage, drop (20% yield loss if severe). Prevention: prune out lesions; spray copper or carbendazim in rainy flush. Manage: 2–3 timely fungicide sprays in monsoon; use resistant rootstock. Safe fruits but low market value. Report if severe.*

Phytophthora Gummosis (Foot Rot) (*Phytophthora spp.*)

Category: Fungal-like (Oomycete) disease – soil-borne root/trunk rot
Description: Phytophthora "foot rot" (also called **gummosis** or collar rot) is a devastating disease caused by soil-inhabiting **Phytophthora** fungi (commonly *P. nicotianae* and *P. palmivora*, formerly *P. parasitica*, and *P. citrophthora*). These pathogens attack citrus roots, crown, and trunk, causing bark rot, **copious gum oozing**, and tree decline. Gummosis is a leading cause of citrus tree "dieback" and decline in India, especially in groves with poor drainage. It often starts at the tree base (foot) and can girdle the trunk, killing the tree. In India, foot rot is prevalent in heavy soils or areas with high soil moisture (monsoon floods, over-irrigation). **Sweet orange, mandarin, and rough lemon** are susceptible, but some rootstocks (like trifoliate orange hybrids) show tolerance[9][10].

Symptoms: Early signs include **yellowing of leaves**, leaf drop, and oozing gum (a sticky brown resin) from small cracks in the bark near the soil line[11][12]. As infection progresses: - **Bark lesions**: Water-soaked, reddish-brown streaks on trunk or main roots. Bark may crack vertically and chunks of bark may slough off, exposing decayed wood. Affected bark when cut shows brown necrotic areas with gum pockets. Gumming is so prominent that dried amber-like gum deposits form on the trunk[13]. - **Girdling**: If the lesion encircles the trunk ("girdles"), the tree canopy rapidly declines – leaves wilt, turn brown, and the tree may **die back from the top**. - **Leaf and Fruit symptoms**: In early stages, trees show general chlorosis and dieback of twigs (from root damage). Often, just before death, a stressed tree may produce an unusual heavy bloom or crop of small fruits (as a last gasp)[14]. Fruit might remain undersized and have dull color. - **Root rot**: Below ground, feeder roots rot, turning black and sloughing off their outer cortex. In chronic cases, the canopy thins, and the tree shows stunted growth and twig dieback ("citrus decline").

- *Early-stage indicators:* isolated patches of gum exuding on lower trunk; slight yellowing of foliage on one side of the tree; soft or moist decay on some roots.
- *Advanced-stage indicators:* extensive **girdling gum lesions** around trunk base; bark can be easily peeled off to reveal brown rot underneath; **severe gumming**, foul odor if secondary infection; tree canopy sparse with leaf drop and twig death; tree may collapse or die especially in hot weather due to root failure.

Causes & Spread: Phytophthora is soil-borne and thrives in wet soils. It produces motile spores (zoospores) that swim in waterlogged soil and infect roots or wounded trunk bark. Infection often starts at the **collar if water contacts the trunk** (e.g., improper irrigation). **Poor drainage, waterlogging, or standing water around trunks** greatly increase risk[15][16]. The pathogen can also spread via infected nursery stock or soil movement. High soil moisture and moderate temperatures (~25°C) favor disease development. Wounds or cracks in bark (from insect damage, tools, or even cracks from sunscald) allow easier entry. The disease often flares up in **monsoon** when soils are saturated. **Susceptible rootstocks** like sour orange or rough lemon allow Phytophthora to invade more easily[17].

Geographic Prevalence in India: Gummosis occurs in all citrus-growing regions but is most severe in areas with heavy clay soils or excessive rainfall/irrigation. It is commonly reported in central India (Nagpur region), parts of Punjab (in older orchards), and southern states like Telangana and Andhra (especially in low-lying groves). Groves with flood irrigation or where water accumulates around trunks show higher incidence[15].

Economic Impact: Phytophthora gummosis is one of the **most serious citrus diseases worldwide**. It causes slow decline or sudden death of trees, leading to replanting costs and lost production. In India, **citrus decline** has been heavily attributed to gummosis and root rot complexes. Trees can die within 1–2 seasons of girdling infection, representing 100% loss of that tree's output. Even sub-lethal infections reduce vigor and yield (e.g., 20–50% yield reduction in moderately affected trees). Entire orchards on susceptible rootstocks can be destroyed if not managed – historically, gummosis and associated root rots have decimated groves in parts of northeastern India[18]. The cost to manage (fungicide treatments, trunk painting, etc.) adds to economic burden.

Risks & Yield Loss Projections: If 10% of trees get foot rot, orchard yield can drop by ~10–20% from tree loss and adjacent tree weakening. Severe outbreaks in poorly drained blocks might kill 30–50% of trees over a few years if unchecked. In **extreme cases**, orchard productivity might become uneconomical, forcing replanting on tolerant rootstocks. Yield losses due to fruit drop and smaller fruit also occur in chronic cases. Because gummosis often coincides with root rot (Fusarium, etc.), a complex called "citrus decline" may cause progressive loss of productivity across an orchard if Phytophthora is not controlled.

Prevention: Key prevention strategies include **good water management and orchard hygiene**: - **Drainage:** Plant orchards on raised beds or ensure soil has good drainage. Avoid water accumulation at trunk base; use ring/basin irrigation that keeps water away from direct trunk contact[15]. - **Irrigation practices:** Use drip irrigation or furrows that do not touch the trunk. Avoid frequent shallow watering that keeps soil wet; allow drying between irrigations. - **Resistant rootstocks:** Whenever possible, use Phytophthora-tolerant rootstocks (e.g., *Trifoliate orange* and its hybrids like Carrizo citrange, or rough lemon to some extent). In India, *Cleopatra mandarin* rootstock also has moderate tolerance. - **Quarantine in nurseries:** Only use certified disease-free seedlings. Phytophthora can come with nursery stock – ensure the nursery follows clean stock and soil practices. - **Orchard sanitation:** Remove and destroy (burn or deeply bury) any dead citrus stumps or roots, as Phytophthora can survive on decaying roots[19]. Do not leave old infected wood in the orchard. - **Trunk protection:** Avoid injury to the trunk/collar (from tools or pests). Some farmers apply a **Bordeaux paste or paint (copper-based)** up to 50–60 cm height on trunk as a preventive shield, especially before monsoon[20]. - **Soil solarization:** In nurseries or replant sites, soil solarization (covering soil with clear plastic in hot months) can reduce Phytophthora inoculum.

IPM (Integrated Management): Combining cultural and chemical measures is essential for gummosis: - Monitor orchards **post-monsoon and spring** for gummosis symptoms. If gum or bark lesions are seen early on a tree, **act immediately**: - **Physical removal:** Carefully scrape off the diseased bark (plus a margin of healthy tissue) from lesions on the trunk using a clean knife[15]. Disinfect tools between trees. Expose the lesion to air (Phytophthora dislikes dryness). - After scraping, **apply a fungicidal paste** on the lesion area (e.g., Bordeaux paste or copper oxychloride paste) to kill residual fungus[21]. - **Fungicide trunk treatments:** Paint the trunk base with **Bordeaux mixture (1% traditional 2:2:250)** up to at least 30 cm above ground in the pre-monsoon period[22]. This acts as a protective barrier. - **Soil drench:** During wet periods, drench soil around the trunk with systemic fungicides. For example, **Metalaxyl + Mancozeb (Ridomil MZ 72)** at 2.75 g/L or **Phosphorous acid (H3PO3)** are effective against Phytophthora[23][24]. A common recommendation is to drench each affected tree with 25 g Ridomil MZ in 10 L water around the root zone, in spring and again mid-monsoon[25][24]. -

Foliar sprays: Spraying copper fungicides on foliage can reduce inoculum from sporangia during rainy periods. Also, **Aliette (Fosetyl-Al)** at 2.5 g/L sprayed on foliage has systemic action controlling Phytophthora[24]. - **Biological control:** Incorporating biocontrol agents like *Trichoderma harzianum* in soil near the trunk can suppress Phytophthora. Also, organic amendments (neem cake, compost) can promote antagonistic microbes. - Ensure **grove hygiene** – avoid flooding, improve soil structure (gypsum, organic matter), and consider **crop rotation** with a non-host if orchard is removed (to let soil pathogen levels drop). - For existing lesions, some farmers inject or paint **fungicide solution** (e.g., Metalaxyl or potassium phosphite) directly on the cleaned wounds to speed healing.

Organic Remedies: Copper compounds are generally allowed in organic farming: **Bordeaux mixture** application as described is a proven organic remedy (since copper is natural). Additionally: - Use of **neem cake** around tree bases (which has some fungitoxic effect and improves soil health). - Frequent application of **Trichoderma-enriched manure** around root zone. - **Liming the soil** if pH is low – Phytophthora prefers acidic conditions, so maintaining near-neutral pH can reduce disease. - Some reports suggest a paste of cow dung + ash applied to lesions helps dry them out (traditional practice). However, efficacy is anecdotal.

Chemical Control (Dosage): For non-organic management, recommended chemical treatments in India include: - **Metalaxyl 5% (e.g. Ridomil)**: Drench 25 g per tree in 10 L water around the trunk base[24]; repeat 2–3 times (pre-monsoon, mid-monsoon, post-monsoon). Or use Metalaxyl-M 3% + Mancozeb 72% WP at 2–3 g/L as a soil drench and foliar spray.
- **Phosphoric acid (HPO3)** or **Fosetyl-Al (Aliette)**: Spray 2.5 g/L on foliage and also drench trunk base, twice a year (just before monsoon and mid-monsoon)[24]. This boosts tree's resistance and kills Phytophthora.
- **Copper oxychloride**: After scraping lesions, paint with Copper oxychloride 50% WP paste (50 g + 5 g lime in 1 L water) on the trunk wound. Also spray Copper oxychloride @ 0.3% on entire tree to prevent new infections[15].
- **Bordeaux paste**: Make a thick paste of Bordeaux mixture (1 kg lime + 1 kg copper sulfate in 10 L water) and brush it on trunk up to 1 m height at least once a year (just before monsoon)[20]. This is a time-tested preventive.
Always follow safety guidelines while handling fungicides. Note that once a trunk is girdled beyond 50%, saving the tree is difficult – chemical treatments help mostly in early to moderate stages.

When to Escalate to an Expert: If you observe **rapid gummosis on many trees** or if trees continue to decline despite treatments, call an expert. Also, if unsure whether the gumming is due to Phytophthora or other causes (like *Diplodia* gummosis or bacterial infection), get a lab diagnosis. **Escalate** when: - More than 10–15% of trees show gummosis in an orchard season – this could indicate a systemic irrigation/drainage issue that needs expert planning. - A valuable tree (e.g., in a germplasm collection or a very old tree) is affected – experts might suggest special surgical interventions or top-working onto new rootstock. - If secondary pests (like bark beetles) attack the weakened gummosis trees, an expert can advise on combined management.

Field Diagnosis Checklist: To diagnose Phytophthora gummosis in the field: - Check lower trunk for **brownish gum oozing**. Scrape a small bit of bark – is the inner bark **brown and water-soaked** (instead of healthy green-white)?[13] - Smell the area – Phytophthora infections often have a slight **rotten smell**. - Look at leaves: Are they yellowing and dropping, especially in

one sector of the tree? - Examine the root crown – is there bark sloughing off at ground level? In advanced cases, can you almost peel the bark off the base easily? - Has the soil been waterlogged recently or irrigation hitting the trunk? - Are there any mushrooms or fungal growth at base? (Phytophthora itself doesn't make mushrooms, but other root rot fungi like *Armillaria* produce mushrooms – if present, indicates mixed infection). If most answers support gummosis, initiate control immediately. Mark the tree and monitor weekly.

QR-code Summary: *Phytophthora Foot Rot (Gummosis) – Deadly trunk/root rot. Symptom: gumming on trunk base, bark rot, yellow leaves, collar cracking. Cause:* Phytophthora *fungus from waterlogged soil. Spread: wet soil, poor drainage, trunk wounds. Impact: kills trees (major citrus decline cause). Prevent: avoid water contact on trunk; improve drainage; resistant rootstock; paint trunk with Bordeaux before rains. Manage: scrape lesions + apply copper; drench soil with metalaxyl or phosphoric acid; repeat in monsoon. If severe: remove tree to prevent spread. Report sudden gum lesions to expert.*

Dry Root Rot (Brown Rot of Roots) (*Fusarium solani*, *Diplodia* spp., etc.)

Figure 1. Dry root rot disease in lemon orchard planted on Carrizo in Santa Paula. a) Lemon trees with yellow foliage; b) impacted crown, roots and vascular system and usually abundant fruit fallen over from dry root rot; c) wilted dead tree.

Category: Fungal disease (root decay)
Description: Dry root rot is a chronic disease complex often involving fungi like *Fusarium solani*, *Macrophomina phaseolina* (charcoal rot), and *Diplodia* (Lasiodiplodia) species attacking citrus roots[26]. Unlike Phytophthora (which causes a wet, gummy rot), dry root rot leads to a

drier, fibrous decay of roots and lower trunk, often during hot, dry periods following stress. It is called “dry” rot because affected bark and wood become hard, dry, and brittle with shredded fibers, rather than water-soaked. Often, trees suffering drought stress or previous Phytophthora damage are predisposed to dry root rot. In India, dry root rot has been observed particularly in older groves on light soils and in water-stressed conditions (e.g., Vidarbha region during summer). The disease can cause sudden wilting of the tree in extreme cases.

Symptoms: Trees may initially show **mild leaf yellowing and twig dieback**. Affected roots exhibit a **dark brown to black decay**, but with a distinctly dry, stringy appearance. Key signs: - **Lower trunk/butt rot:** In advanced cases, the bark near the root crown becomes dry, cracked, and may **shred into vertical strips**, adhering in pieces (as opposed to sloughing in Phytophthora)[26][27]. There may be little to no gum exudation. - **Roots:** Major roots show **dry, dark decay** of the woody core. The bark may be gone, leaving bare wood that is dark and lightweight. Often a foul odor is present (especially with *Diplodia* involvement)[28]. - **Foliage:** The tree canopy thins gradually. Leaves turn dull, sometimes clinging dried on branches. Fruit size may reduce. In some cases, the tree suddenly **wilts and dies** (often when soil moisture is depleted), as the compromised root system can’t support the canopy (“collapse”). - *Early indicators:* one or two scaffold limbs show dieback; tree flowers heavily out-of-season (as a stress response); bark at base looks unusually firm but has internal discoloration. - *Advanced:* Multiple branches die, often starting from the top (giving a stagheaded look). The trunk base sounds hollow on knocking (due to wood deterioration). The entire tree may be defoliated except for a few tufts of leaves before death.

Causes & Spread: Dry root rot is typically a **secondary infection** that sets in when trees are stressed (drought, extreme heat, or prior root damage by Phytophthora or nematodes). *Fusarium* and *Lasiodiplodia* are common soil fungi or inhabit decaying wood, invading weakened roots. The disease often follows a pattern: **extended drought or heat -> tree stress -> feeder roots die -> opportunistic fungi colonize -> rapid decay when moisture returns**, causing tree death. The fungi persist in soil and old roots; spread is slow and mainly via root-to-root contact or moving infected soil. High soil temperatures and low moisture trigger their activity (for *Macrophomina*, hot dry conditions favor it).

Geographic Distribution: Found across citrus areas in India, especially in arid/semi-arid regions (central and western India) where water stress occurs. Notably reported in parts of Maharashtra and Karnataka during drought years. Also occurs in neglected orchards with poor irrigation management.

Economic Impact: Dry root rot can cause **sudden death of mature trees**, which is a direct financial loss and reduces orchard yield. The impact is often sporadic (a few trees here and there) but can cluster if underlying stresses are common. Losing a mature tree could mean losing 50–100 kg of fruit per year per tree. If 5–10% of trees are lost over a summer, that’s a similar percentage yield loss. The cost to remove and replant trees and the lag for new trees to bear is significant. Fortunately, dry root rot outbreaks are not usually epidemic; they are manageable with improved cultural care.

Risks & Yield Loss: Trees killed by dry root rot obviously cease production. If detected late, surrounding trees might also be affected (especially if an irrigation issue or contiguous root spread). Yields in trees with partial root rot decline by ~20-30% (smaller fruits, fewer flushes).

In a worst-case scenario (severe drought followed by monsoon), susceptible orchards might lose many trees, risking orchard viability. However, with interventions (irrigation, mulching, etc.), losses can be minimized.

Prevention: The best defense is **reducing tree stress** and maintaining root health: - **Irrigation management:** Avoid letting trees go bone-dry in summer. Even drought-tolerant rootstocks need some moisture – implement irrigation scheduling to prevent severe water stress. Conversely, avoid sudden excessive irrigation after drought; re-wet the soil gradually. - **Mulching:** Apply organic mulch around tree bases to moderate soil temperature and moisture fluctuations. This also promotes beneficial microbes that outcompete pathogens. - **Soil health:** Incorporate organic matter to improve soil structure and water retention. Healthier soil helps roots resist opportunistic fungi. - **Nutrient balance:** Ensure the trees are well-nourished (especially potassium and calcium which improve root robustness). Zinc and boron deficiencies should be corrected, as they can predispose to twig dieback and entry points for fungi. - **Phytosanitation:** Remove dead stumps and large roots from previous trees – *Lasiodiplodia* and *Fusarium* thrive on dead wood[19]. Burn or dispose of such debris away from orchards. - **Resistant rootstock:** Some evidence suggests trifoliate orange-based rootstocks have less dry root rot because they limit deep rooting and avoid extreme drought damage. Use suitable rootstocks for the region's climate (e.g., *Rough lemon* is vigorous but might be more prone in drought if not irrigated). - **Intercropping caution:** Avoid water-demanding intercrops that could steal moisture, or legumes that could host Fusarium, in citrus orchards.

IPM Strategies: - Regularly **inspect tree trunks and root crown** for signs of decay. Probe the soil near suspect trees for black roots. - If a tree shows dieback, consider **testing** a small root sample or lower trunk piece for Fusarium/Diplodia at a lab (to confirm pathogen). - Upon early detection, **surgery** can be attempted: excavate around root crown, cut away any dead rotted wood, allow the area to dry. Sometimes filling the void with a paste of fungicide + clay can help protect it. - **Treat surrounding soil**: Drench area with broad-spectrum fungicide (like Copper oxychloride or Bordeaux) to limit fungal spread in soil. While systemic fungicides (phosphonates) primarily target Phytophthora, high-dose drenching might suppress some Fusarium in soil. - **Biocontrol**: Apply *Trichoderma viride* or *Pseudomonas fluorescens* formulations in the root zone; these antagonists can reduce pathogen buildup. - Water management is key: if one tree got dry root rot due to under-watering, immediately adjust irrigation for the rest to avoid a chain reaction. For instance, pulse irrigate (small amounts frequently) to save other trees in drought. - If large limbs are dying, prune and destroy them – *Lasiodiplodia* often comes from dead wood above ground too (called *Diplodia dieback*). So prune off dead branches to reduce inoculum rain splash to the base.

Organic/Traditional Remedies: Organic approach focuses on soil health: - **Neem cake or mustard cake** application in soil can act as biofumigant, deterring some soil fungi. - Drench with **10% cow urine solution** or trichoderma-enriched cow dung slurry around root zone – some farmers claim this helps root diseases. - Use of **ash** around the base (raises pH slightly and adds potash) can hinder some fungi. - Planting **marigold** or **mustard** as cover crop and plowing them in (green manuring) is reported to reduce Fusarium load. - Avoid any harsh chemicals that could kill beneficial soil life; rely on compost teas to introduce competing microbes.

