# An Overview of Mites in Plantation Crops with Emphasis on Sustainable Management

**Payel Kar, Pritha Bandyopadhyay, Soumita Bera, Rajeswari Nandi, Rittik Sarkar**

Mites are tiny, ubiquitous arthropod organisms distributed in a wide array of habits and habitats. In agroecosystems, mites have multifaceted roles, from pests to predators and even the soil engineers. The phytophagous mites of families, mainly Tetranychidae*, Tenuipalpidae*, *Tarsonemidae* and *Eriphyiodae* wreak havoc on the crop plants by feeding on the plant tissues, transmitting viruses and eventually killing the plant in the long run. Their microscopic nature helps them to avoid early detection, usually their population is visible after they have crossed the ETL. Many of these mites have polyphagous nature and are able to feed on a wide array of host plants, making their control even more difficult. But not all mites are harmful, predatory mites of families *Phytoseiidae, Laelapidae, Bdellidae* etc., feed on other mites and soft bodied insects, reducing their populations. The soil-inhabiting mites, in addition to killing soil pests, also help to improve soil quality and structure by forming soil aggregates. This chapter deals with the different roles mites play in Agroecosystems, focusing mainly on the plantation and fruit crops.

***Keywords:*** *Mites, Crop Pest, Biocontrol, IPM, Sustainable Agriculture*

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## Introduction

Mites are small arthropodan organisms belonging to the class Arachnida and subclass Acari, associated with almost every sphere of life and increasingly recognized for their ecological and agricultural significance. With nearly 50,000 described species worldwide, they represent one of the most diverse and species-rich groups of arthropods. However, the known fauna constitutes only a small fraction of the estimated diversity, with 0.5-1.0 million species believed to remain undiscovered (Halliday et al., 2000; Zhang, 2003). Their remarkable ecological diversity encompasses predaceous, phytophagous, mycophagous, saprophagous, coprophagous, necrophagous, phoretic and parasitic species, enabling them to occupy nearly every ecological niche.

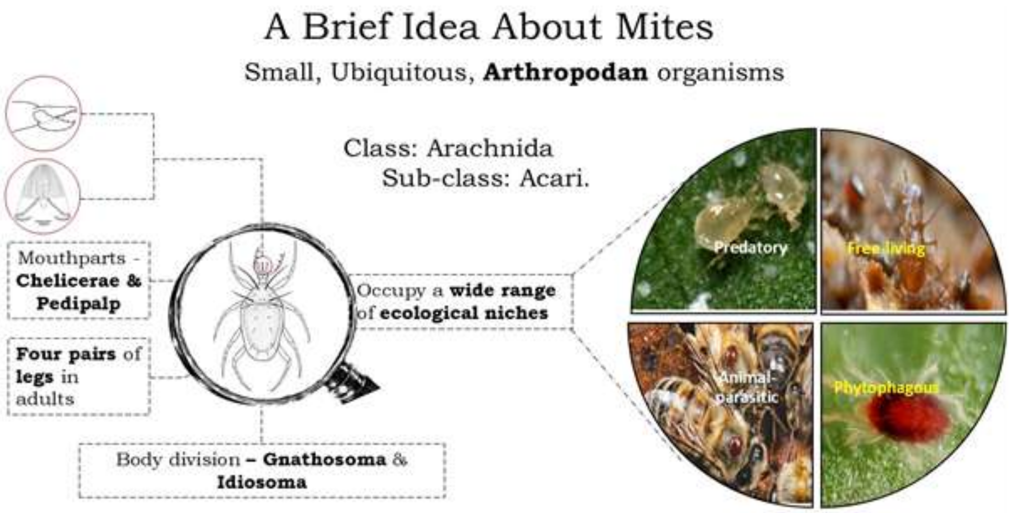


**Figure 1. General Morphology, Habit and Habitat of Mites**

The agricultural importance of mites has been considerably increased over recent decades by intensified crop production, indiscriminate use of broad-spectrum pesticides, monoculture cultivation, climate change and globalization of agricultural trade. These elements usually disrupt natural biological control, cause pesticide resistance, facilitate secondary outbreaks of phytophagous mites. Concurrently, predatory mites, particularly phytoseiid mites have become indispensable components of integrated pest management programmes worldwide, supported by efficient mass-production technologies that have enabled their large-scale application in agriculture.

In India, the study of plant-associated mites has gained increasing attention because of their growing economic importance in agriculture, forestry and stored products (Gupta, 1985; Karmakar & Bhattacharya, 2005; Debnath & Karmakar, 2013). According to Gupta (2010), approximately 1,700 mite species have been recorded from India, of which 998 are phytophagous. Subsequently, Singh & Raghuraman (2010) estimated the country's mite fauna to comprise about 2,670 species, including phytophagous forms (Singh & Raghuraman, 2011).