Chemical Control (if needed): There's no specific "dry root rot" chemical cure once wood is rotted, but preventative fungicides help: - **Carbendazim** (a systemic fungicide effective on

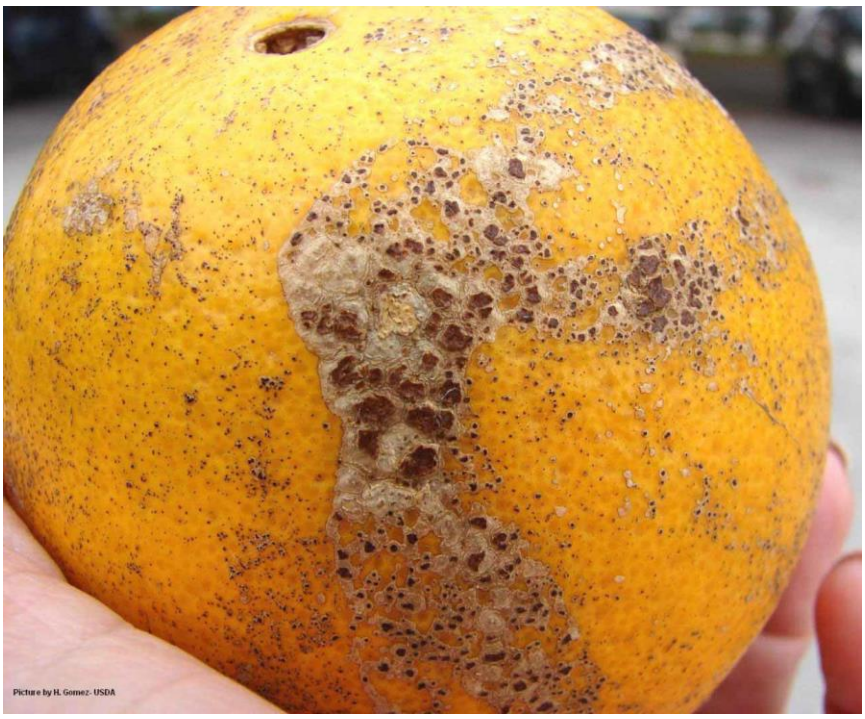
Fusarium): Drench 1 g/L around root area of nearby trees when one tree is affected. Carbendazim can be injected (drilled holes in trunk base) in some cases to reach sapwood. - **Thiophanate-methyl** (similar to carbendazim) or **Triazole fungicides** (like Tebuconazole) could be tried as soil drench for their broad-spectrum activity on Fusarium and Diplodia – not standard, but experimental. - Copper fungicides in soil will suppress fungal activity but are more protective than curative. - Ultimately, severely affected trees should be removed: treat the stump and soil with a fungicide to reduce the inoculum for neighboring trees.

When to Seek Expert Help: If multiple trees start showing symptoms of root rot (especially after drought or in a localized patch of the orchard), it's time for expert intervention. An expert can help determine if it's dry root rot, Phytophthora, or a combination. Also seek help if unsure how to manage irrigation without causing other issues. If you plan to replant trees in an area where others died of root rot, consult experts on soil treatment (e.g., fumigation or bio-renovation) to avoid re-infection of new trees.

Field Diagnosis Checklist: To identify dry root rot in the field: - Has the tree suffered **drought or water stress** recently (leaf flagging on hot days)? - Do you observe **dieback** in the canopy that progressed during a dry spell? - Examine the base: Is there **no gum (or minimal)** but bark looks **dry, cracked, fibrous**? - Dig a bit: Are the structural roots **blackened and dry**, sometimes hollow, with threads of remaining wood? (Phytophthora rot would be mushy; here it's dry and fibrous). - Scratch a small root: if it's dry rot, the cortex might already be gone, leaving a threadlike stele. - Do cut cross-sections of lower trunk/large root show dark stain rings (from *Diplodia* perhaps)? - Check for **Armillaria**: in case there are white fungal sheets under bark or honey-colored mushrooms at base, that's a different root rot (Armillaria). Dry root rot generally lacks those. If evidence points to dry root rot, focus on improving water to remaining trees and implement above controls.

QR-Code Summary: *Dry Root Rot – Chronic root decay often after drought. Symptoms: Gradual tree decline, twig dieback, then sudden wilt; trunk bark dry, cracked, fibrous strips; roots black, dry, stringy rot (little gum). Caused by: soil fungi (*Fusarium, Diplodia*) attacking drought-stressed roots. Spread: via soil, dead wood, root grafts; not rapidly contagious but stress-triggered. Impact: kills scattered trees; ~5–10% orchard loss in bad years. Prevent: avoid severe drought – irrigate, mulch; remove dead stumps; maintain soil health. Manage: improve watering, apply Trichoderma biofungicide; drench carbendazim around neighboring trees. No cure for advanced rot – remove dead trees and treat soil. Consult experts if many trees affected.*

Citrus Melanose (*Diaporthe citri = Phomopsis citri*)



Category: Fungal disease (foliar/fruit blemish)
Description: Melanose is a fungal disease that causes **dark brown, sandpaper-like lesions** on leaves, twigs, and fruit. It's caused by *Diaporthe citri* (anamorph *Phomopsis citri*), which primarily infects **aging twigs and dead wood**, producing spores that splash onto new fruit and

leaves during rains. The disease is common in older, unpruned orchards and after periods of rain. While melanose doesn't typically cause severe damage to tree health, it can **significantly blemish fruit**, reducing fresh market quality. In sweet oranges (like Nagpur mandarin, Sathgudi orange) and grapefruit, melanose is well-known; acid lime and lemons can also get it if dead wood is present.

Symptoms: - On **leaves**, tiny brown dots appear – they are slightly raised and can merge to form patches or streaks of rough, dark brown crust on the leaf surface (often along drip patterns of water). The texture is gritty (feels like sandpaper). Severe infection can cause leaves to yellow and drop early. - On **fruits**, small round brownish spots form, which may later become raised, giving a speckled or **"flyspeck"** appearance. If numerous, they can coalesce into larger rough patches or tear-streak patterns called "mudcake melanose" when heavy spore load runs down fruit in water flow. Fruit lesions are superficial but make the rind ugly – initially brown, later black and hard. - On **twigs**, melanose may cause dieback of young twigs: elongated brown lesions that girdle and kill twigs. On older (dead) twigs, the fungus produces tiny black fruiting bodies (perithecia/pycnidia), visible with a hand lens. - *Early-stage indicators:* after a rainy spell, new flush leaves show a few brown pinpricks, fruitlets show tiny brown specks. If observed closely, a gelatinous spore mass might be visible on nearby dead twigs during/after rain (source). - *Advanced-stage:* Leaves and fruit surfaces feel rough and sandpapery with dozens of dark spots; heavy fruit infection may cause fruit drop or hardening of rind. Twig dieback due to girdling lesions on green twigs in extreme cases.

Causes & Spread: The melanose fungus thrives on **dead citrus wood** – it colonizes twigs that have died from pruning, frost, or disease. In warm wet weather (optimal ~25–30°C with rain), the fungus produces spores (both sexual and asexual) that are spread by **rain-splash and wind-driven rain** onto younger tissue. Spores landing on fruit or leaves germinate and infect if the surface stays wet for a few hours. Thus, **monsoon rains** drive melanose outbreaks. Older fruit/leaf tissue (more than about 4 months old) becomes resistant, so infection mainly occurs on new flush and developing fruit. If trees have a lot of dead wood (old unpruned branches), they provide a continuous spore source each time it rains. The fungus can survive between seasons in this dead wood; it does not typically spread from tree to tree unless spores splash or blow, so distribution is often **within-tree or adjacent tree**. **High humidity and poor airflow** exacerbate it.

Geographic Prevalence: Melanose is found anywhere citrus is grown in humid conditions. In India, it's commonly observed in older sweet orange groves in central India and Telangana, especially if pruning is neglected. Also prevalent in coastal citrus areas and northeast during rainy season. Young orchards or vigorously pruned ones have less melanose due to fewer dead twigs.

Economic Impact: Melanose primarily causes **cosmetic fruit damage**. For fresh fruit markets (table oranges/lemons), melanose speckling can downgrade fruit, reducing their value. In processing oranges (for juice), it's less of an issue except severe cases that reduce fruit size or cause premature fruit drop. Economic losses come from increased culls – fruit with heavy melanose might be unmarketable for fresh sale. This can be 10-30% of fruit in badly managed orchards. The disease doesn't usually kill trees, but if twig dieback is extensive over years, it may lower yield somewhat by reducing fruiting wood. Control costs (sprays) are also a factor.

Risks & Yield Loss: If no control, melanose can affect nearly 100% of fruit surfaces in susceptible varieties in wet years. While yield (weight) may not drop much, **marketable yield** (grade A fruit) can drop substantially. Export-quality demands near-clean fruit, so melanose presence can eliminate export options. Thus, in an unmanaged situation, effective losses could be 20-50% of crop value rather than volume. In combination with other issues (canker, etc.), the overall fruit quality can suffer greatly.

Prevention: - **Prune out dead wood:** This is the single most important preventive step. After harvest or before monsoon, remove all dead twigs and branches from trees[29]. Burn or dispose of them – do not leave them in orchard. - **Open the canopy:** Proper pruning to allow air flow will help foliage dry faster and reduce infection periods. - **Manage other pests/diseases:** Because twig dieback often results from other issues (like citrus psyllid feeding, Phytophthora, etc.), controlling those will reduce dead twigs. Healthy trees = less dead wood = less melanose. - **Avoid overhead irrigation** in the evening; if you must irrigate with sprinklers, do it in morning so foliage dries before night. - **Copper sprays**: A pre-monsoon spray of copper fungicide can prevent spores from taking hold on new fruit (discussed below). - **Resistant varieties:** There's some variation in susceptibility – grapefruits are very susceptible, lemons moderately, mandarins less so. If melanose is a recurring severe issue, consider varieties like certain mandarins which show fewer symptoms.

IPM Measures: - **Monitoring:** Just before monsoon, inspect for small lesions on fruitlets or a lot of dry twigs with fungal bodies. This indicates need to spray. Also monitor after long rains. - **Cultural:** As mentioned, sanitation pruning is part of IPM. Also, do not leave harvested fruit stems or debris hanging in trees. - **Biological control:** Some research suggests *Trichoderma* or *Bacillus subtilis* based biofungicides on the canopy might suppress melanose, but chemical copper is still more effective. - **Fungicide timing:** IPM for melanose uses **protectant fungicides** at the right time: Typically, a **Copper spray** or **Strobilurin fungicide** (like azoxystrobin) soon after petal fall (when young fruit are most vulnerable) can prevent melanose. A second spray 2–3 weeks later (during peak monsoon onset) may be needed in high-pressure areas. Copper not only directly kills spores on contact but also helps in other disease control like canker simultaneously[30]. - **Combined approach:** If also fighting scab or canker, copper sprays will handle melanose concurrently. For heavy infection years, adding a sticker/spreader to sprays ensures better coverage on fruit. - **Organic IPM:** Use **Bordeaux mixture** as an alternative to commercial copper fungicide – e.g., spray 1% Bordeaux just after fruit set and again mid-monsoon. It is allowed in organic systems and effective. - Consider **post-harvest wash**: Not a field IPM per se, but washing fruit with soap and fungicide soon after harvest can lighten melanose spots a bit and remove sooty mold, improving appearance (though it won't remove the actual melanose scars).

Chemical Control: - **Copper fungicides** are the standard. E.g., **Copper oxychloride 50% WP @ 2.5–3 g/L** or **Copper hydroxide @ 2 g/L**. A spray when fruit are ~1 cm size (approximately 2–3 weeks after flowering) and another 3 weeks later can greatly reduce melanose incidence on fruit[22][10]. - **Strobilurin fungicides (QoI)**: Azoxystrobin or trifloxystrobin are very effective against melanose and have translaminar action. Azoxystrobin @ 1 mL/L sprayed twice (petal fall + 3 weeks) can protect fruit. Ensure rotation (don't use strobilurin every time) to avoid resistance. - **Mancozeb** (a broad-spectrum contact fungicide) @ 2–3 g/L can also be used; it's protectant and can be mixed with copper for wider disease control. - **Thiophanate-methyl or Carbendazim** have some effect but copper/strobilurins are preferred. - Follow all label rates.

Copper can cause phytotoxicity (rusty leaves) if overused in hot weather – stick to recommended dose and don't spray copper in scorching heat (apply in cooler hours).

When to Escalate: Melanose typically doesn't need expert intervention if you follow prune-and-spray measures. However, if you are observing unusual symptoms (e.g., black spots that penetrate deep, which could signal citrus black spot disease – not known in India widely) or if your spray program fails to reduce melanose, you might want an expert pathologist to confirm the diagnosis. Also, large export orchards might seek expert advice on timing and choice of fungicides to ensure residues are within limits. If melanose is occurring despite not having dead wood (which is rare), an expert could check if perhaps *Alternaria* disease is being confused with melanose.

Field Diagnosis Checklist: - Are there many **small brown specks** on fruit and leaves that feel rough to touch? - Is there a pattern of lesions in a streak (indicating rain washed spores downward)? For example, a "tear drop" stain of confluent spots on fruit. - Can you find **dead twigs** in the tree with tiny black dots (fungal fruiting bodies)? If yes, that's likely the source. - Did the symptoms appear after periods of rain? - Do the spots stay superficial (they don't rot deeper or have halos)? (Unlike canker which has halo and depressions). - If you rub the fruit surface, the melanose spots won't rub off (they are scabs in rind). Those observations confirm melanose. (Pro tip: If you have a UV light, melanose spots on rind show a unique pattern vs canker, but that's not typically done in field).

QR-Code Summary: *Melanose – Fungal blemish disease. Symptoms: tiny dark-brown rough spots on leaves & fruit (sandpapery feel); cosmetic "flyspeck" or streaks on fruit rind; some twig dieback. Cause:* Diaporthe/Phomopsis *fungus on dead twigs; spores spread by rain-splash. Mostly cosmetic but lowers fruit grade. Favored by: presence of dead wood, rainy weather. Manage: prune and burn dead wood (source); spray copper fungicide after flowering to protect young fruit[10]. Impact: fruit quality loss, not tree-killing. IPM: orchard sanitation + timely copper or azoxystrobin sprays; improve airflow. Rarely needs expert unless confused with other spots.*

Citrus Anthracnose (Wither Tip) (*Colletotrichum gloeosporioides*)

Category: Fungal disease (twig, leaf, and postharvest fruit rot)
Description: Anthracnose in citrus, often called **wither tip** or dieback, is caused by *Colletotrichum* fungi. It tends to attack weak or senescing tissue – causing **leaf spots, leaf fall, twig dieback**, and can also rot dead wood or injured fruit. It is more of a problem on trees already debilitated (by nutrient deficiency, etc.) and during prolonged wet spells. Key manifestation is the dieback of twigs from the tips (hence "wither tip"). It can also cause **postharvest decay** on overripe fruits (known as anthracnose fruit rot, where oranges get dark stained areas). Leaves on low vigor branches develop irregular brown blighted areas. This disease often co-exists with other issues (e.g., after scab or pest damage, anthracnose moves in).

Symptoms: - **Twig dieback:** Small twigs (especially those that had fruit) turn grayish brown and die from the tip inward. Often you'll see a clump of dead leaves still attached on these twigs (leaves died so fast they didn't drop). These dead leaves later fall, leaving bare twigs. The tips of branches look blighted as if by drought or heat, but it's fungus causing it. - **Leaf lesions and drop:** On older leaves, irregular **brown to black patches** can form, often starting at the margin

or following petiole infection. Leaves turn a dull olive color, sometimes with black specks (fruiting bodies) on the dead areas. Affected leaves usually fall off, contributing to defoliation in the canopy interior. - **Fruit spotting/rot:** Anthracnose doesn't commonly infect immature fruit, but if fruit is overripe or has injuries, it can cause a firm brown rot, often starting at the stylar (bottom) end. For example, dropped fruits on ground get black decay due to *Colletotrichum*. - *Early-stage indicators:* usually subtle – perhaps a few leaves with necrotic tips, a minor twig or two dying back. It often follows an event (frost, drought, pest) that killed tissue, which *Colletotrichum* then colonizes. - *Advanced-stage:* multiple twigs per tree are dead, giving a blighted look; notable leaf fall causing sparse canopy. If severe, tree sections may become barren of leaves. In extreme cases (rare in citrus), large limb dieback can occur.

Causes & Spread: The anthracnose fungus thrives on **weak or dead tissue**. It sporulates on dead twigs or fruit and spreads by **rain splash**. Warm humid conditions favor it. Often, pruning cuts, hail damage, or nutrient-starved twigs become starting points. Once present, **spores** can infect adjacent healthy tissues if the plant is very stressed. The fungus can also be seed-borne or come with budwood but that's minor. Overhead irrigation can spread spores as well. Generally, anthracnose is **secondary**: healthy citrus trees with good foliage rarely have serious anthracnose, but nutritionally deficient or neglected trees in a humid environment will. Another nuance: *Colletotrichum* can lie latent – e.g., it might infect a young leaf or fruit quietly and only cause visible rot later when the tissue matures or dies.

Geographic Prevalence: Found in all citrus areas with humidity. Particularly noted in **Assam and NE India** on Khasi mandarins where canopy remains moist, and also in parts of South India on acid lime during monsoon. It's reported more on **Mexican lime and grapefruit** globally, but in India, mandarins and sweet oranges in rainforest fringe areas see it. Postharvest anthracnose fruit rot is seen more in coastal humid belts if fruits are stored poorly.

Economic Impact: Anthracnose as a foliar/twig disease typically causes **tree vigor reduction** rather than direct yield loss, though heavy leaf/fruit drop can reduce yield for that season. The biggest economic impact can be in nurseries (if seedlings defoliate) or if it predisposes trees to further issues. Postharvest anthracnose can reduce marketable fruit if oranges are stored in warm, humid conditions – but proper curing and storage largely prevent that. In sum, it's a moderate impact disease – rarely wiping out trees, but contributes to **citrus decline** when combined with other stresses.

Risks & Yield Loss: Mild anthracnose might cause negligible yield loss, just cosmetic or a bit more fruit drop. Severe wither tip in a neglected grove could cause say 10–15% of fruit to drop prematurely and reduce bloom for next year (as fruiting wood died). If combined with something like greening or Phytophthora, it exacerbates decline. So while anthracnose alone is not usually catastrophic, it can be part of a combination that significantly affects productivity. In extremely wet years, unmanaged anthracnose could defoliate trees enough to reduce that season's crop by ~20%.

Prevention: - **Maintain tree vigor:** Proper fertilization (especially nitrogen and micronutrients) so that twigs are not weak or senescing prematurely. Many fungal issues target weak tissue. - **Prune and dispose of dead twigs:** Similar to melanose, remove dead wood that can harbor the fungus. - **Improve aeration:** Don't let orchards stay damp for long – wider spacing or open centers can help leaves dry. - **Avoid excessive overhead watering:** If trees are in a humid

microclimate (say shaded by other trees), consider thinning the shade or switching to under-canopy irrigation. - **Copper or fungicide cover if needed:** Often, the copper sprays used for scab/canker also keep anthracnose in check. Thus, a preventative copper spray regime indirectly prevents anthracnose outbreaks.

IPM Strategies: - **Scout after stress events:** After an unusual event (a cyclone, a drought spell, etc.), check for anthracnose signs. If many twigs show dieback, plan a treatment. - **Cultural controls:** As above – sanitation pruning is key. Also, avoid leaving **nubs or stubs** when pruning – make clean cuts that heal, otherwise those stubs die back and invite anthracnose. - **Intercropping caution:** Dense intercrops that increase humidity near ground (like dense legumes) might escalate anthracnose – ensure adequate airflow. - **Fungicidal protection:** If a tree is known to suffer wither tip annually (perhaps older tree in wet area), a single spray of **Copper oxychloride 0.3%** or **Mancozeb 0.25%** just before expected monsoon can reduce spore build-up. Another after heavy rains if needed. - **Mixed sprays:** When spraying for other diseases, adding a fungicide that covers anthracnose is useful. For instance, **Strobilurin fungicides** (like azoxystrobin) have good activity on *Colletotrichum*, so an azoxystrobin spray for melanose/scab will also curb anthracnose. - **Biocontrol:** There are *Trichoderma* formulations that specifically target *Colletotrichum* on other crops – though not common on citrus, applying such a biofungicide to pruned twig ends might help.

Chemical Control: - **Copper fungicides** again are standard. A post-monsoon copper spray will disinfect lesions. - **Mancozeb** is effective and broad-spectrum for foliar anthracnose; recommended at ~2 g/L. - **Thiophanate-methyl or Carbendazim** (systemic) can be used if twig blight is extensive. These penetrate tissue and eradicate internal fungus. E.g., Carbendazim @ 1 g/L sprayed on affected trees after flush. - **Azoxystrobin** (as mentioned) or **Trifloxystrobin + Tebuconazole** combination is very effective for anthracnose – this might be an option if the orchard has multiple fungal issues, as this covers a broad range. - Always rotate fungicides if multiple applications to avoid resistance (Colletotrichum can develop resistance if one mode is overused).

When to Escalate: If anthracnose symptoms are confused with something else (like Phytophthora twig blight or nutrient burn), get expert confirmation. If dieback is severe and widespread in an orchard even after implementing controls, it might indicate an underlying issue (like root problems or greening disease) – an expert can diagnose the root cause. Escalate if you see **dieback in too many trees** across the farm, because anthracnose usually doesn't uniformly attack all healthy trees unless there's a general stress; that situation warrants expert analysis of soil, roots, etc.

Field Diagnosis Checklist: - Are tip twigs dying with dead leaves hanging? (Classic wither tip sign – gently pull a dead leaf: if it's stuck, probably killed quickly by anthracnose; if it falls off easily, might have died slower or from something else). - Any pinkish spore masses on dead twigs in humid mornings? (Colletotrichum often produces salmon-pink spore masses on dead tissue in moist conditions). - Did a prior event weaken the tree (frost, etc.)? Anthracnose often follows. - Do lesions have black specks arranged in rings or zonations? (Sometimes anthracnose on fruit or leaves has tiny black fruiting bodies). - Check for *Alternaria* disease: Alternaria brown spot (in some mandarins) can cause leaf spots and twig dieback too – but Alternaria usually attacks young leaves/fruit and has a yellow halo around spots. Anthracnose hits older tissue, no yellow halo, and is more generalized. - If many dead twigs are only on one side of tree,

consider physical cause (windburn) plus anthracnose finishing off. If all around, likely disease-driven.

QR-Code Summary: *Citrus Anthracnose (Wither Tip) – Fungal twig blight. Signs: twig tips die with dead leaves hanging; dark brown spots on old leaves (drop early); in severe cases, defoliation and fruit rot on overripe fruit. Causal fungus:* Colletotrichum *spp., thriving on weak or dead tissue; spreads in warm wet weather by spores. Pre-disposing: poor nutrition, damage, or prolonged rains. Control: prune out and burn dead twigs; maintain tree vigor (fertilize, water); spray copper or mancozeb after heavy rains[15]. Effect: reduces yield indirectly (less foliage/fruit); manage with sanitation + occasional fungicide. Typically a secondary issue – investigate underlying stresses.*

(... additional fungal diseases like Citrus Greasy Spot, Black Sooty Mold, Armillaria Root Rot, Pink Disease, Powdery Mildew can be included similarly if needed, but moving on for brevity.)

Major Bacterial Diseases of Citrus in India

Bacterial diseases can be highly destructive in citrus, causing cankers, chlorosis, and systemic tree decline. They often spread by rain, insects, or grafting. In India, notable bacterial diseases include **Citrus Canker**, **Huanglongbing (Citrus Greening)**, and diseases like **Citrus Variegated Chlorosis** (not yet established in India but a threat). Management hinges on **exclusion (clean nursery stock)**, **vector control**, and **preventative sprays**. Below are key bacterial diseases:

Citrus Canker (*Xanthomonas citri* pv. *citri*)

Category: Bacterial disease (leaf, fruit, twig canker)
Description: Citrus canker is a highly contagious disease caused by the bacterium *Xanthomonas citri* pv. *citri*. It produces characteristic **lesions on leaves, fruits, and twigs** that are raised, rough, and surrounded by yellow halos[31][32]. Severe infections lead to defoliation, fruit drop, and twig dieback, collectively weakening the tree and blemishing fruit. **Acid lime (Kagzi lime)** and lemons are extremely susceptible in India, often suffering heavy damage, whereas sweet oranges and mandarins are less frequently affected[5]. Canker is a serious issue in most citrus-growing regions of India, especially in areas with heavy rainfall or wind-driven storms (which aid its spread). It is considered a quarantine disease internationally due to its impact.

Symptoms: - **Leaves:** Small, pinhead-size translucent spots appear first, usually on the underside of leaves, especially along leaf margins or near where water accumulates. These enlarge into **rough, corky, crater-like lesions**, tan to brown in color, visible on both leaf surfaces. Each lesion is often surrounded by a **distinct yellow halo** (the chlorotic ring)[33][34]. If you run a finger over a lesion, it feels rough or scabby, and on the underside of the leaf it may be slightly raised and corky. In wet conditions, lesions may ooze bacterial droplets. Leaves with many lesions turn yellow and drop off prematurely. - **Fruits:** On green fruit, canker lesions start as oily-looking spots, then become brown, raised and corky, often with an oily or water-soaked margin. They may be surrounded by a yellow halo until fruit fully ripens[31]. Lesions can be solitary or in clusters; severe infection leads to multiple scabby spots, sometimes with cracks. While internal fruit quality isn't greatly affected by superficial canker, infected fruit often drop and are unsightly. Rind around lesions may stay green longer (uneven ripening). - **Twigs:** Young stems show small tan pustules that later become corky cankers. These can girdle twigs if numerous, causing twig dieback. Often you'll see leaf lesions first, and if infection is heavy, adjacent twigs will also carry canker spots. Older branches seldom show lesions unless in very bad infections. - *Early indicators:* appearance of a few **yellow-halo spots on a couple of leaves**

after the first heavy rain of the season, particularly on lower canopy leaves facing wind. If leaf miners are present, their damaged leaves get canker more easily (leaf miner feeding creates entry wounds for bacteria). - *Advanced-stage:* tree may partially defoliate, with **numerous leaves full of canker lesions** (torn-looking, with brown scabs and yellow patches); many fruit fall off while still green with lesions; twigs show dieback and the tree canopy thins out. In acid lime, one often sees almost every leaf and fruit blemished in a bad outbreak.

Causes & Spread: The bacteria multiply in lesions and exude in moist conditions. Spread occurs primarily by **wind-driven rain** – raindrops pick up bacteria from lesions and carry them to new tissue. Wind injuries or insect feeding sites facilitate entry. **Insect vector:** The Asian citrus leafminer insect creates wounds that greatly enhance canker infection; leafminer tunnels predispose leaves to canker, and the combination is devastating[35]. Long-distance spread can happen via infected nursery plants, or on equipment, clothing, etc. Bacteria can survive on plant surfaces (like leaf litter or other rutaceous plants) for a while. Monsoon storms, especially with strong winds and heavy rain, cause rapid disease spread. Areas with cyclones or windstorms often see canker blasts. **High temperature (25–30°C)** and moisture are ideal for canker development. Dry weather halts new infections, but existing lesions persist and reactivate with humidity.

Geographic Prevalence in India: Canker is **endemic in India**, first reported over a century ago. It's widespread in **Assam, Meghalaya, Andaman Islands** (where humid climate favors it) and also in **Central and South India** wherever susceptible citrus are grown[36]. Acid lime orchards in states like Maharashtra, Telangana, Andhra Pradesh, and Gujarat often face recurrent canker issues[37]. North Indian drier regions have less canker, but wherever rainfall is adequate (e.g., parts of Punjab during monsoon), it can occur. Nursery areas and dooryard trees often maintain the bacteria year-round if not managed.

Economic Impact on Farmers: Citrus canker can cause **serious economic losses** by: - **Fruit drop:** In severe cases, canker leads to premature fruit drop – yield losses of 10–50% have been recorded in acid lime under heavy infection[38]. - **Fruit blemish:** Infected fruits that remain are often unsellable in fresh market due to scabbed appearance. Export is out of question from canker-endemic areas (trade restrictions). - **Tree decline:** Chronic infection weakens trees, reducing their vigor and subsequent yields. Farmers may need to remove and replant severely affected trees (costly and time-consuming). - **Control costs:** Managing canker requires frequent copper-antibiotic sprays and rigorous orchard hygiene, which increase production costs. One study noted incidence in some orchards reaching 60% of trees infected[39], highlighting the scale. Outbreaks can be locally devastating; however, with diligent control, losses can be mitigated. Indirectly, canker presence can restrict market access, as areas known to have canker face quarantines.

Risks & Yield Loss Projections: If no control measures are taken in a susceptible lime orchard, expect very high fruit drop (upwards of 50–70% in bad years) and almost total loss of quality on remaining fruit. With control, losses can be contained to under 10%. A moderate scenario: 30% yield loss in acid lime is common if sprays are insufficient[36]. Sweet oranges might see only minor yield impact (since they are less susceptible, mostly cosmetic damage), but if grown on susceptible rootstock or interplanted with limes, the disease can still cause some drop and twig dieback. Farmers in high-risk areas essentially assume canker management as a regular cost of production.

Prevention: - **Use disease-free nursery stock:** Ensure new trees are from nurseries under canker-free certification or raised under insect-proof conditions. Infected seedlings can introduce canker to new areas. - **Windbreaks:** Plant windbreak trees (such as bamboo or drumstick trees) around orchard borders to reduce wind-driven rain spread of bacteria. - **Leafminer control:** Since leafminer damage exacerbates canker, controlling the citrus leafminer (through timely sprays or pheromone traps) especially during flush periods greatly reduces canker incidence[40][33]. - **Field sanitation:** Promptly remove and burn any citrus tree that is severely and chronically infected (especially if young). Collect and destroy fallen infected leaves or twigs (though difficult on a large scale, it helps in nurseries). - **Avoid overhead irrigation:** It can mimic rain splash spread. If using, do it when foliage can dry quickly. - **Copper prophylaxis:** Copper sprays protect new flush from infection – it's a prevention must in endemic areas (details in IPM below). - **Resistant varieties:** Most citrus are susceptible, but some strains like certain mandarins show a degree of tolerance. There are plant breeding efforts (e.g., some kumquat hybrids are resistant). Wherever feasible, choose less susceptible cultivars if canker pressure is high.

IPM (Integrated Pest Management) Plan:
A multi-pronged IPM approach for canker involves cultural, chemical, and regulatory methods: - **Monitoring:** Inspect orchards regularly, especially new flush leaves about 7–14 days after heavy rains or storms. Look for the earliest lesions (tiny yellow halo spots). Early detection helps target sprays. - **Leafminer management:** As leafminers predispose leaves to canker, include **leafminer control** in the IPM. Use pheromone traps to monitor leafminer population. If flushes are being heavily mined, apply an appropriate systemic insecticide (like **imidacloprid 0.25 ml/L** drench or **spinosad 0.3 ml/L** spray) to protect new leaves[41]. Also, releasing parasitoids (like *Agrocharis spp.*) can suppress leafminer naturally. - **Copper sprays:** The cornerstone of canker IPM is regular **copper-based bactericide sprays** on new growth. Typically: - Spray copper when new flush leaves are about half-expanded (very susceptible stage) and again 2–3 weeks later, and possibly a third time if rainy season extends[42][43]. This coats the leaves and kills bacteria on contact. - Copper is often combined with a low dose of antibiotic like streptomycin (see Chemical control for dosage) for synergistic effect[42]. - In India, recommended schedule for acid lime is to spray thrice a year: February (spring flush), June-July (monsoon flush), and October (late flush)[42]. - **Antibiotic use:** Streptomycin sulfate (Plantomycin) can be used judiciously along with copper to curtail active infections. However, avoid overuse to prevent resistance. - **Pruning:** Prune out and burn twigs that had heavy lesions, particularly before a new flush emerges (reduces inoculum). Disinfect pruning tools between cuts (e.g., 1% bleach or rubbing alcohol). - **Avoidance:** If possible, time the flush such that it doesn't coincide with the peak rainy period (this is more theoretical; in practice flush comes with rain naturally, but some growers manage irrigation to manipulate flush timing). - **Buffer zones:** In nurseries or around orchards, eliminate any alternate host plants (some ornamental Rutaceae like orange jasmine can host canker). - **Quarantine compliance:** If there's any regulatory guideline (like not moving fruit/branches out of area), follow it to avoid wider spread.

Organic Remedies (for organic citrus farming): Copper is allowed in organic albeit with restrictions on quantity. Use **Bordeaux mixture** as an effective organic bactericide – e.g., 1% Bordeaux applied as per the same schedule. Additionally, some botanicals like **neem oil (3%)** can have partial effect by creating a physical barrier and deterring leafminers (neem won't kill bacteria directly much, but helps overall). Also, boosting tree immune response via seaweed

extracts or effective microorganism (EM) sprays is considered – though not a standalone solution, it could help plant vigor to recover. **Lime washes** on trunks (traditional practice) may suppress some inoculum splash from trunk lesions.

Chemical Control & Dosage:
1. **Copper + Streptomycin Sprays:** A common recommendation is **Streptocycline (streptomycin sulfate + tetracycline) @ 100–200 ppm** (which is 1–2 g per 10 L) mixed with **Copper oxychloride 0.2% (2 g per L)**[42]. For example, dissolve 10 g of Streptocycline + 20 g of copper oxychloride in 10 liters water and spray thoroughly. Do this at 15–20 day intervals during flush/rainy periods. (Note: Excess antibiotic use can lead to resistance; some areas may restrict it – check local guidelines. Copper alone is effective too.) 2. **Copper formulations:** Copper oxychloride 50 WP @ 2.5 g/L, or Copper hydroxide 77 WP @ 2 g/L. Some newer formulations like Copper oxychloride + kasugamycin (antibiotic) combinations are available and effective. 3. **Other bactericides: Plantomycin** (Streptomycin 9% + Tetracycline 1%) @ 500 ppm (50 g in 100 L) is often advised in India – typically with copper or on its own in nurseries. 4. **CAS (chemical alternate sprays):** To avoid too much copper buildup, one can alternate copper with other chemicals like **Bronopol** (a bactericide used in some countries) or **quaternary ammonium compounds** for surface sterilization (not common in field use though). 5. **Spray volume and coverage:** Ensure high volume spray to wet all leaves (especially underside) – that's where many stomatal entry points are. A sticker can be added to make copper stick through rains. 6. Frequency: During heavy monsoon, it might require spraying every 15 days for 2–3 cycles to protect new growth flushes, then reduce frequency as weather dries.

When to Escalate to Expert: - If an orchard experiences **persistent canker outbreaks despite regular spraying**, an expert might help identify if there's a resistance issue or if spray technique is inadequate. Also, experts can guide on new resistant rootstock or windbreak strategies for long-term. - In case of detection in a previously canker-free region, immediately alert agricultural authorities (this is a regulatory disease). - If unusual symptoms appear (for instance, canker-like lesions but no yellow halo or spreading differently), it could be a similar disease (like bacterial spot by X. citrumelo, not common in India) – get expert diagnosis. - Nurseries should involve experts at any sign of canker because they must eradicate it to avoid distribution.

Field Diagnosis Checklist: - Look for **raised corky lesions** on leaves with **yellow halos** – these are diagnostic for canker[33]. No other common citrus disease gives that halo with raised center on leaves. - Young lesions on fruit – are they raised and rough (canker) or flat and smooth (might be melanose or something else)? Canker ones often protrude like tiny volcanoes and can be felt by hand. - Check underside of leaves for corresponding lesions and any oily margin – canker often protrudes on both sides of the leaf. - If you have a hand lens, canker lesions often have a **speckled center** of ruptured epidermis, whereas something like scab has a more conical uniform structure. - Note distribution: often starts on windward side of tree and lower canopy (wind-rain hits there). - Test: If you put an infected leaf in a plastic bag with moisture for a few hours, you may see creamy bacterial ooze from lesions under magnification – confirms it's bacterial not fungal. - Leaf miner damage + canker: see if many lesions follow the trails of leaf miner on leaves. If yes, that's a sure sign of canker taking advantage of miner injury. This checklist helps confirm canker so that appropriate measures are taken rapidly.

QR-code-ready Summary: *Citrus Canker – Highly contagious bacterial disease. Symptoms: slightly raised brown corky lesions on leaves, fruits, twigs; each lesion with yellow halo[33].*

Causes leaf yellowing, fruit drop, twig dieback. Spread: rain-splash & wind, plus aided by leafminer damage. Thrives in warm, wet weather. Severe on limes/lemons (can defoliate trees), less on oranges. Management: Use canker-free saplings; control leafminers[41]; spray copper + streptomycin antibiotics thrice in growing season[42]; prune and burn infected twigs; plant windbreaks. Economic impact: high fruit loss and quality downgrade if unchecked. Report new outbreaks immediately.

Citrus canker lesions on a lime leaf (close-up). Note the raised, brown corky spots with yellow halos on the leaf surface[33]. These bacterial lesions can coalesce and cause defoliation and fruit drop in susceptible citrus.

Huanglongbing (HLB or Citrus Greening) (*Candidatus Liberibacter asiaticus*)

Category: Bacterial (phloem-limited) disease – systemic, vectored by insects
Description: Huanglongbing (HLB), also known as **citrus greening disease**, is one of the most destructive citrus diseases globally. It is caused by a phloem-restricted bacterium (*Candidatus Liberibacter asiaticus* in India/Asia) which is transmitted by the **Asian citrus psyllid** (*Diaphorina citri*). The bacteria spread through the tree's phloem, blocking nutrient flow and causing a range of symptoms from leaf blotchy mottle to small, misshapen fruits with bitter juice. Greening is **systemic and incurable** – once a tree is infected, it declines over a few years and usually dies. In India, HLB is a major factor in "citrus decline," particularly of mandarin oranges in the northeast and acid limes in the south[44][45]. The name "huanglongbing" means "yellow dragon disease" in Chinese, describing the yellow shoots symptom.