**Recognition of Mite Damage**

Accurate recognition of mite infestation is often challenging because of the microscopic size of these organisms and the subtle, non-specific symptoms they produce. Most phytophagous mites feed by piercing epidermal or mesophyll cells with their stylet-like mouthparts and extracting cellular contents, disrupting normal physiological processes. As feeding continues, localized injury develops into characteristic symptoms that vary with the mite species, host plant, infestation level, and environmental conditions. These symptoms frequently resemble those caused by nutrient deficiencies, fungal, bacterial, or viral diseases, herbicide injury, and other abiotic stresses, often delaying diagnosis until infestations become severe. Therefore, regular field monitoring, careful examination of susceptible plant parts, and the detection of mites or their characteristic signs are essential for accurate diagnosis and timely implementation of appropriate management strategies.

**Figure 2. Damage symptoms caused by mites. (1) Leaf curling by yellow mite (*Polyphagotarsonemus latus*); (2–4) damage by rice sheath mite (*Steneotarsonemus spinki*); (5) erineum on litchi plant; (6–9) varying degrees of damage caused by spider mite (*Tetranychus* spp.).**

**Table 1. Some Important Pest Mites of Agricultural Importance**

| Family | Scientific Name | Host Range |
|---|---|---|
| **Tetranychidae** | *Dolichotetranychus floridanus* Banks | Pineapple |
| | *Eutetranychus banksi* (McGregor) | Citrus, papaya, cassava, guava and several other fruit crops |
| | *Eutetranychus orientalis* (Klein) | Citrus, mango, guava, fig and several tropical fruit crops |
| | *Oligonychus coffeae* (Nietner) | Tea, coffee, cashew, mango and ornamentals |
| | *Oligonychus indicus* (Hirst) | Sugarcane, maize, sorghum and other grasses |
| | *Oligonychus mangiferus* (Rahman and Sapra) | Mango, litchi and other fruit trees |
| | *Oligonychus oryzae* (Hirst) | Rice |
| | *Panonychus citri* (McGregor) | Citrus |
| | *Panonychus ulmi* (Koch) | Apple, pear, peach, plum and other rosaceous fruit trees |
| | *Petrobia latens* (Müller) | Wheat, barley, oats, onion, garlic and other field crops |
| | *Schizotetranychus andropogoni* (Hirst) | Sugarcane |
| | *Schizotetranychus oryzae* Rossi de Simons | Rice |
| | *Tetranychus bioculatus* Wood-Mason | Cotton, okra, brinjal, cucurbits and several vegetables |
| | *Tetranychus cucurbitae* Sayed | Cucurbits, cotton and vegetables |
| | *Tetranychus ludeni* Zacher | Cotton, beans, brinjal, okra, cucurbits and other vegetables |
| | *Tetranychus macfarlanei* Baker and Pritchard | Cotton, legumes and vegetables |

| | | |
|---|---|---|
| | *Tetranychus neocaledonicus* André | Cotton, vegetables, ornamentals and fruit crops |
| | *Tetranychus truncatus* Ehara | Soybean, cotton, pulses, vegetables and ornamentals |
| | *Tetranychus urticae* Koch | Highly polyphagous (More than 1,100 host plant species including vegetables, fruits, ornamentals and field crops) |
| **Tarsonemidae** | *Acarapis woodi* (Rennie) | Honeybee |
| | *Phytonemus pallidus* (Banks) | Strawberry, Cyclamen and ornamental plants |
| | *Polyphagotarsonemus latus* (Banks) | Broad host range including chilli, jute, sesame, cotton, tea, citrus, vegetables and ornamentals |
| | *Steneotarsonemus spinki* Smiley | Rice |
| **Eriophyidae** | *Acaphylla theae* (Watt) | Tea |
| | *Aceria cajani* Channabasavanna | Pigeonpea |
| | *Aceria guerreronis* Keifer | Coconut |
| | *Aceria jasmini* Channabasavanna | Jasmine |
| | *Aceria mangiferae* Sayed | Mango |
| | *Calacarus carinatus* (Green) | Tea |
| | *Oxypleurites convolvuli* Keifer | Sweet potato and *Convolvulus* spp. |
| | *Phyllocoptruta oleivora* (Ashmead) | Citrus |
| **Tenuipalpidae** | *Brevipalpus australis* (Tucker) | Citrus, ornamentals and fruit crops |
| | *Brevipalpus californicus* (Banks) | Citrus, tea, ornamentals and several fruit crops |
| | *Brevipalpus lewisi* McGregor | Grapevine, pomegranate, citrus and ornamentals |
| | *Raoiella indica* Hirst | Coconut, banana, arecanut, date palm and ornamental palms |
| **Tydeidae** | *Lorryia formosa* Cooreman | Citrus, tea and several fruit crops (minor pest) |
| **Varroidae** | *Varroa jacobsoni* Oudemans | Honeybee |
| **Laelapidae** | *Tropilaelaps clareae* Delfinado and Baker | Honeybee |
| **Acaridae** | *Acarus siro* Linnaeus | Stored grains |
| | *Tyrophagus putrescentiae* (Schrank) | Stored grains |