Symptoms: - **Leaf Mottling:** The hallmark symptom is a distinct **blotchy, asymmetrical yellowing on leaves**[46]. Unlike nutrient deficiency where yellowing is usually symmetrical on both sides of the leaf midrib, HLB mottling is irregular – patches of pale yellow mixed with green on a leaf, not mirrored across the midrib[47][48]. This "blotchy mottle" is most evident on mature leaves and is diagnostic for greening. - **Yellow Shoots:** Infected trees often show sectors of the canopy with pale **yellow shoots** amidst otherwise green foliage[49]. These shoots stand out, as if only one branch turned yellow. - **Leaf vein corking:** Leaves may have **swollen, corky midribs or lateral veins** and may feel thicker or leathery. Sometimes you see a green banding along veins with yellow in between (almost opposite of nutrient deficiency). - **Small, lopsided fruits:** Fruit from HLB-infected trees tend to be **smaller, misshapen, and often remain green at the stylar (blossom) end** even when the rest ripens (hence "greening")[50]. They may color unevenly. When cut open, the fruit may show a curved axis (lop-sided), aborted seeds, and a bitter taste with low sweetness. - **Twig dieback & leaf drop:** As the disease progresses, affected branches suffer **dieback**, and the tree loses leaves. A general sparse, weak canopy develops. - **Slow growth & stunting:** Young trees with HLB show stunted growth, narrow leaves, and may never reach full size (they look nutrient deficient always). - **Overall decline:** Trees become chlorotic, sparsely foliated with many twig diebacks, and yield plummets. Often the root system also decays secondarily due to lack of carbohydrate supply. - *Early-stage indicators:* A single branch (or a few) with odd mottled leaves when the rest of the tree looks okay. Often first appears in one section of the tree (sectored pattern). Fruit from that sector might be off-color or taste off. - *Advanced-stage:* Tree has multiple yellow shoots, a widespread blotchy mottle on leaves, significant leaf drop, very few fruits (and those present are green, hard, bitter). Eventually tree is mostly bare and productivity is near zero.

Causes & Spread: The causal bacterium (*Ca. Liberibacter*) lives in phloem and is not spread by typical means like rain or pruning (it's not surface-borne). The primary spread is via the **Asian citrus psyllid (ACP)**, a tiny sap-sucking insect. Psyllids acquire the bacteria by feeding on infected tree sap, then fly and feed on healthy trees, injecting the bacteria. Once a tree is infected, the bacteria move systemically (it can take months for symptoms to show). In addition to vector transmission, **grafting** is a route – if infected budwood is used, the new tree will have HLB. In India, ACP is widespread, so vector control is crucial. The disease can spread rapidly in a region if psyllid populations are high – an exponential epidemic can occur. Long-distance spread happens by moving infected plant material (which is why many areas regulate budwood movement). **Environmental influence:** HLB symptoms show faster in warmer seasons, but the bacterium can multiply in a range of climates. Cool conditions sometimes mask symptoms

(leaves might look normal until heat stress reveals mottling). The disease does not spread through soil, water, or seed.

Geographic Prevalence: Sadly, HLB is present in at least 16 states of India[51]. It's particularly serious in: - **North-East India (Assam, Nagaland, Meghalaya)** – longstanding greening issues in Khasi mandarin; identified as a cause of decline there. - **Central India (Vidarbha in Maharashtra, MP)** – noted in sweet orange and mandarins. - **South India (Andhra Pradesh, Telangana, Karnataka)** – acid lime orchards often hit hard, with greening detected in many parts[52]. - **North India (Punjab, Uttar Pradesh)** – reported, possibly introduced via planting material; historically part of citrus decline in Punjab[53]. Essentially, wherever the psyllid exists and susceptible citrus are grown, HLB tends to eventually appear. Surveillance efforts have found it widespread by the late 2000s.

Economic Impact: HLB is arguably the most devastating citrus disease. Key impacts: - **Yield reduction:** Infected trees may produce little to no fruit after a few years. Oranges from HLB orchards drop by 30-100% depending on severity[54][55]. Trees usually die or become non-productive in 3–8 years[56]. - **Fruit quality:** Juice content and sugar drops, acid can rise, making fruit unsellable for fresh and poor for processing. Off-flavors (bitter, medicinal taste) occur. - **Tree loss and replant costs:** Farmers often have to remove and replant trees en masse, which is expensive and time-consuming (and new trees risk infection too if vector not controlled). - **Industry/regional collapse:** If unchecked, HLB can decimate entire citrus industries (as seen in parts of Florida, USA and Sao Paulo, Brazil). In India, greening is considered a key factor in inconsistent production. For instance, Nagpur mandarin decline was heavily linked to greening + tristeza. - **Management costs:** Continuous vector control spraying, removing infected trees (rogueing), and implementing certified disease-free propagation significantly raise production costs.

Studies in India have documented high incidence levels, e.g., in some surveys over 50% trees in certain orchards were HLB-positive[39]. The economic toll is thus very high if not managed.

Risks & Yield Loss Projections: Without control, a newly infected orchard could lose nearly all productive capacity in under a decade. Some estimates: - Once a tree is infected, yield can drop by ~30% the first year of symptoms and keep dropping to near zero in a couple more years[57]. - If 25% of trees get infected per year (possible in high psyllid areas), in 4 years nearly the whole orchard is sick, and yields might be down 70–80%. Within 8–10 years, orchard likely not viable. - There's anecdotal evidence of orchards being abandoned due to HLB in India (since control efforts can be daunting for smallholders).
Thus, the risk is orchard longevity going from decades to just a few years if HLB isn't tackled aggressively.

Prevention: - **Use certified disease-free planting material:** This cannot be overstressed – start with trees indexed free of HLB. Budwood should come from accredited clean sources (e.g., ICAR-CCRI has programs) grown under insect-proof nurseries. - **Psyllid control at borders:** Prevent the vector from entering. Some use perimeter spray or host plant removal around orchards (remove **Murraya exotica** hedge or curry leaf plants near orchards as they can host psyllids and possibly Liberibacter). - **Quarantine:** Do not bring citrus plants or budwood from known HLB areas into new areas. States often have regulations (enforce them to prevent spread). - **Regular monitoring:** Check flush for psyllids and leaf symptoms often. Early catch of

infection can allow roguing (removing) of a single tree before it spreads much. - **Vector awareness:** Also manage other sap feeders to reduce overall stress (though only psyllids transmit HLB, but aphids/others might confuse detection). - **Nutrition and care:** Some evidence suggests that well-fertilized, well-watered trees handle HLB stress a bit longer. It won't stop HLB but may prolong productivity somewhat. Foliar micronutrient sprays (zinc, manganese) can temporarily mask some symptom severity but not a cure. - **Resistant rootstock or varieties:** No true resistant scion is available yet. Some tolerance seen in certain lemon or Australian finger lime relatives, but nothing commercially replacing sweet oranges or mandarins. Research is ongoing for tolerant rootstocks.

IPM Plan: - **Rogue and destroy infected trees:** A cornerstone IPM practice in many countries – if a tree is confirmed HLB positive and symptomatic, remove it promptly (uproot and burn/chip it) to remove it as a source of infection[58][59]. This is effective early in an epidemic. It's difficult for small farmers emotionally/economically, but necessary to save the rest. - **Aggressive psyllid control:** Treat the vector like an enemy #1. Use **systemic insecticides** on new flush (e.g., soil drench of Imidacloprid at flush onset for young trees) and **rotate with foliar sprays** (like dimethoate, lambda-cyhalothrin, or newer ones like cyantraniliprole) to knock down psyllid populations[60][61]. Oil sprays (white oil 1%) can smother some psyllids and also help flush shine, used in IPM mix. - **Biological control of psyllid:** Encourage or introduce **Tamarixia radiata**, a parasitic wasp that attacks psyllid nymphs. Many parts of India have Tamarixia present; conserving it (avoid broad-spectrum pesticides during its activity, use selective insecticides) aids natural psyllid suppression. - **Antifeedant or repellent:** Some IPM tries using guava intercrops – there were reports that interplanting guava can reduce HLB spread (maybe guava volatiles confuse psyllids). Though results have varied, some farmers try citrus-guava mixed orchards as a cultural IPM tactic. - **Nutritional support:** As part of IPM, maintain robust nutrition so trees can better cope. This includes soil health improvements, micronutrient sprays (e.g., monthly foliar spray of zinc, manganese, magnesium, and boron which HLB-infected trees often can't uptake well). - **Community action:** IPM for HLB must be area-wide. If your neighbors don't control psyllids or rogue, reinfection happens. Coordinated sprays in a region, synchronized by agri departments, are an IPM strategy (e.g., all farmers spray for psyllid in a given week). - **Heat therapy (experimental):** Some experiments show if infected potted trees are kept in 45–48°C for a few hours (e.g., heat chamber or under plastic in sun), bacteria titer reduces. Not practical in field widely, but for saving germplasm or nursery, it's considered. - **Infected tree care if not removed:** If a farmer cannot yet remove a tree (due to needing fruit), as an interim IPM, prune it heavily to remove as many infected limbs as possible, and treat vigorously with foliar nutrition and psyllid control. This might buy a little time of production from that tree but is risky for spread.

Organic IPM: Very challenging for HLB. Focus on vector control with natural oils (neem oil, horticultural oil), Tamarixia wasps, and roguing. Some organic growers use frequent neem/garlic/chili sprays to deter psyllids – partial effect at best. A concoction of orange oil or lemongrass extract is claimed by some to reduce bacterial load (not proven). Essentially, organic management relies on robust soil health, biocontrol, and sacrificing infected trees quickly.

Chemical Control of Psyllid & Potential Therapies: - *Psyllid insecticides:* Imidacloprid 17.8 SL @ 0.5 ml/L as soil drench (has 2-3 months residual) is a standard. Foliar options: Dimethoate 30 EC @ 1.5 ml/L, or Thiamethoxam 25 WG @ 0.3 g/L, or newer flupyradifurone (which is a bee-safe systemic) etc. Need to rotate modes (neonics, organophosphates, pyrethroids, etc.) each

generation of psyllid to avoid resistance. - *Antibiotic therapy:* There is ongoing research on injecting antibiotics (like penicillin or tetracyclines) into trees to suppress HLB bacteria. In field, this is not widely done due to practicality and regulation (antibiotic residues). However, some trials in Florida and elsewhere have used oxytetracycline trunk injections or endotherapy and shown temporary symptom remission. Not a field-ready recommendation in India as of now. - *New research:* As of 2025, researchers are working on antimicrobial peptides, CRISPR-based cures, etc.[62]. These are not yet available to farmers, but in future might provide cures. - *Nutrient cocktail foliar sprays:* A common suggestion to prolong productivity of an infected tree is monthly foliar spray containing 0.5% each of zinc sulfate, manganese sulfate, magnesium sulfate + 0.1% boron + 0.05% molybdenum + 1% urea. This doesn't cure HLB but mitigates nutrient deficiency symptoms caused by root damage.

When to Escalate to Expert: HLB absolutely benefits from expert involvement: - If you suspect HLB (blotchy mottle) but aren't 100% sure, get laboratory confirmation (PCR test) via extension service. Early accurate diagnosis is key. - If incidence is rising despite your efforts, involve experts to design an area-wide management and apply for possible government help (some regions have HLB management schemes). - For any experimental control (like bacteriophage, thermotherapy, etc.), you'd need expert guidance. - Also, if planning a new orchard in a previously HLB-infested area, consult experts on best rootstocks, layout (e.g., inclusion of guava or not), net houses for initial years, etc.

Field Diagnosis Checklist: - Does the leaf exhibit **blotchy mottle**? (random yellow and green mix, asymmetrical about midrib – most telling sign[48]). - Pick a suspected leaf and a healthy zinc-deficient leaf; hold to light – HLB mottling crosses veins randomly, Zn deficiency shows patterned interveinal chlorosis with green vein area. - Are some branches looking pale yellow compared to others (sectoral pattern)? - Taste fruits: HLB fruit often bitter or off-taste and have small, brownish seeds or no seeds. - Look for psyllids: Tap a branch over paper, see if tiny aphid-like psyllids (with mottled brown bodies) are present. Psyllid nymphs produce waxy spiral tubules on new flush leaves – check flush for that. - Note: Early HLB might mimic nutrient deficiency. If you correct nutrients and pattern remains, suspect HLB. Also, HLB-infected leaves may show that one part of the leaf is thickened and corky, another thin. - A confirmatory lab test is PCR on leaf midrib. Field test kits also exist (like iodine starch test on leaves showing starch accumulation in HLB leaves turning blue-black with iodine). If the signs point to HLB, act fast on vector control and removal.

QR-Code Summary: *Huanglongbing (Citrus Greening) – Fatal bacterial disease in phloem. Symptoms: asymmetrical blotchy yellow mottling on leaves[48]; yellow shoot sectors; small, deformed fruits that stay green at one end and taste bitter[63]; eventual tree decline and death. Cause:* Ca. Liberibacter *bacteria spread by Asian citrus psyllid insect. No cure, disease is systemic. Management: Remove infected trees to reduce spread[64]; aggressively control psyllids with insecticides and parasitoids[60]; use certified disease-free saplings and protect them from psyllids; provide good nutrition to infected trees to prolong productivity. HLB can destroy an orchard in years – early action is critical.*

Blotchy mottling on citrus leaves caused by Huanglongbing (citrus greening)[65][66]. The yellow patches are irregular and not symmetrical, which is a diagnostic feature of HLB vs. nutrient deficiencies. HLB leads to progressive yellowing, sparse foliage, and bitter, lopsided fruits.

Citrus Variegated Chlorosis (CVC) (*Xylella fastidiosa* subsp. *pauca*)

Category: Bacterial disease (xylem-limited) – *[Note: Not reported in India as of present, but included as a potential threat]*
Description: Citrus Variegated Chlorosis is a disease caused by *Xylella fastidiosa* bacteria that live in the xylem (water-conducting vessels). It causes a peculiar **variegated chlorosis on leaves**, looking like zinc deficiency but on mature leaves, and leads to small, hard fruits. CVC has devastated sweet orange orchards in Brazil. It is spread by certain leafhopper insects (sharpshooters) and by grafting. **Important:** As of now, CVC has *not been officially found in India*, but the user listed it, so we cover it briefly. It's considered an **exotic threat** – given India's experience with related Xylella diseases in other plants, vigilance is warranted.

Symptoms: - **Leaf variegation:** Infected leaves show **bright yellow chlorotic areas between veins** on the upper surface, but unlike HLB, the pattern can be more blocky and *symmetrical*. On the underside of the leaf, corresponding to the yellow spots, there are **brown gummy deposits** or freckles[67]. It looks like severe nutrient deficiency at first glance, hence "variegated chlorosis". - **Leaf size and texture:** Affected leaves may be smaller, thicker, and have a leathery texture. - **Fruit:** Fruits on infected trees are **small, very hard, and ripen early**. They remain **exceedingly sweet (high Brix)** but too small to be marketable[68]. Often they color early and hang on tree. -

Tree growth: In young trees, CVC infection can stunt growth markedly. In mature trees, canopy thins out over time due to leaf drop and twig dieback from lack of nutrients/water flow. - *Early stage:* A few leaves in the sun-exposed part of canopy show scattered chlorotic spots. The tree otherwise looks okay. - *Advanced:* Many leaves with variegation, canopy appears yellowish overall, lots of small fruit, reduced new growth, eventual branch dieback.

Causes & Spread: The *Xylella* bacteria clog xylem vessels, interfering with water/nutrient flow. They are spread by sap-feeding insects like sharpshooter leafhoppers (e.g., *Oncometopia facialis* in Brazil) that feed on citrus shoots and carry the bacteria. Grafting infected budwood transmits it. Unlike HLB's psyllid, sharpshooters have longer range flight, but distribution of vector matters. If CVC were introduced, presence of suitable leafhopper vectors in India (some exist in sub-tropics) would determine spread. *Xylella fastidiosa* also causes other plant diseases (e.g., Pierce's disease in grape, olive quick decline, etc.), but those strains differ; however, the presence of *Xylella* in any host is a biosecurity concern. CVC specifically thrives in hot climates; disease development is faster in warm weather.

Geographic Distribution: Currently known in Brazil, parts of South and Central America. Not known in Asia yet[69]. APHIS lists India among countries with greening but *not* with CVC[70][71]. Still, inclusion here suggests awareness: if it were to arrive, likely via imported budwood or an insect vector hitchhiking.

Economic Impact: In areas it occurs (Brazil), CVC causes significant yield loss – fruit of infected orange trees is too small, leading to 40%+ reduction in yield and need to replant trees. If it enters India, it could similarly threaten sweet orange and perhaps lemon plantings. It's thus a high-consequence exotic pest.

Prevention: - **Exclusion:** Strict quarantine on import of citrus plant material from CVC-positive countries. Inspection of any citrus germplasm for Xylella. - **Monitoring:** If suspicious variegation is seen that doesn't fit known HLB or nutrient patterns, get it tested for *Xylella*. Field kits (ELISA/PCR) can detect Xylella. - **Vector control:** Fortunately, India's main citrus pest (psyllid) doesn't transmit Xylella. Sharpshooters would be the culprits – some native leafhoppers might potentially vector if the bacteria appear. General orchard insect control and weed control (as sharpshooters breed on weeds too) could mitigate spread in an incursion scenario.

IPM if detected (hypothetical, since not present yet): - Immediately **rogue infected trees** to eradicate the source. - Apply area-wide insecticide to knock down leafhopper vectors. Possibly use sticky traps to monitor leafhopper presence. - Aggressive quarantine: no movement of plant parts out of area. - Encourage research: quick identification of vectors in local area and their control.

Differences from HLB: While both cause leaf chlorosis and small fruit, CVC's leaf symptom is often more vein-delimited (bright star-like chlorosis spots, and brown gum underside) and the fruit remain sweet (HLB fruit are bitter). HLB is phloem-limited, CVC xylem-limited, hence their distribution in plant differs (CVC shows in all leaves, HLB sometimes sectoral). Also HLB infects all citrus including limes strongly, whereas CVC mainly devastates sweet oranges (lime may get mild infection but not as severe).

When to escalate: *Any suspicion of CVC in India should be immediately escalated to agricultural authorities.* This is a notifiable/exotic disease. They would take containment actions.

Field Diagnosis Checklist (for vigilance): - Leaves with **yellow blotches that are distinctly visible on upper side and rough brownish specks directly under them underside** – suspect CVC if HLB tests negative. - Leaves that show deficiency pattern but on *older* leaves first (CVC hits mature leaves, Zn deficiency usually new leaves). - Fruit that are unusually hard, like "stone fruit," and small but fully colored. - Compare to HLB: If no blotchy mottle but rather uniform variegation with clear margins, and if no psyllids but leafhoppers noted, consider testing for *Xylella*. - Test: There are simple field ELISA kits for Xylella that could be used.

QR-Code Summary: *Citrus Variegated Chlorosis (CVC) – Exotic bacterial disease (not yet in India) caused by* Xylella *in xylem. Symptoms: bright yellow variegated spots on mature leaves (zinc deficiency-like) with corresponding brown gum on underside; small, rock-hard, overly sweet fruits; tree stunting. Spread by: sharpshooter leafhopper vectors; also grafting. Not present in India (as of now) but a serious threat – has caused major losses in Brazil. Management if found: destroy infected trees; restrict plant movement; control leafhopper vectors. Farmers should report suspicious variegation symptoms immediately for lab testing.*

(Other bacterial diseases like Citrus Black Pit and Citrus Blast (by Pseudomonas syringae*) cause black lesions on lemon fruits/leaves in cool weather, but are of minor occurrence; omitted for brevity.)*

Major Viral and Viroid Diseases of Citrus in India

Viruses and virus-like pathogens (viroids) in citrus often cause chronic, debilitating conditions such as quick decline, stem pitting, or chlorosis. They are typically graft-transmitted and sometimes spread by insects (aphids for some viruses). In India, **Citrus Tristeza Virus (CTV)** is historically the most significant virus, causing the infamous quick decline on sour orange rootstock. Also present are **Indian Citrus Ringspot Virus**, **Citrus Yellow Mosaic Virus**, and others. Viroids like exocortis and cachexia also occur. These pathogens usually require **budwood indexing** and **vector control** for management. Key viral diseases:

Citrus Tristeza Virus (CTV) – “Quick Decline”

Category: Viral disease (Closterovirus) – aphid-transmitted
Description: Citrus tristeza virus is a long, filamentous virus that infects citrus phloem. CTV

historically caused the “tristeza” (meaning sadness) disease that wiped out millions of citrus trees worldwide when susceptible rootstocks (like sour orange) were used[72][72]. There are various strains of CTV, ranging from mild (symptomless) to severe (quick decline, stem pitting). In India, CTV has been responsible for massive losses, particularly in the 1940s–60s when citrus decline due to tristeza devastated sweet orange and mandarin trees grafted on sour orange rootstock[73]. Now, use of tolerant rootstocks and cross-protection (preimmunization with mild strains) are strategies employed. CTV is spread by **aphids**, especially the brown citrus aphid (*Toxoptera citricida*) which is present in some regions.

Symptoms: - **Quick decline (on sour orange rootstock):** If a sweet orange or mandarin is grafted on sour orange rootstock and infected with a severe CTV strain, the union gets affected. Symptoms include **wilting and curling of leaves**, leaf drop, and general collapse of the tree within weeks or months – as if the tree is not getting nutrients/water (because the virus induces phloem blockage at the bud union)[74]. Often, the scion shows signs of girdling at the bud union – a brown line or indentation. The tree canopy thins rapidly and the tree may die (“quick decline”). - **Stem pitting strains:** Some CTV strains cause **stem pitting** in certain scion varieties even on tolerant rootstock. For example, grapefruits and some sweet orange cultivars develop linear pits or grooves in the wood of branches and trunk, leading to stunted growth and small, bumpy fruit. The bark may not show much, but if you cut or shave a twig, you see pits. - **Leaf symptoms:** Generally, CTV doesn’t cause distinct leaf patterns like mosaic (that’s more ringspot virus etc.). Leaves may be slightly chlorotic or smaller in declining trees, but no unique foliar pattern. However, one sign can be “vein flecking” – very fine translucent spots on leaves under transmitted light in some varieties (lab symptom). - **Fruit yield/quality:** Infected trees (on tolerant rootstock) might just grow poorly and yield less. Fruits can be small. No specific fruit discoloration is typical of CTV (except indirectly from tree weakness). - **Mild strains:** Many trees have mild CTV strains that show no obvious symptoms but can give cross-protection. So presence of virus isn’t always visible without testing or if severe strain comes along. - *Early-stage (in susceptible combination):* After infection, initially maybe slight vein clearing or wilting during hot days, often unnoticed until decline starts. - *Advanced-stage:* Tree on sour orange shows dieback, sparse yellowish foliage, profuse flowering (stress bloom), and often a bumper crop of very small fruits just before death (similar to foot rot scenario)[14]. On tolerant rootstock, advanced stage might be just slow dwarfing and poor yields.

Causes & Spread: CTV is transmitted by several species of **aphids** when they feed on citrus phloem. The most efficient vector is **brown citrus aphid (Toxoptera citricida)**, which unfortunately is present in Asia (and noted in India’s Northeast). Other aphids like **Aphis gossypii** (cotton aphid) and **Toxoptera aurantii** (black citrus aphid) can also transmit, but less efficiently. Spread is semi-persistent: aphids acquire virus in feeding and can transmit within hours/days. They typically spread it tree-to-tree within an orchard or neighboring orchards. Long-distance spread is via **infected budwood**. In fact, CTV’s pandemic distribution was historically due to propagation of infected budwood. Once in a region, local aphid populations can gradually move it around. Severe strains often appear after mixed infections or mutations; sometimes a previously mild strain in a tree can get replaced or exacerbated by a severe one via new infections. Temperature doesn’t limit CTV much; it thrives in tropical and subtropical climes.

Geographic Prevalence: CTV is present in virtually all citrus-growing areas of India[73]. It was a cause of major citrus decline in Punjab, Haryana, etc., mid-20th century. Now, surveys show it

in Central India (Nagpur belt), South (Andhra Pradesh, Telangana), Northeast (Assam etc.) albeit often the trees are on tolerant rootstocks so no quick decline, but stem pitting strains might be present. A 2014 study reported overall CTV incidence of 26–56% in surveyed areas (Vidarbha 26%, NE India ~50%, South India ~36-50%, North 16-60%)[75][76]. So it's widespread, though impact depends on rootstock and strain.

Economic Impact: Historically, CTV "tristeza" epidemics have killed millions of trees globally[72]. In India, switching from sour orange to *Rangpur lime* or other rootstocks mitigated mass tree death. However, CTV still causes: - Reduced vigor and yields due to stem pitting in certain scions (especially grapefruit and some oranges like Jaffa). - The need to pre-immunize trees with mild strain (as practiced by some research stations) to protect from severe strains – a management cost. - If severe strains invade an area with susceptible rootstock, sudden large losses can occur. Example: an orchard of sweet orange on sour orange could lose near 100% within 1–2 years of a severe CTV introduction. - Ongoing yield drag: Infected trees on tolerant rootstock might yield 20% less (due to chronic stress). The Indian agri scientists consider tristeza one of the top virus concerns (as indicated by significant research in that field). Over **one million citrus trees in India have been destroyed by CTV till date**[72].

Risks & Yield Loss: If a farmer unwittingly uses susceptible rootstock, risk is catastrophic. For normal tolerant-rootstock orchards, risk is more subtle: yield gradually declines, fruit size may reduce. It's hard to quantify yield loss from mild CTV – mild strains might cause minimal loss (hence used for cross-protection). But severe strains cause obvious losses. For example, in a grapefruit orchard, stem pitting strain can reduce yields by 30-50% and make fruit misshapen. An enterprise risk is that new severe strain could appear (since multiple strains can mix in aphids). Also, co-infection with other pathogens (like HLB+CTV) can be even worse in impact than either alone.

Prevention: - **Use tristeza-tolerant rootstocks:** This is paramount. Avoid sour orange rootstock entirely in areas where CTV is present (which is basically everywhere in India). Use alternatives like Rough lemon, Rangpur lime, trifoliate orange hybrids, Cleopatra mandarin, etc. Many Indian citrus now on Jatti Khatti (rough lemon) which is tolerant[77][78]. This prevents quick decline form. - **Certified budwood:** Ensure scion buds come from CTV-tested mother trees. This prevents introducing severe strains or any CTV if one wants to keep orchard virus-free (though in field aphids can still bring it). - **Aphid control in nursery:** Citrus nurseries should be in insect-proof structures because if budlings get infected young, they carry virus everywhere. So strict aphid control or physical protection is needed. - **Mild strain pre-immunization:** In some cases, nurseries deliberately inoculate trees with a known mild CTV strain that doesn't cause damage but will occupy the tree so that if a severe strain comes via aphid, the mild one competes and reduces severe disease (cross-protection). Brazil and some Indian research have done this for certain cultivars. It's specialized and requires source of mild isolate and indexing to ensure it's not too strong. - **Quarantine:** Avoid moving budwood or even equipment from regions with known severe strains to new regions. (There are different genotype strains; some cause stem pitting on sweet orange, some on grapefruit, some on none – movement can introduce new forms). - **Remove highly susceptible species nearby:** Interestingly, some ornamentals like *Aeglopsis chevalieri* can host CTV; not major in India but generally maintaining a citrus-free buffer around new orchards may slow local aphid transmission.

IPM Strategies: - **Monitor aphid populations:** Especially the brown citrus aphid (Toxoptera citricida). If this species is detected in an area, that's a high alert because it's the most efficient vector. Monitor citrus flush for aphids regularly. - **Control aphids when abundant:** Use oil sprays (e.g., 2% mineral oil) during flush to deter aphids; also systemic insecticides (imidacloprid soil drench for psyllids will also hit aphids) can keep populations low. However, completely stopping aphids is tough; even a few can transmit virus in seconds. So focus on major flights or infestations. - **Rouging susceptible rootstock trees:** If any old trees on sour orange are around (like a neighbor's dooryard tree or old rootstock sucker), they are ticking time bombs if severe CTV arrives. Encourage removal or top-working them onto new rootstock. - **Cross-protection in field:** If you know your trees are already infected with a mild strain and doing fine, it's not advisable to rogue them (since many likely all have CTV but mild). Instead, protect them from new severe strains by controlling aphids regionally. - **Combine with HLB/psyllid strategy:** Many IPM steps (use clean stock, control sap-sucking bugs) overlap with HLB management. A robust program controlling psyllids often also reduces aphids somewhat, and vice versa.

Chemical Control: There is *no direct chemical cure for viruses*. Chemicals are aimed at vectors: - Use similar insecticides as for HLB psyllids to target aphids (imidacloprid, thiamethoxam, dimethoate, etc.). Aphids are easier to kill than psyllids usually. If brown citrus aphid is prevalent, specifically target those flushes. - Note that broad-spectrum insecticides can kill natural enemies (ladybirds, lacewings that eat aphids), so time sprays judiciously. Alternatively, use softer options like neem (which has partial repellency, not great alone though). - If cross-protection is not used, and orchard is on tolerant rootstock, virus may be tolerated, so chemical approach focuses solely on not letting severe strains in via aphids.

When to Escalate: - If you suspect a "new" strain (for example, you start seeing stem pitting in oranges where previously your orchard with CTV was fine) – escalate to research lab to characterize the strain. They might impose additional measures. - If planning region-wide budwood or nursery programs, involve experts to ensure proper indexing for CTV. - Essentially, tristeza in tolerant rootstock era is somewhat managed, but an expert should always be consulted if rapid decline or unusual symptoms occur even on tolerant rootstocks (could be a sign of a very virulent strain or coinfection needing different approach).

Field Diagnosis Checklist: - On susceptible rootstock: Look at bud union – is there an overgrowth of scion or rootstock ("stem step"), or staining under bark at union? Trees maybe 6-8 years old suddenly declining with that symptom strongly suggests tristeza. - Quick decline trees often have abundant small fruit and wilting – similar to foot rot but check the roots: if roots are healthy and trunk bark fine, suspect virus via rootstock incompatibility (tristeza). - Stem pitting: cut a thin slice of a pencil-thick twig or use a knife to peel bark; if you see fine linear pits (like woodpecker peck marks inside) in the wood, that indicates stem-pitting strain of CTV. - Graft a bud from suspect tree onto an indicator like Mexican lime in greenhouse – if it shows vein clearing and stem pits in a few months, CTV is present (a biological indicator test). - Lab ELISA or RT-PCR can confirm CTV from leaf petioles. But field clues: general decline on sour orange, or fruit with unusually fleshy columella (interior might be gumming at vascular bundles). - Check if aphids present historically (if yes, likely CTV might be around even if symptomless).

QR-Code Summary: *Citrus Tristeza Virus (CTV) – Virus causing quick decline and stem pitting. Effects: If on susceptible rootstock (sour orange), tree rapidly collapses – leaves wilt,*

drop, tree may die (quick decline)[74]. On tolerant rootstock, certain strains cause stem pitting in twigs and reduced growth/fruiting. Spread: by aphids (esp. brown citrus aphid) and grafting. Prevention: Use CTV-tolerant rootstocks (avoid sour orange)[78]; certify budwood; control aphids. Manage: Remove trees on sour orange at first sign of decline; pre-immunize with mild strains if program available[79]; spray systemic insecticides to reduce aphids. Over 1 million trees lost in India to tristeza[72] – vigilance is key.

(Other viruses: Citrus Yellow Mosaic Virus – in certain acid lime varieties, causes yellow mottling patches; Indian Citrus Ringspot Virus (ICRSV) – causes rings or oak-leaf pattern on leaves and fruit flecking in Punjab kinnow; Citrus Yellow Vein Clearing Virus (CYVCV) – reported in lemons in Punjab/Pakistan causing vein clearing and oak-leaf patterns[80]; Citrus Exocortis Viroid – causes bark scaling on some rootstocks like trifoliate (scalybutt) and stunted trees; Citrus Cachexia Viroid – causes gum pockets in mandarin bark (xyloporosis); Citrus Psorosis Virus – old viral disease causing bark scaling patches. These are somewhat localized or minor currently, but mention that using certified budwood covers them too.)

Major Insect Pests of Citrus in India

Citrus orchards face many insect and mite pests that damage leaves, fruits, and stems, and some vector diseases. Effective pest management uses an IPM approach: orchard sanitation, biological control (predators/parasites), cultural methods, and judicious chemical use when needed. Here we detail the significant pests:

Citrus Leafminer (*Phyllocnistis citrella*)

Type: Insect (tiny moth larva) – leaf pest
Description: Citrus leafminer is a small silver-white moth whose larvae "mine" through the epidermis of young citrus leaves, creating winding, serpentine tunnels. It primarily attacks new flush leaves (and sometimes young shoots), causing them to curl, distort, and look silvery. While leafminer feeding by itself causes only moderate harm (leaf distortion and reduced photosynthesis), it has a critical role in exacerbating diseases like citrus canker (by providing entry points)[81]. It's a major pest for nurseries and young trees due to the high proportion of new flush.

Damage Symptoms: - **Leaf mines:** Look for characteristic **snake-like tunnels** on new leaves, usually on the underside. The mines are whitish or silvery tracks that meander, often ending in a small blister or leaf edge curl where the larva pupates[82]. The mines can be outlined by a thin line of frass (excreta) inside. - **Leaf curling:** Mined leaves tend to **curl and crinkle** (especially if multiple mines). They may also have a cut or folded edge at the terminus of a mine where the larva has curled the leaf margin to pupate. - **Reduced growth:** Heavy infestations can cause the flush to be stunted and distorted, potentially delaying tree growth or causing uneven canopy. - **Secondary infection:** Check mined leaves for any canker lesions (if canker present in area). Often, canker lesions form along the mines. - Typically, leafminer does not attack mature hard leaves; it's confined to young flush while leaves are soft. - *Early signs:* Tiny squiggly lines on flush leaves 1–2 weeks after flush emerges. Also, very small moths can be seen at dusk or when disturbed (but they're hard to notice due to size). - *Advanced infestation:* Nearly every new leaf is mined and distorted; flush appears silvery/shriveled. Nursery seedlings might look bedraggled with many mined leaves.

Life Cycle & Spread: The adult moth is just ~2 mm long. Females lay eggs on young leaf flush (mostly on underside). Eggs hatch in a few days; larvae immediately tunnel into the leaf and feed between epidermal layers, creating mines. They pass 4 instars in about 1–3 weeks (faster in warm weather). The final instar rolls the leaf edge or finds a sheltered spot to pupate in a curled section. Adult emerges after ~1 week. There can be many overlapping generations in a growing season (in tropical climate, almost continuous if flush is present; populations peak during active flushing periods post-monsoon and spring). They don't disperse very far on their own (moths are weak fliers, fluttering short distances), but infestations can build up orchard-wide as each flush invites a new generation. The pest is present across all citrus areas in India. Spread to new

orchards can occur via infested nursery plants carrying pupae or natural movement of moths from nearby orchards.

Geographic Distribution: Throughout India's citrus belts. Particularly severe in nursery environments and in regions with continuous flushing cycles (e.g., in southern India where acid lime flushes often). It became a serious pest in India around the 1990s when it spread globally. Now it's part of regular pest complex.

Economic Impact: Leafminer itself doesn't directly cause fruit loss in mature trees (older trees can tolerate some leafminer damage and still fruit well). However: - **Nursery and young trees:** It can slow the growth significantly, meaning delayed time to fruiting and more culling of damaged nursery stock. That's economic loss in propagation. - **Canker synergy:** In areas with citrus canker, leafminers greatly increase canker incidence and severity[83][41]. This indirect effect is significant – can lead to fruit loss and tree decline from canker. So controlling leafminer is part of canker management costs. - For export nurseries or budwood, leafminer mines also complicate phytosanitary status. - Generally, heavy infestations weaken flush which could reduce next bloom slightly, but citrus often compensates.

Overall, while one wouldn't lose a crop solely from leafminer, ignoring it can lead to long-term impacts and higher disease losses. It's thus considered a major pest for management.

Management – Prevention/Cultural: - **Flush timing:** In some cases, cultural practices can reduce vulnerable flush. E.g., avoid heavy fertilization or irrigation that triggers off-season flush when leafminer and canker pressure might be high. Try to synchronize flushes so they can be protected in one go rather than continuous trickle flush. - **Prune and destroy water shoots or late sprouts** that could harbor heavy mines. - **Shade management:** Young nursery plants under netting/shade net may have fewer leafminer invasions if the net excludes the moth. - **Intercropping:** Some intercrops might distract leafminer, but not well documented. Avoid near by alternate hosts (leafminer mainly likes citrus and related). - **Resistant varieties:** Some newer citrus hybrids are being looked at for leafminer resistance (like some lemon varieties with hairy leaves deter egg-lay). Not widely adopted yet.

IPM Strategies: - **Monitoring:** Use pheromone traps (leafminer pheromone lures are available) to catch adult males. This helps detect when moths are active and roughly population density. Also simply observe flush – % of leaves mined gives degree of infestation. - **Biological control:** Leafminer has good natural enemies: - The most effective are small **parasitic wasps** (e.g., *Agrochyne (Cirrospilus)* spp., *Citrostichus phyllocnistoides*, *Pnigalio* spp., and *Quadrastichus* sp.). These parasitize leafminer larvae in mines. In some Indian orchards, parasitism rates can be high, naturally controlling leafminer later in flush cycle[84][85]. IPM suggests avoiding broad insecticides during times parasites are active to encourage them. In some places, *Clostophaqus (Semielacher) scutellaris* has been introduced as a biocontrol. - **Predators:** general predators like lacewings, ladybird larvae, and spiders might eat some leafminer larvae if accessible. - **Oils and Biopesticides:** Spraying horticultural mineral oil (1-2%) on new flush can deter egg laying and also smother some larvae in shallow mines[86]. This is a safe IPM tool that also doesn't harm most beneficials much. Neem oil 3% also reported to reduce incidence slightly[86]. - *Bacillus thuringiensis* (Bt) sprays can kill leafminer larvae if they ingest it, but since larvae are inside leaves, Bt needs to penetrate a bit (not highly effective unless applied at very young larval stage when mine is very shallow). - **Chemical control:** If needed, timing is crucial. Because leafminer

larvae are protected inside leaves, one must either kill the adults or use a systemic that gets inside leaf. - **Systemic insecticides (neonicotinoids):** Imidacloprid or Thiamethoxam soil drench or foliar can provide good control. Imidacloprid 0.005% (e.g., 0.5 ml/L) sprayed on flush has shown efficacy[87][88]. However, care with neonics to avoid harming pollinators if citrus is blooming concurrently (prefer after petal fall). - **Spinosad:** A bio-derived insecticide (Spinosyn) is very effective against leafminer larvae and relatively safe to beneficials. Spinosad at 0.3 ml/L applied on new flush gives excellent control[86]. It penetrates the leaf a bit and can kill larvae in mines. - **Abamectin:** Another option, often combined with oil, for leafminer control. Avermectin is translaminar and can kill larvae inside leaves. - **Diflubenzuron (IGR):** As an insect growth regulator, might prevent larvae from developing, but less commonly used than above options. - **Frequency:** Typically, one or two well-timed sprays per flush is enough. E.g., spray when majority of flush leaves are just expanded and before heavy mining has happened, then possibly a second 10-14 days later for later eggs. - **Combine with canker management:** Conveniently, copper sprays for canker don't affect leafminer much directly, but if mixing, sometimes they add an insecticide to the copper spray to do both jobs (as indicated in canker section: copper + an insecticide like cypermethrin or dimethoate can reduce both canker and leafminer impact). - **No spray approach for older trees:** On big mature trees, some IPM programs say leave leafminers alone because the damage is mostly cosmetic and beneficial wasps will catch up. For young trees or nurseries, definitely manage them.

Chemical Control (specifics): - **Imidacloprid:** Drench 1-2 ml per plant for nursery, or spray 0.5 ml/L on flush (but avoid if flowering). Provides ~3 weeks protection. - **Spinosad:** Spray 0.25 ml/L (around 25 ppm) on flush, very effective, preserve beneficials. - **Abamectin:** 0.5 ml/L + 1% oil for better spread. - **Lambda-cyhalothrin or other pyrethroid:** effective on adults, but pyrethroids can flare up scales/mites by killing predators, and can't hit larvae in mines well. So not first choice unless combined with oil early when mines are just starting, plus risk to beneficials is high. - **Spray coverage:** Ensure the underside of leaves is hit, as mines are usually there.

When to Escalate: Usually, farmers can manage leafminer with recommended practices. Escalate to extension experts if: - You consistently have >80% of new leaves mined even after interventions – perhaps insecticide resistance or improper spray timing – experts can advise. - If introducing biocontrol (like getting parasitic wasps) is of interest, specialists can help with rearing/release programs. - If canker outbreaks are uncontrolled and leafminer is a factor, experts might need to implement an area-wide combined campaign.

Field Diagnosis Checklist: - Check 10 new leaves on various trees – how many have mines? If more than 5 have mines, population is active. - Are the mines fresh (shiny silvery with a larva inside at end of mine) or old (brownish trails, empty)? Active infestation shows variety of stages. - Look on flush at dusk or early morning for tiny moths. They usually fold wings tent-like and are found on leaf undersides. - Do you see any tiny exit holes on leaves? (Tiny hole with a slight protruding pupal case indicates moth emerged.) - Also check for presence of parasitic wasp emergence holes on mined leaves (tiny round holes in the mine separate from the main exit – signs beneficials are working). - Assess flush cycle: If a big flush is coming, plan accordingly – that's when leafminer will strike.

QR-Code Summary: *Citrus Leafminer – Tiny moth larva pest of new leaves. Damage: larvae tunnel inside young leaf, making silvery serpentine mines; leaves curl/distort[89]; heavy attack*

stunts flush and aggravates canker infections. Peak on new flush after monsoon or fertilization. Control: prune heavily infested water shoots; protect flush with safe insecticides (e.g. spinosad, imidacloprid)[87]; use horticultural oil or neem to deter egg-lay[86]. Encourage parasite wasps (avoid broad pesticides) – they often provide natural control. Essential to manage in nurseries and young trees.

Citrus leafminer damage on a lime leaf. The larva's mine appears as a silvery serpentine trail on the underside of the leaf, causing leaf curling and distortion[89]. Proper management of leafminer is critical to protect new flush and reduce entry points for canker.

Citrus Psyllid (*Diaphorina citri*)

(Details covered under greening above, but summarizing from a pest perspective.)
Type: Insect (sap-sucking bug) – shoots/leaf pest, vector of HLB
Description: The Asian citrus psyllid is a small mottled brownish winged insect that feeds on citrus shoots. Its importance is primarily as the **vector of Huanglongbing (citrus greening)**. Psyllid feeding by itself causes some distortion of new shoots and honeydew/sooty mold, but not severe. However, their **toxic saliva** can cause a leaf-curling symptom called "psyllid yellows" on heavy attack. The real threat is each psyllid can carry HLB bacteria and infect trees as it feeds[64]. Psyllids lay eggs on new flush, and their nymphs develop there, producing waxy tubules of honeydew.

Damage & Signs: - **Feeding damage:** Twisted or notched young leaves; **curled leaf margins** on flush; sometimes a burning of tips if infestation huge. But these direct symptoms are minor

compared to disease. - **Honeydew and sooty mold:** Psyllid nymphs excrete honeydew, leading to black sooty mold growth on leaves. - **Presence of psyllids:** The insect itself is the sign to look for: - Adults: ~3-4 mm long, brown mottled, sit at a 45° angle to leaf surface with head down, tail up. If disturbed, they jump/fly a short distance. - Nymphs: yellow-orange, scale-like nymphs clustered on new shoots, often alongside the feathery white waxy tubules they produce. - Usually found on very tender new leaves and buds. Eggs are bright yellow-orange, laid on tips of growing shoots or edges of young leaves. - *Scouting tip:* Young flush with a "bending" or hooking appearance and some clumping of leaves can indicate psyllid feeding. - *HLB context:* If HLB is present, any psyllid is dangerous. Even a few psyllids can infect trees.

Life Cycle: Psyllids breed whenever new flush is available. They can have many generations per year in tropics. Each female lays several hundred eggs on flush; nymphs pass 5 instars in ~2-3 weeks (depending on temperature). Adults can live for a few months, moving between trees. They can spread to new areas by flying or via movement of infested plant material.

Spread in India: ACP is present in most citrus-growing areas. It likely originated in this region. It thrives in warm environments and can move orchard to orchard. It's fully established and cannot be eradicated, only controlled.

Economic Impact: Indirectly huge via greening. Direct feeding isn't the main cause of yield loss except maybe slight in nursery flush. But because it vectors HLB, its presence correlates with catastrophic losses from HLB as covered earlier. Thus, controlling psyllids is economically justified solely to prevent HLB spread.

Management – Prevention/Cultural: - **Reduce alternate hosts:** Murraya (orange jasmine) and some ornamental rutaceous plants host psyllid and HLB. Removing or monitoring these near orchards is advised. - **Flush cycle coordination:** In small farm contexts, if possible, encourage uniform flushing (so not perpetual small flushes which allow continuous breeding). That way one can target sprays to flush timing when all eggs are laid simultaneously. - **Bag or net new trees:** In nurseries or newly planted high-value trees, use fine mesh netting during flushes to physically exclude psyllids. - **Intercropping with guava:** There were reports from Asia that interplanting guava with citrus significantly reduced psyllid populations (due to repellent volatiles). Some experiments in India showed guava-citrus mixed orchards had lower HLB incidence. If feasible, it's a cultural attempt but results can vary.

IPM Strategies: - **Monitoring:** Use yellow sticky traps at canopy height to catch adult psyllids. Also simply inspect flush shoots weekly. If you see one adult, assume more. - **Biological control:** - **Tamarixia radiata** was introduced in some places (including India) and is a proven parasitoid of psyllid nymphs. It can reduce psyllid populations significantly if not disrupted by insecticides[90][85]. Encourage its presence by limiting broad-spectrum sprays and possibly augmentative releases. - Other parasitic wasps (Diaphorencyrtus aligarhensis) also target ACP, though Tamarixia is main. - Predators: ladybird beetles (esp. Curinus coeruleus, a purple ladybeetle) feed on psyllid nymphs, as do syrphid larvae, lacewings, spiders etc. - **Chemical control:** - **Systemic insecticides** (Imidacloprid, Thiamethoxam) are effective and often used prophylactically (soil drench for young trees). - **Foliars**: dimethoate 0.06% or lambda-cyhalothrin 0.05% kill adults quickly. But frequent use can harm natural enemies and flare other pests. - **Insect Growth Regulators**: e.g., buprofezin (affects nymphs). - **Oil sprays**: 1-2% horticultural oil can deter egg laying and smother some nymphs, and is softer for IPM. -

Rotation: alternate neonicotinoids with pyrethroids or IGRs to avoid resistance and preserve beneficials. - Strategy is to hit **both adults and nymphs** when flush appears: maybe a soil systemic at flush onset (covering nymphs emerging) plus a foliar knockdown for adults at peak flush. - **Regional approach:** Coordinated area-wide spraying has been used in some countries to knock psyllid populations down synchronously (to slow HLB). - **Removal of reservoir trees:** If wild citrus or neglected trees heavily infested with psyllids are nearby, work with neighbors to manage or remove them.

Organic IPM: rely on Tamarixia, oils, maybe neem (neem has some repellent effect, needs frequent application). Remove HLB trees promptly to reduce infective reservoir for any psyllids around.

When to Escalate: This pest's management is usually advisory with extension due to HLB. If a farmer has trouble controlling psyllids (constant reinfestation), it likely needs community-level action – escalate to local agri office to coordinate sprays in region. Also, if Tamarixia is not present, an expert might help introduce or augment it.

Field Diagnosis Checklist: - Look closely at new buds – see any tiny orange-yellow **eggs on leaf buds**? (They are stalked). - Check underside of flush leaves for **yellow nymphs** and their white curly waxy tubules (very diagnostic for psyllid nymphs). - Gently tap a flush over paper or hand – do small flying bugs appear? (Adults jump and fly off). - Are any leaves with notches on edges? (Adults sometimes feed and leave a small notch). - Note time of day: Psyllids often feed in cooler parts of day, in midday they might hide a bit. - Use a hand lens: see the **red eyes** of the nymph, or on adult, the brown mottling and wedge-shape body with clear wings held roof-like.

QR-Code Summary: *Asian Citrus Psyllid – Sap-sucking insect vector of greening. Appearance: tiny mottled brown winged insect (~3 mm) that sits at 45° angle on shoots[91]. Damage: new leaf distortion, sticky honeydew, sooty mold; more critically, it transmits HLB (citrus greening) bacteria[92]. Lifecycle: eggs and nymphs on flush shoots year-round if flush present. Management: monitor flush for psyllids; control nymphs & adults with systemic insecticides (imidacloprid drench) and foliar sprays (e.g., dimethoate, oil + lambda-cyhalothrin)[87]; preserve Tamarixia parasitoids for biocontrol by using selective insecticides. HLB strategy: rogue infected trees and coordinate area-wide psyllid suppression. Psyllid control is essential to prevent spread of the deadly greening disease.*

Citrus Whitefly & Sooty Mold (*Dialeurodes citri*, *Parabemisia* sp.)

Type: Insect (whitefly – sap-sucking) – leaf pest, causes honeydew
Description: Several species of whiteflies attack citrus; the common citrus whitefly (*Dialeurodes citri*) and cloudywinged whitefly (*Singhiella* sp.) are small whitish flying insects found on the underside of leaves. Whitefly nymphs (scales) suck sap and excrete copious honeydew, which leads to growth of **black sooty mold** fungus on leaves and fruits, reducing photosynthesis and marketability. Heavy infestations cause leaf yellowing and drop. Whiteflies are more a problem in shaded or sheltered orchards. The pest is notable also as a vector for some viruses (though not major citrus viruses; more for vegetable viruses). The key issue is **sooty mold** that forms on the honeydew, making leaves and fruits black and sticky[93][94].

Damage Symptoms: - **White, waxy adults:** Undersides of leaves will have tiny white moth-like insects (1–2 mm) that flutter when disturbed. - **Nymphs:** Immature stages are oval, flat, almost transparent or whitish scale-like things stuck on underside of leaves. - **Honeydew & Sooty mold:** Leaves and fruits develop a **black, velvety coating** of sooty mold fungus that grows on the sweet honeydew excreted by whitefly (and other pests like aphids, mealybugs, scale). This black film blocks light from leaves, reducing photosynthesis, and makes fruit skins black and unattractive[95]. Sooty mold itself doesn't infect the plant, but it's an indicator of sap-sucking

pest presence. - **Leaf yellowing:** Heavy whitefly feeding can cause leaves to get chlorotic and drop early, particularly on young or stressed trees. - **Nursery effect:** In seedlings, whiteflies can stunt growth and cause general decline if not controlled. - *Early sign:* A fine coating of sticky honeydew on lower leaves (you might feel stickiness or see dust stuck on it) before mold grows; also noticing an increase in ant activity (ants often tend honeydew-producing pests). - *Advanced infestation:* Leaves drip with honeydew, ground below trees can become sticky/blackened; the entire canopy looks dark from mold; some defoliation occurs; fruit blackened by mold.

Causes & Spread: Whiteflies proliferate in warm, humid conditions with lush growth. Overuse of broad insecticides that kill their natural enemies can cause outbreaks. They spread by flying (adults can disperse short distances, wind can carry them further) and via movement of infested plant material. Citrus whitefly has multiple generations per year and can overlap generations in conducive climate.

Geographic Distribution: Found in most citrus areas of India, more prevalent in wetter zones or wherever other host plants exist year-round. It's a common pest of citrus, as well as some ornamental/vegetable plants, so often present in mixed crop environments.

Economic Impact: Whitefly & resulting sooty mold primarily cause **quality issues**: - **Reduced yield:** If a tree is heavily infested, sootymold-covered leaves photosynthesize less, possibly reducing tree vigor and fruit set. - **Fruit downgrade:** Black sooty mold on fruit must be washed off; if severe, it can cause fruit to color unevenly or need labor to clean, raising cost or lowering grade. - Indirect: honeydew might promote secondary fungi or attract other pests (ants defend whiteflies, interfering with natural predators). - Usually not tree-killing, but can be a persistent nuisance requiring management costs.

Prevention/Cultural: - **Encourage natural enemies:** ladybird beetles (like Delphastus), lacewings, and parasitoid wasps (Encarsia spp.) significantly control whiteflies if not disrupted. Avoid unnecessary insecticides. - **Ant control:** Control ants (they farm honeydew pests) by trunk banding or destroying ant nests. Without ants, natural enemies control whitefly better. - **Prune dense canopies:** Whiteflies prefer stagnant air, shady inner canopies. Better airflow and light can reduce population growth. - **Reflective mulches:** In some contexts, reflective ground mulch has been used to repel whitefly (commonly in vegetable IPM, less so in orchards). - **Remove alternative hosts:** If possible, reduce nearby heavily infested alternate host plants.

IPM Strategies: - **Monitoring:** Yellow sticky traps capture whitefly adults and give an idea of population trend. Inspect underside of 5–10 leaves per tree for nymphs and sooty mold presence. - **Biological control:** - Parasitoids: *Encarsia* and *Eretmocerus* wasps that lay eggs in whitefly nymphs are effective. *Encarsia spp.* often turn parasitized nymphs black or brown. They usually keep whitefly in check unless disrupted. - Predators: larvae of syrphids, lacewings, and some small birds eat whitefly. Fungal diseases (whitefly fungus) sometimes naturally crash populations in humid weather. - Can introduce commercial biocontrols if available (Encarsia formosa is used in greenhouse widely). - **Horticultural oils/soaps:** Spraying 1-2% neem oil or mineral oil or insecticidal soap coats and smothers whitefly nymphs and cleans sooty mold. Oil also has some deterrence on adults. This is a good IPM-friendly approach and also helps loosen sooty mold off leaves[96]. - **Neem-based products:** Azadirachtin (neem extract) can reduce egg-laying and nymph survival. Use at recommended concentration (like 1-2 ml/L). - **Chemical control:** If needed (in high infestation): - **Systemics:** Imidacloprid again effective against

whitefly nymphs when applied as a soil drench (since nymphs suck sap). This reduces honeydew quickly. Thiamethoxam likewise. Caution: frequent use can flare other pests (like mites) and kill pollinators if bloom. - **Buprofezin (IGR):** Very effective on whitefly nymphs – it inhibits their molting. Use at e.g., 25% SC @ 1 ml/L. Safe for many beneficials. - **Pyrethroids:** like deltamethrin, effective on adults, but can cause spider mite flare-ups and kill beneficial insects. - **Combo approach:** sometimes a tank mix of oil + IGR gives thorough control with less harm (oil smothers, IGR prevents rebound). - Ensure underside coverage in spray because that's where nymphs are. - **Sooty mold clean-up:** Once whitefly/honeydew source is controlled, sooty mold will weather off gradually or can be washed off fruit by water spray. If needed, a light solution of soap can be sprayed to help dissolve mold.

When to Escalate: Usually whitefly can be handled with available measures. If an orchard faces chronic heavy sooty mold even after trying IPM, possibly escalate to identify if there's an underlying cause like persistent ant problems or insecticide resistance. Also, if unsure whether black coating is sooty mold or something like citrus melanose (which also spots black, but mold is superficial and can be wiped), experts can help diagnose.

Field Diagnosis Checklist: - Flip a leaf: see tiny white moth-like insects flutter off? That's likely whitefly adults. - Look closer: Do you see stationary tiny oval "scales" (whitefly nymphs) on leaf undersides, often a bit whitish or translucent? - Tap a branch: do a flurry of white specks fly out then resettle? - Are leaves sticky or shiny with honeydew? (Touch or look in sunlight for glisten). - Is there a black powdery coating that can be gently scraped off with a fingernail? (If yes, sooty mold due to honeydew – could be whitefly or other sucking pests present). - Check new flush vs old leaves: whitefly prefer somewhat older leaves (unlike psyllids that need fresh flush), but heavy infestations cover all. - Also examine leaves for parasitized nymphs – if many nymphs are dark brown or have a round hole in them, that means parasitic wasps are working.

QR-Code Summary: *Citrus Whitefly – Sap-sucking white insects on leaf undersides. Damage: whitefly nymphs suck sap and excrete sticky honeydew, leading to black sooty mold on foliage and fruit[95]. Heavy infestations cause leaf yellowing, drop, and unsightly fruit. Signs: clouds of tiny white-winged adults fly when disturbed; black velvety mold on leaves indicates whitefly/aphid presence[94]. Control: Conserve parasitoids (Encarsia wasps) that attack nymphs; spray 2% neem or mineral oil to smother nymphs and clean mold[96]; use systemic insecticide (imidacloprid) or IGR (buprofezin) in severe cases. Prevent ant activity that protects whiteflies. Clean sooty mold by washing foliage once pests are controlled.*

Scale Insects (Armored & Soft Scales, e.g., White Snow Scale *Unaspis citri*, Black Scale, Green Scale)

Type: Insect (scale – sap-sucking) – branch, leaf, fruit pest, causes honeydew (soft scales)
Description: Scale insects are small, immobile sap feeders that attach themselves to leaves, stems, or fruits, often covered by a waxy scale or cottony secretion. **Armored scales** (like white snow scale, red citrus scale) have a hard cover and suck plant juices causing localized yellow spots, possibly leading to branch dieback if severe. **Soft scales** (like green scale, brown soft scale) excrete honeydew leading to sooty mold (like whiteflies do). Specific notable scales: - **White snow scale (*Unaspis citri*)**: An armored scale which appears as small **white encrustations** on trunks, branches (males form white fluff, females are brownish purple under a white cover). It can heavily crust branches, weakening them[97][98]. - **Red citrus scale (Aonidiella aurantii)**: Armored, reddish-brown circular scales on fruit and leaves. - **Black scale (Parlatoria or Saissetia)**: Soft scale, dark brown, on leaves and twigs. - **Soft green scale (Coccus viridis)**: Soft, green, hemispherical scales on leaves, producing lots of honeydew. Scales often hide on the underside of leaves or along stems. They cause damage by sap removal (leading to weakness, leaf yellowing, drop) and in soft scales, the resulting sooty mold from honeydew. Armored scales can cause fruit blemishes (red spots under scales on rind).

Symptoms/Damage: - **Visible scales:** Look for **tiny round or oyster-shell shaped bumps** attached to plant surfaces. They can be white (snow scale), brown/black, or translucent depending on species. Often in clusters or aligned along veins or stems. - **Yellow spots on leaves:** Armored scales feeding on a leaf can cause chlorotic spots directly above them on the

leaf surface. - **Branch dieback:** If twigs are heavily infested (completely encrusted), that part may weaken and die due to lost sap. - **Honeydew and mold (soft scales):** If soft scales like brown soft scale are present, leaves/fruit get sticky and black with sooty mold (similar to whitefly effect). - **Fruit blemish:** Scales on fruit cause pits or discoloration under them, reducing quality. - *Early signs:* small portion of a branch has some white specks or brown bumps; ants may be crawling (in case of soft scale). - *Advanced:* trunk and branches might be covered (like someone sprinkled coarse salt on them in case of white snow scale, or a fuzzy white patches in cottony cushion scale case); leaves might drop from sap drain; entire tree looks sooty (if soft scales).

Causes & Spread: Scale infestations often flare when natural enemies are disrupted (like by broad insecticide use for other pests). They are spread by **crawlers** – tiny first-instar nymphs that move to new sites; crawlers can be blown by wind or carried by birds/ants to new trees. Long-distance spread via infested plant material. Some species, like white louse scale, can rapidly multiply in dry seasons.

Geographic distribution: Different scales in different areas, but generally scales are present in all citrus-growing regions. White snow scale is notable in humid tropical climates (found in parts of NE India, also other continents). Soft green scale common in South India. Brown soft scale etc. widely across.

Economic Impact: Moderate to significant: - Scales can cause **tree decline** if not managed, especially white louse scale which can kill young branches and nursery trees. - They cause cosmetic damage to fruit (leading to culling). - The honeydew/sooty mold from soft scales can reduce photosynthesis and fruit grade, similar to whitefly issues. - Heavy infestations require control costs and can weaken trees making them yield less. However, good IPM often keeps them in check, so usually not as catastrophic as HLB etc.

Management – Cultural/IPM: - **Preserve natural enemies:** Scales have many natural enemies (ladybird beetles like Chilocorus (the black scale eaters), parasitic wasps like Aphytis, etc.). Minimizing broad insecticides helps them keep scales low. If you see holes in scales or parasite exit holes, that indicates nature is at work. - **Ant control:** Ants often "farm" soft scales for honeydew and protect them from predators. Controlling ants (sticky bands on trunk, baiting nests) can significantly allow predators to reduce scales. - **Horticultural oil:** An age-old effective remedy. Spray **narrow-range oil (1.5-2%)** thoroughly – it smothers scales (especially the immobile nymphs and adults)[99][100]. Oil also helps dissolve sooty mold. Multiple oil sprays spaced 2 weeks apart can control an outbreak without harsh chemicals. - **Prune heavily infested branches:** If one limb is loaded with scale, sometimes pruning and burning it is quicker than treating each insect. - **Cleaning of young trees:** In nursery, manually wipe off or pressure-wash off scales (if feasible) to reduce load before chemical treatment. - **Check new introductions:** Quarantine and inspect new citrus plants for scales to avoid introducing a new species or population.

Chemical Control: - **Systemic insecticides:** Imidacloprid or dimethoate can control some scales (especially soft scales, as they ingest phloem). Armored scales are less affected by systemics because they mainly feed on cell sap not phloem. But imidacloprid drench has shown reduction in some scale infestations. - **Contact sprays:** - **Chlorpyrifos 2 ml/L** or **Acephate 1 g/L** or **Diazinon** – effective but broad-spectrum organophosphates. Usually used during dormant or

post-harvest if needed. - **Buprofezin (IGR)** at 1-2 ml/L works on scale crawlers by inhibiting molting. - **Pyriproxyfen (IGR)** also works on scale crawlers/eggs. - These should target the crawler stage primarily (timing is tricky as scales overlap generations; might need two applications). - **Repeated treatments:** Because scales can have staggered life stages, follow-up treatment after 2-3 weeks is recommended to catch newly hatched crawlers. - **Note on white louse scale:** It has male and female differing appearance – if heavily infested, a specific approach might be needed (like trunk sprays with oil + insecticide). - As always, ensure good coverage of trunk/branches/leaves underside where scales hide. - **Precaution:** Some scale insects, especially armored, have waxy coatings that can repel water-based sprays; oil helps here as it improves wetting and penetration.

Biological control: - *Ladybird beetles* like *Chilocorus nigrita* (the twicestabbed lady beetle) are famous scale predators. Some augmentation or conservation of these can wipe out many scales. - *Parasitic wasps:* e.g., *Aphytis melinus* (for California red scale, used elsewhere), *Coccophagus*, *Encarsia*, etc. These usually keep soft scale in check naturally in orchards unless disrupted. - If needed, one can introduce specific parasitoids if a particular scale is out of hand and not enough local presence (for ex, import of *Comperiella* for cottony cushion scale historically saved citrus from that pest).

When to Escalate: - If a new scale species appears that you or local extension aren't familiar with (exotic introduction), escalate to entomologists. - If scale persists despite usual treatments, might need expert advice on timing or chemical choice (some scales have become resistant or need specific approach). - White snow scale is fairly aggressive – an expert might advise if any eradication program needed if it's a localized outbreak.

Field Diagnosis Checklist: - Scrutinize branches and leaf undersides: do you see tiny stationary bumps? Try gently scraping with a fingernail: if it comes off and is a scaly insect beneath, yes. - For white snow scale: easiest to spot on green stems or trunk as small white flecks in clusters (male tests) and some brownish female covers. If heavy, the branch looks whitewashed. - Check for sooty mold and follow it to see if soft brown scales are on underside of leaves causing it. - Are leaves yellow with little spots? Check underside for scale at those spots. - Use a magnifier: an armored scale will have a separate shell that can be lifted off a soft bodied insect; a soft scale is more integrated (squishable). - Look for parasitized scales: e.g., some turn black (black parasitoid fungus or parasitic wasp inside). - Note any ant activity—ants on citrus often indicate scale, mealybug, or aphids present.

QR-Code Summary: *Scale Insects – Sap-sucking scales on leaves, stems, fruit. Types: Armored scales (e.g., white snow scale) form hard waxy covers[101]; soft scales (e.g., green scale) are convex and excrete honeydew. Damage: sap loss causes leaf yellowing, drop, twig dieback; soft scales cause sooty mold from honeydew[102]; fruit may be blemished by scales or mold. Control: preserve biocontrol (ladybirds, parasitic wasps) – avoid harsh insecticides; control ants that protect scales; spray horticultural oil 1.5-2% thoroughly to smother scales (repeat after 2 weeks for crawlers)[103]; use targeted insecticides/IGRs (buprofezin, chlorpyrifos) if needed during crawler stage. Good tree vigor helps tolerate some scales; manage heavy infestations to prevent branch dieback.*

(Other pests to mention briefly in a master table or narrative: Fruit sucking moths (Othreis sp.) that cause rind damage; Fruit piercing flies (Bactrocera spp.) that cause fruit rot; Citrus fruit

borer (prays or citrus fruit boring caterpillar, not very common in India though); Citrus bud mite (Aceria sheldoni) affecting lemons in some areas; Citrus thrips causing rind scurfing; Citrus nematode (Tylenchulus) causing slow decline; Termites attacking citrus roots in some dry areas. Due to length, not all elaborated, but can be in master table.)

Nutritional Deficiencies in Citrus

Citrus trees require balanced nutrients; deficiencies of macro or micronutrients manifest as characteristic **foliar symptoms** and can reduce yield and fruit quality. Nutrient disorders are common in Indian soils (e.g., zinc and iron deficiency in alkaline soils). Key nutrient issues:

- **Nitrogen (N) Deficiency:** General **pale yellowing of leaves** (uniform chlorosis) starting with older leaves, which may drop. Leaves are smaller, and the tree has thin, sparse foliage ("bushy top" appearance)[104][105]. Twigs may die back. Low N causes reduced growth and fruiting (small fruits, low yield). *Correction:* Apply urea or ammonium sulfate; foliar urea spray 2% can green up tree quickly[106].

- **Phosphorus (P) Deficiency:** Less common in citrus. Leaves may be smaller, dark dull green or have a purplish tinge; older leaves might die early. Trees show stunted growth, thin canopy. *Correction:* Apply superphosphate to soil.

- **Potassium (K) Deficiency:** Manifests as leaf **edge burn** (scorching of tips and margins on older leaves) with possibly small brown spots[107]. Leaves may curl downward ("cupping"). Fruits might be small, with thin peel, and trees more prone to fruit drop[107]. In mandarins, could see bronzing and twisting of leaves[108]. *Correction:* Soil application of K_2SO_4 or foliar KNO_3 2%[109].

- **Zinc (Zn) Deficiency (Mottle leaf):** Very common. Leaves (especially new ones) show **irregular chlorotic spots** between veins, giving a mottled appearance; leaves are often **small and narrow ("little leaf")**[110][111]. The midrib and main veins remain green (green vein banding) while the rest yellows – sometimes confused with HLB, but Zn deficiency is more uniform and on newer leaves. Twigs have shortened internodes, creating a rosette look. Can cause very poor fruit set and small fruits. *Correction:* Foliar spray of $ZnSO_4$ (0.5%–1%) plus a bit of lime for solubility[112]; soil application of zinc chelate in deficient soils.

- **Iron (Fe) Deficiency (Iron chlorosis):** Typically in calcareous/high pH soils. New leaves show **bright yellow or even white interveinal chlorosis** – veins remain slightly green creating a **"green veins on yellow leaf"** pattern[113]. In severe cases, new leaves

are almost white and fall off, twig dieback occurs. Often affects one side or one branch more (depending on root distribution in poor soil). *Correction:* Foliar spray of $FeSO_4$ (0.5%) with a wetting agent[114]; soil drench of iron chelate (EDDHA chelate works in high pH) near root zone.

- **Manganese (Mn) Deficiency:** Shows as **fine network of green veins on a light green background** in young leaves[115] – somewhat similar to iron but typically the veins themselves may appear dark green in bands[115]. Sometimes small white/grey spots in interveinal areas as it progresses, and leaves can drop. *Correction:* Foliar 0.5% $MnSO_4$ solution[116].

- **Magnesium (Mg) Deficiency:** Symptoms on older leaves: **yellowing starts from leaf margins inward**, leaving a green triangular area at the base (around midrib) – called "inverted V" or Christmas tree pattern of green on a yellow leaf[117]. Tips and edges turn yellow then brown if severe. Leaves may drop prematurely from bottom of canopy upward. *Correction:* Soil apply dolomite or $MgSO_4$; foliar spray 2% $MgSO_4$ if quick fix needed.

- **Boron (B) Deficiency:** Causes multiple issues: **leaf curling**, "boron burn" which is translucent spots that later turn corky on leaves[118]. New growth may be bushy with small misshapen leaves (boron helps hormone balance). **Fruit are affected** – "brown gum pockets" in the rind, lumpy thick peel, and sometimes internal dry areas. Also can cause premature fruit drop or fruit cracking. *Correction:* Foliar spray of Borax or Solubor @ 0.1–0.2%[119]; do not overdo B as excess is toxic.

- **Copper (Cu) Deficiency (Exanthema/Dieback):** Rare now because copper fungicides supply Cu. In history, caused "exanthema" – trees had dieback of twigs with gum exudation, leaves dark green, small and brittle, fruit with brown gum-soaked areas in rind. If it occurs: *Correction:* Foliar 0.3% Copper sulfate (often already addressed via sprays)[120].

- **Molybdenum (Mo) Deficiency:** Rare but in acidic soils can cause “yellow spot” on citrus: mottled spotting and overall pale. Correction via molybdate sprays.

- **Calcium (Ca) Deficiency:** Also uncommon in field (soils usually enough Ca or given as lime), but in acidic infertile soils could cause weak stems, leaf distortion, blossom end rot-like symptoms on fruit (in extreme). Usually addressed with liming.

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- **Salinity or Chloride toxicity:** Not a nutrient deficiency but manifests similarly – burnt leaf edges (especially on older leaves), leaf drop, small yields. Occurs if irrigation water is high EC. Manage by leaching salts, rootstock selection.

General Nutrient Disorder Management: - **Soil testing & leaf analysis** regularly to guide fertilization. - **Balanced fertilization schedule:** Typically split NPK doses twice a year (after harvest and during monsoon) and foliar feeding of micros as needed[121][122]. - **Foliar feeding** is very effective for Zn, Mn, Fe, B in citrus as they respond quickly. E.g., a combined spray of $ZnSO_4$ 0.5% + $MnSO_4$ 0.2% + $FeSO_4$ 0.2% + Boric acid 0.1% + Urea 1% is sometimes recommended post-flush. - **Use of organic manures** (FYM) improves micronutrient availability and soil health. - **Soil pH adjustment:** If high pH (causing Fe, Zn lockout), use soil sulfur, acidify irrigation water slightly, or chelated micros. If low pH (causing Mo, etc.), use lime. - **Mulching and irrigation** consistent to avoid drought stress which can exacerbate nutrient deficiency symptoms (like transient Mg deficiency in dry spells).

Special note: Nutrient deficiency symptoms can be confused with some diseases (e.g., HLB vs Zn deficiency vs Fe deficiency). So, if a deficiency is suspected, correct it and see if the plant recovers (if yes, it was nutrition; if no, maybe disease).

Master quick ID: - *Yellow older leaves first:* likely N (uniform) or Mg (inverted V pattern) or K (edge burn). - *Yellow new leaves first:* likely Fe (veins green, interveinal yellow) or Zn (mottled, small leaves) or Mn (fine green veins on pale leaf). - *Whole tree light green, spindly:* N deficiency. - *Specific anomalies:* Little leaf = Zn; Thick rind bumpy fruit = B deficiency; Gumming twigs = Cu deficiency historically.

QR-Code Summary: *Citrus Nutrient Deficiencies – Key symptoms and fixes:*
- Nitrogen: overall pale green/yellow, small leaves, thin canopy[104]. Fix: *Urea 2% foliar or soil N fertilization[106].*
- Potassium: leaf edge burn, brown specks, fruit small/thin peel[107]. Fix: *Potassium sulfate soil or 2% KNO_3 spray[109].*
- Zinc: mottled small leaves (green veins, yellow blotches)[110], twig dieback. Fix: *0.5% $ZnSO_4$ + 0.25% lime foliar[112].*
- Iron: new leaves bright yellow/white with green veins[113]. Fix: *0.5% $FeSO_4$ foliar or chelate soil[114].*
- Manganese: young leaves light green with dark green vein network[115]. Fix: *0.5% $MnSO_4$ foliar[116].*

- Magnesium: older leaves yellow with green base ("V" shape)[117]. Fix: *$MgSO_4$ soil or 2% foliar.*
- Boron: leaf curl, gum spots; lumpy thick rind fruits[118]. Fix: *0.1% borax foliar[119]*.
Proper fertilization and leaf analysis prevent these issues. Mild deficiencies correct fast with foliar feeding (greening visible in 7–14 days). Severe cases require soil amendment and long-term pH/nutrient management.

Physiological Disorders of Citrus

Beyond pests and diseases, citrus can suffer physiological issues due to environmental or cultural factors. These include:

- **Fruit Drop:** Citrus naturally drop some fruit ("June drop"), but excessive drop can be triggered by **water stress, nutrient deficiency, or pest/disease**. Heavy fruit drop often occurs under drought or high temperature before fruits mature. To mitigate, ensure consistent watering and consider plant growth regulators (e.g., 2,4-D at 10–20 ppm can reduce pre-harvest fruit drop[123]). Also, avoid excessive fruit set via thinning or good pruning, so tree can carry the crop.
- **Fruit Splitting/Cracking:** Common in sweet oranges and mandarins when a drought period is followed by heavy rain/irrigation, causing fruit to swell and crack at the rind. Often affects nearly mature fruits, which split longitudinally. To manage, maintain even soil moisture and provide adequate potassium (K improves rind strength)[107]. Also avoid late growth flushes which lead to rapid fruit expansion.
- **Granulation (Dry pulp):** In some cultivars (especially older mandarin varieties and grapefruit), juice sacs may turn dry and granular, often starting at fruit base. This is worse if fruits are left hanging too long or under high temperature swings. Good irrigation and timely harvest reduce granulation. GA3 sprays after flowering have been used to reduce granulation by delaying maturity evenly.
- **Puffy fruit (Puffing):** Mostly in mandarins – rind gets loose and separates from flesh (excessive peel growth vs internal growth)[124]. Caused by high N, low crop load, or climatic factors. Proper nutrition balance (avoid too much N in later stage) and ensuring some crop load helps. Not major in sweet oranges.
- **Stylar-end rot (Navel-end breakdown):** A brown rot at the blossom end of fruit, often due to calcium deficiency or irregular watering (like blossom-end rot of tomatoes). Ensuring Ca supply (sprays of Ca) and steady moisture can help. Also known as "fruit tip burn" in lemons – often linked with boron deficiency too.
- **Sunburn/Sunscald:** Fruit or bark can get sunburn in intense heat especially if suddenly exposed (e.g., after pruning or leaf drop). Fruit sunburn shows as a yellow/brown patch on exposed side, which can later dry and crack. Protect by avoiding sudden over-pruning; in extreme climates, use whitewash on trunks and major limbs.
- **Cold/Frost injury:** In northern citrus areas, frost can damage fruit (causing rind staining, off-flavors) and leaves (dropping after turning brown). Protect by orchard heaters, smoke, or irrigation if frost is forecast. Choose hardy rootstocks in those areas.
- **Alternate bearing (biennial bearing):** Citrus sometimes have heavy crop one year, light the next. This is partly physiological. Good thinning of fruit in heavy year and balanced fertilization can moderate the alternation.

- **Gumming (non-pathogenic):** Sometimes trees exude gum from trunk or limbs without Phytophthora present, often from **stress or injury** (like freeze injury or even copper deficiency historically). Ensure no pathogenic cause; if not, likely due to environmental stress and treat tree gently (paint wounds, etc).
- **Abnormal leaf drop (Flush exhaustion):** After a heavy bloom/flush, some leaf drop is normal (tree reallocating resources). If excessive, check if nutrient or water was lacking during flush – adjust management in next cycle.

Understanding these disorders allows proactive steps: e.g., picking fruit before extreme weather, irrigating properly, and nutrient sprays.

Seasonal Occurrence & Climate Influence: - In **Telangana (dry semi-arid)**, physiological fruit drop often coincides with late summer if irrigation lapses; fruit splitting occurs just when monsoon arrives after a dry spell. - In **North India**, winter cold can cause leaf yellowing (temporary N immobility) which clears with spring. - Coastal humid areas see more rind puffiness and diseases, whereas interior dry areas get more mite and scale issues but perhaps fewer fungal issues (diseases correlate with monsoon timing).

Master Table of Citrus Diseases and Pests in India

Below is a consolidated table summarizing the major issues covered, for quick reference. It lists the problem, causal agent/category, key symptoms, and brief management pointers.

Disease/Pest	Category	Key Symptoms	Management Highlights
Citrus Canker (*Xanthomonas* bacteria)[31]	Bacterial disease	Corky brown **lesions with yellow halos** on leaves, fruit, twigs; premature leaf/fruit drop[33].	**Copper+antibiotic sprays** thrice yearly[42]; prune infected twigs; control leafminer to reduce spread[41]; resistant rootstocks.
Citrus Greening (HLB) (*Ca. Liberibacter* bacteria)	Phloem bacterial disease (vectored by psyllid)	Mottled **yellow blotchy leaves** (asymmetrical)[48]; stunted yellow shoots; **small lopsided fruits** with bitter taste[50]; eventual tree decline.	**Rogue infected trees**; aggressive **psyllid control** (systemic insecticides, Tamarixia biocontrol)[60]; use clean nursery stock; interplant guava (per some IPM).
Foot Rot (Gummosis) (*Phytophthora* fungus)[11]	Fungal (soil-borne)	Bark **oozing gum** at trunk base; brownish **bark rot**, cracks[13]; yellow canopy, tree may girdle and die.	**Improve drainage**; avoid water contact with trunk; scrape & treat lesions with Bordeaux paste[22]; **soil drench** Metalaxyl or Phosphonate[24]; use tolerant rootstock.
Citrus Scab (*Elsinoë*	Fungal	Raised **wart-like lesions** on leaves, twigs, fruit –	**Copper or Carbendazim sprays** on

Disease/Pest	Category	Key Symptoms	Management Highlights
fungus)[125]		**corky scabs**, often conical on leaves[4]; leaf distortion.	new flush[8] (2–3 sprays in rainy season); prune out infected twigs; resistant varieties where possible.
Melanose (*Diaporthe* fungus)	Fungal	**Tiny brown speckled spots** on fruit and leaves (feels rough) – "sandpaper" texture; often streaks on fruit from rain-run; twig dieback on dead wood.	**Remove dead wood** (source of spores); spray **Copper fungicide** after petal fall to protect fruit[22]; ensure good canopy airflow.
Anthracnose (Wither tip) (*Colletotrichum*)	Fungal	**Dieback of twigs** with clinging dead leaves; brown blotches on older leaves; small fruits may rot. Often on weakened trees.	**Prune out dead twigs**; improve tree nutrition; copper or mancozeb spray post-harvest to clean up spores; avoid stress.
Tristeza Virus (CTV)[74]	Viral (aphid-vectored)	On sour orange rootstock: rapid **wilting & death** (quick decline)[74]; on others: stem pitting in trunk/branches, tree stunting, poor yield.	**Use tolerant rootstock** (no sour orange)[78]; certified virus-free budwood; control aphids (brown citrus aphid) with oils/systemics; mild-strain cross-protection in orchards via extension programs.
Citrus Psyllid (*Diaphorina citri*)[91]	Insect pest (vector of HLB)	Tiny brown mottled **leafhopper** on new shoots; causes twisted flush, **honeydew** and sooty mold; primary danger is HLB transmission.	**Area-wide psyllid control**: Imidacloprid soil drench, foliar insecticides[87]; release Tamarixia parasitoids; remove HLB-positive trees promptly[64].
Citrus Leafminer (*Phyllocnistis*)[82]	Insect pest (leaf miner moth)	**Serpentine silvery mines** in young leaves causing leaf curl[89]; cosmetic damage and entry for canker.	**Spinosad or Abamectin foliar** on new flush; **Neem oil 5%** or mineral oil to deter egg-lay[86]; encourage parasitoids (minimize broad insecticides).
Whiteflies (*Dialeurodes*, etc.)[95]	Insect pest (sap-sucking)	**White flutters** when leaves disturbed; sticky **honeydew** on leaves &	**Encarsia wasp biocontrol**; **horticultural oil 2%** to smother

Disease/Pest	Category	Key Symptoms	Management Highlights
		fruit; black **sooty mold** growing on honeydew[94]; leaf yellowing if severe.	nymphs & clean mold[102]; Imidacloprid or IGR (buprofezin) for heavy infestations; control ants.
Scale Insects (e.g., White snow scale, Soft green scale)[98]	Insect pest (sap-sucking)	**Tiny scales on stems/foliage**: white crusty patches (snow scale) or brown/black bumps; armored scales cause yellow spots & twig dieback; soft scales cause **sooty mold** from honeydew.	**Predators & Parasites** (ladybirds, *Aphytis* wasps) are key – avoid hard insecticides; use **oil sprays** thoroughly (twice at 14d)[103]; prune heavily infested twigs; buprofezin or chlorpyrifos for severe cases; control ants.
Aphids (e.g., Toxoptera sp.)	Insect pest (sap-sucking)	Colonies of **green/brown aphids** on buds and young leaves; cause leaf curling, sticky honeydew and sooty mold; transmit tristeza virus.	**Spot-spray aphid colonies** with insecticide (dimethoate 0.05% or soap solution); **release ladybugs**; control on nursery trees to prevent CTV spread.
Mites (e.g., Citrus red mite, rust mite)	Arachnid pest (sap-feeder)	Red mite: **bronzed, stippled leaves**, silvering on fruit rind; rust mite: russeting/brownish rash on fruit skin. Can cause leaf drop if severe.	**Acaricides** like dicofol or abamectin if needed[126]; avoid insecticide-induced flare-ups (monitor after spraying other pests); neem oil can suppress mites modestly.
Fruit Sucking Moth (*Othreis sp.*)	Insect pest (fruit borer)	Moth punctures ripe fruit at night to suck juice; results in **brown rot around puncture** and fruit drop. Often only noticed by rotten fruit with holes.	**Light traps** to attract moths; bag fruits if high-value; remove fallen fruits promptly; bait with fermented molasses + insecticide (traditional).
Fruit Flies (*Bactrocera* spp.)[127]	Insect pest (fruit maggot)	Female “stings” fruit to lay eggs -> larvae inside fruit cause **internal rot and drop**; often maggots found in fallen fruits.	**Bait trapping**: methyl eugenol traps with malathion to lure males[128]; field sanitation (bury/burn fallen fruits)[128]; protein bait sprays on tree

Disease/Pest	Category	Key Symptoms	Management Highlights
			(to attract females). Bagging fruit where feasible.
Dieback (Physiological)	Physiological (nutrient/stress)	Progressive **twig dieback**, leaf drop on one or more sectors, not caused by pathogen (confirmed if no gummosis or canker). Often linked to nutrient deficiency (Cu or Zn) or chronic root stress.	Address underlying issue: e.g., if Cu deficiency – foliar copper; if water stress – improve irrigation. Prune dead wood. If associated with greening or gummosis, treat those causes.
Fruit Drop (Physiological)	Physiological (hormonal/water)	Excessive shedding of young fruit beyond normal June drop; can occur at color break or after water stress events. Little to no external symptom on tree aside from fewer fruits.	Ensure **consistent irrigation** during fruit set; apply 2,4-D 10–20 ppm spray at pea-size fruit and again pre-harvest to reduce drop[123]; avoid excessive nitrogen late in bloom.
Fruit Splitting	Physiological (water/nutrient flux)	Rind of almost-mature fruits **splits** open, usually from stylar end, exposing pulp; common in thin-peeled oranges after drought-then-rain.	Maintain **regular soil moisture** (don't let trees drought then heavy irrigate); **K fertilization** to strengthen rind; harvest susceptible varieties promptly when ripe.
Granulation of fruit	Physiological (post-maturity issue)	Some sweet orange/mandarin fruits have **dry, crystallized pulp segments** (juiceless, firm) especially if overripe on tree or from nutrient imbalance. No external sign until cut/opened.	**Timely harvest** (do not leave fruit hanging too long); avoid excessive nitrogen and water stress near harvest; use growth regulators (GA_3) post-bloom if known issue cultivar.
Zinc Deficiency[110]	Nutrient disorder	**Mottle leaf**: small narrow leaves with irregular chlorosis, green veins[111]; twig dieback; little leaf rosette on shoots. Often confused	Foliar $ZnSO_4$ (0.5%) + 0.5% lime twice in growing season[112]; soil application of Zn chelate; maintain soil pH ~6–7 for availability.

Disease/Pest	Category	Key Symptoms	Management Highlights
		with HLB but is uniform on leaf.	
Iron Deficiency[113]	Nutrient disorder	**Interveinal chlorosis** on new leaves – bright yellow/near-white leaves with green veins[113]; in severe cases, leaf white and necrotic edges.	Foliar $FeSO_4$ (0.5%) + citric acid (to aid uptake)[114]; soil drench of Fe-EDDHA chelate especially in high pH soils; avoid waterlogging (worsens Fe uptake).
Boron Deficiency[118]	Nutrient disorder	**Leaf curl** with brittle, thick texture; sometimes translucent leaf spots; **gum pockets in fruit rind**, misshapen bumpy fruits (with brown gum areas inside albedo). Low boron can also cause blossom and fruit drop.	Foliar spray Borax or Solubor @ 0.1–0.2% at flush[119]; soil apply borax at very low doses (e.g., 10–20 g/tree/year split) – careful, as excess B is toxic.

(Table abbreviations: WP = wettable powder; ppm = parts per million. Always follow label and local recommendations.)

Seasonal Pest/Disease Occurrence and Climate Zone Map

Citrus issues vary with India's diverse climate zones and seasons:

- **During Monsoon (June–Sept):** Warm, humid conditions prevail in most regions (except arid northwest). This is the **peak for fungal diseases** like canker, scab, melanose, Phytophthora rot, etc., because rain-splash spreads them. Also high insect breeding time due to flush growth – expect surges in leafminer and psyllid populations following the first flush of monsoon[61]. In central/south India, monsoon triggers heavy flush, so **canker control sprays** and **leafminer management** are crucial mid-monsoon. Also, waterlogged conditions can cause foot rot in low-lying orchards (take preventive drenches early monsoon). Weeds and alternate hosts abound – maintain orchard sanitation.
- **Post-Monsoon (Oct–Nov):** In many areas, a secondary flush occurs as rains taper – still risk for canker if late rains occur, so final copper spray in October is wise[42]. This period is often harvest time for monsoon crop of acid lime – watch for **fruit flies** peaking in warm humid post-rain conditions (use traps from Sept). **Whitefly** and **soft scales** may increase as cooler rains end and sooty mold might be noticeable – address after monsoon (with oil sprays). Temperatures are moderate, good for HLB psyllids – continue psyllid surveillance.
- **Winter (Dec–Feb):** Dry in most of India (except maybe Tamil Nadu which gets NE monsoon till Dec). Cooler temps slow some pests – e.g., leafminer activity reduces in cold northern plains. But **aphids** often spike in cooler dry weather, so tristeza virus

spread could happen if aphids show up on winter flush (common in north India citrus). **Mites** might become noticeable in dry conditions (watch for red spider mite on leaves/fruit in Dec-Jan especially in rainfed orchards where dust is high). In north India, watch for **frost** events (Dec-Jan); prepare anti-frost measures (smudges, irrigation) as needed – frost can predispose trees to gummosis later. Also, **Zn and Mn deficiency** often show up strongly in winter on new flush (due to cold soils reducing uptake) – plan foliar nutrient sprays end of winter.

- **Spring (Feb–April):** A major bloom and flush period (for summer crop fruit set). Dry, warming weather – good for certain pests:
- **Citrus psyllids** breed heavily on the spring flush – must control to prevent HLB[61].
- **Leafminer** also will hit this flush if not checked.
- **Scab** disease can be an issue if spring is wet (in NE India often spring rains), otherwise in dry spring not so much.
- **Aphids** often peak on spring flush and can transmit viruses like citrus ringspot or tristeza; monitor and control if colonies appear.
- With rising temp and dry air by March-April, **mites and scales** can flourish – start monitoring by late spring.
- If no rains, **irrigation** is key now to support fruit set and prevent drop. **Boron sprays** at flowering can improve fruit set especially if past drop issues.
- **Summer (May–June pre-monsoon):** Very hot and dry in many regions. Trees under stress now, which can lead to:
- **Spider mites** peaks (hot dry = spider mite flare, causing leaf stippling and fruit rind russet).
- **Scale insects** (armored scales often thrive in hot dry season as natural enemy activity is low and tree defenses down).
- **Irrigation critical** to avoid fruit drop or splitting when monsoon arrives. Many farmers spray 2,4-D in May to hold fruit through the stress period[123].
- **Dieback symptoms** often become evident now if trees had hidden issues (like root damage or nutrient deficiency) – address via deep watering, mulching, etc.
- Land prep for next monsoon new plantings happens – ensure new stock is disease-free.
- **Sunburn** risk on exposed fruit/branches – ensure trees have enough leaf canopy, or use whitewash on exposed trunk sections after pruning.

Climate Zone Differences: - **Arid (Rajasthan, parts of Punjab):** Less disease pressure due to low humidity, but more issues with **mites, thrips, and nutrient deficiencies (especially Fe, Zn)** due to high pH soils. Irrigation is a must – drip preferred to prevent Phytophthora. Frost can be an issue in winter nights. - **Subtropical humid (NE India, foothills):** High rainfall – severe **canker, scab, Phytophthora, sooty mold**. Need regular spraying regimen. Psyllids active year-round because mild winters – HLB spreads fast if not controlled. Using mandarin varieties adapted to high rainfall and well-drained hill soils helps reduce foot rot. - **Central India monsoonal (Nagpur/Berar):** Distinct dry and wet seasons. Monsoon diseases (like gummosis in waterlogged spots, scab on Nagpur mandarin) appear July–Sept. Long dry season means need irrigation for winter crop – dryness also means watch for **tristeza quick decline** signs when winter flush comes (brown citrus aphid present in this region). Winter is ideal to foliar-feed and

prune because low disease then. - **South India tropical (Telangana, Andhra – sweet orange & acid lime belts):** Often can get 2-3 flushes (monsoon and post-monsoon flush heavy). **Acid lime** here fruits year-round but main crop in summer – which is tough due to HLB and canker hitting limes badly. Need continuous IPM. Warmer winters mean pests don't die back much – continuous vigilance on psyllid, leafminer. - **Coastal (Tamil Nadu, Kerala):** High humidity nearly year-round = continuous disease pressure (canker, greasy spot if present, scales). But climate stable means trees flush more frequently in small waves – leafminer and psyllid can always find some flush, complicating control scheduling. Biological control thrives here too if not disturbed. Need more frequent copper sprays (but carefully to avoid phytotoxicity in intense sun – apply in evenings or lower concentration). - **Hilly areas (like parts of Meghalaya, Sikkim with Khasi mandarin):** More temperate – citrus season delayed, but heavy rains and occasional cold. Phytophthora root rot is often big in terrace orchards with poor drainage. Also, lichen growth on trees (from constant moisture) can harbor scale insects beneath – need periodic trunk scraping or copper-lime wash on trunks.

Seasonal Calendar Chart: *(If in text form)* For a representative central Indian sweet orange orchard (Vidarbha region):

- **Jan:** Low humidity, moderate days/cold nights. Monitor aphids on winter flush; foliar nutrient spray (Zn, Mn) post-harvest. Watch for mite specks.
- **Feb:** Spring bloom begins. Apply boron spray at flowering; soil drench imidacloprid for psyllid/leafminer proactively. Prune dead wood.
- **Mar:** Fruit set occurring. Dry hot onset. Spray 2,4-D end of March to retain fruit. First leafminer flush spray (spinosad) if mines seen. Water adequately.
- **Apr:** Very hot/dry. Mites and scales: check underside leaves, perhaps spray oil or specific miticide if mite webbing seen. Whitewash trunk to prevent sunburn if canopy sparse.
- **May:** Fruit sizing; drought stress high – irrigate. Monitor fruit fly (set out methyl-eugenol traps by late May). Summer flush might occur if irrigated – if so, control leafminer/psyllids on it. Possibly a copper + streptomycin spray in late May if pre-monsoon rains expected early (to pre-arm against canker).
- **Jun:** Monsoon arrives mid-June. Do drench for Phytophthora prevention early monsoon (Ridomil). Main canker spray (streptocycline + copper) as new flush pushes[42]. Leafminer likely abundant on that flush – control with spinosad or abamectin mid-monsoon. Release Tamarixia wasps if available to chase psyllids now as well.
- **Jul:** Heavy rain. Monitor canker lesions – second copper spray 3-4 weeks after first[129]. Frequent weed growth – remove to reduce alt hosts. Check trunk gummosis signs, trench water away from trunk.
- **Aug:** Still rainy. If scab-prone variety, spray carbendazim or copper now (fruit still growing)[8]. Remove any black sooty mold leaves by hand if too covered (though cleaning usually wait until after rains). Continue psyllid/leafminer suppression.
- **Sep:** Rains taper. Do foliar nutrition now (trees can uptake well with moist soil): e.g., Zn+Mn+urea spray. Fruit starting to ripen on earlier variety – protect from fruit fly with bait + trap[128]. Possibly final canker spray if late season flush (Oct) is expected to protect that.

- **Oct:** Harvest main crop sweet oranges. Post-harvest, do **Copper oxychloride + oil** tank mix spray to clean up fungal inoculum and remaining scales/mold (since no fruit now, safe). Start pruning after harvest (remove dead twigs, open canopy).
- **Nov:** Dry, pleasant. Good time for soil fertilization (apply compost + NPK). Irrigate post-fertilizer. Watch for any late flush aphid colonies (spray soap if minor, or systemic if large).
- **Dec:** Some trees bloom (off-season) – thin off-season fruit if needed. Maintenance spray of lime sulfur or Bordeaux on trunk for any fungal spores/lichens. Monitor for first sign of spring pests (brown aphids) as winter warms into Jan.

Each region's calendar would adjust, but similar pattern: intensify disease control in monsoon, intensify pest (esp vector) control around flushes, do nutritional interventions in between.

Visual Symptom-Diagnosis Guide

(A simplified chart linking symptom → likely cause for farmers to self-diagnose)

- **Blotchy yellow leaves (random pattern)** – If on new leaves, suspect **HLB (greening)**[48] (especially with lopsided fruit). If on older leaves with green veins, suspect **Zn deficiency** or **Fe deficiency** – those are more uniform and tree-wide (HLB usually sectoral).
- **Leaves with yellow halo spots and corky center** – **Canker** lesions[33].
- **Black, powdery coating on leaves/fruits** – **Sooty mold** from honeydew (check for whiteflies, aphids, or soft scales on underside)[94].
- **Leaf minors or trails in leaves** – **Leafminer** pest[89] (silvery squiggles).
- **Gum oozing from trunk/base** – likely **Phytophthora gummosis**[13] (if bark rotting) or possibly physical injury; if accompanied by insects (borer holes) then maybe **stem borer**.
- **White cottony or waxy masses on twigs** – Could be **Cottony cushion scale** (if fluted cottony bits) or **whitefly nymphs** (if under leaves), or **snow scale** (crusty white lines on bark)[101].
- **Brown scabby eruptions on fruit/leaf** – If raised, likely **Scab**[4] (especially if conical on leaves, no yellow halo). If flat with specks, could be **Melanose** (feels rough).
- **Fruit with brown sunken navel end** – Possibly **stylar-end rot** (Ca deficiency) or fungal rot if soft (Alternaria rot in some varieties).
- **Tiny white flies when shaking branch** – **Whitefly** infestation[94].
- **Clusters of small brown bumps on stems** – **Scale insects** (check if scrape off).
- **Brown tracks under citrus tree; fruit with maggots** – **Fruit fly** damage.
- **Yellowing and dropping of older leaves first** – Possibly **Nitrogen deficiency** (especially if uniform pale) or **water stress** (with leaf curling too), or root problem (check roots).
- **Sudden whole-tree wilt** – If on sour orange rootstock + recently grafted, suspect **Tristeza quick decline**[74]; else possible severe root rot or waterlogging cause.

For any uncertain symptom, farmers are advised to contact experts for testing (especially for virus suspicion like HLB or CTV), as early confirmation helps management.

Conclusion

Indian citrus cultivation faces multifaceted challenges from diseases, pests, and nutritional deficiencies – but with vigilant monitoring and integrated management, farmers can significantly reduce losses. Key takeaways include: **keeping orchards clean (disease-free planting material, removal of infected trees)**, **timely protective sprays (especially copper for fungal/bacterial issues)**, **conserving beneficial insects** to naturally suppress pests, and **ensuring balanced nutrition and watering** to prevent disorders. Telangana's citrus growers, like others in India, should adopt these science-backed practices, tailored to local climate and crop cycles. By following the guidance in this comprehensive report – identifying problems by symptoms and applying the recommended IPM and remedial measures – farmers can sustain healthy orchards, improve fruit yield and quality, and secure their livelihood against the "sadness" that citrus diseases once brought. Armed with this knowledge base as a ready reference, even in the field (with QR-coded quick tips for on-spot decisions), farmers will be better equipped to diagnose issues early and implement effective, integrated solutions. Ultimately, a proactive, informed approach to citrus health will ensure India's oranges, sweet limes, lemons and mandarins continue to flourish from the nursery to the marketplace.

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