**Mites as Vectors of Plant Diseases**

A limited number of mite species transmit economically important plant pathogens. Among these, eriophyid mites are the best-documented virus vectors. Their high host specificity, specialized feeding habits and cryptic nature facilitate efficient acquisition and transmission of viral diseases.

**Mite-mediated Plant Diseases and their Mode of Transmission**
**Virus transmission mechanism**

Transmission of viral diseases by eriophyid mites is a highly specialized and species-specific process. The transmission cycle generally proceeds through four successive stages-

1. **Virus acquisition-** during feeding from infected host tissues.
2. **Virus retention-** within specific tissues of the mite.

3. **Transport and survival-** of viral particles during mite dispersal.
4. **Virus inoculation-** into healthy plants during subsequent feeding.

Unlike mechanical transmission, successful biological transmission depends upon compatibility between the virus and its specific mite vector. Most eriophyid-transmitted viruses exhibit a semipersistent mode of transmission in which the virus is retained by the mite for several days but does not replicate within the vector (Druciarek et al., 2026).

**Table 2. Major Diseases Transmitted by Mites**

| Family | Name of Vector Mite | Host Plant | Transmitted Virus |
|---|---|---|---|
| **Eriophyidae** | *Abacarus hystrix* (Nalepa) | Rye Grass, Agropyron | Rye Grass Mosaic, Agropyron Mosaic viruses |
| | *Aceria cajani* Channabasavanna | Pigeonpea | Pigeonpea Sterility Mosaic Virus |
| | *Aceria ficus* (Cotte) | Fig | Fig Mosaic Virus |
| | *Aceria mangiferae* Sayed | Mangoes | Mango Malformation Virus |
| | *Aceria tosichella* Keifer | Wheat, barley, maize and grasses | Wheat Streak Mosaic Virus (WSMV) and Wheat Spot Mosaic Viruses |
| | *Aceria tulipae* (Keifer) | Garlic, Onion | Garlic Mosaic Virus, Onion Mosaic Virus |
| | *Eriophyes inaequalis* Wilson and Oldfield | Cherries | Cherry Mottle Leaf virus |
| | *Eriophyes insidiosus* Keifer and Wilson | Peaches | Peach Mosaic Virus |
| | *Phyllocoptes fructiphilus* Keifer | *Multiflora* and other roses | Rose Rosette Disease virus |
| **Tenuipalpidae** | *Brevipalpus* spp. | Citrus<br>Passion fruit | Citrus leprosis virus<br>Passion fruit green spot virus |

Notably, in rice ecosystems, sheath mites inflict damage through direct feeding and by facilitating fungal infection via transmission of phytopathogenic fungi such as *Sarocladium oryzae* (Rice sheath rot disease), *Fusarium* spp., and *Helminthosporium* spp., resulting in mechanical injury, sterile panicles and grain deformities (Chen et al., 1979).

**Impact of Mites on Fruit Crops**

Mites infest a wide array of fruit crops in the Indian subcontinent. They feed on the leaves and tender fruits, leading to reduced marketability of the crops to total crop failure in extreme cases. The following table provides a snapshot of the mites associated with fruit crops and the kind of damage they cause.

**Table 3. Summary of Different Mite Attack on Fruit Crops**

| Fruit crop | Important mite species | Nature of damage | Yield loss | Disease transmission |
|---|---|---|---|---|
| Mango | *Oligonychus mangiferus*, *Aceria mangiferae* | Leaf bronzing, webbing, bud injury | 15–60% (depending on infestation) | Bud mite may facilitate fungal infections; no major confirmed viral transmission |

| | | | | |
|---|---|---|---|---|
| Citrus | *Phyllocoptruta oleivora*, *Panonychus citri*, *Brevipalpus* spp. | Rusting, rind blemishes, reduced fruit quality | 20–70% in severe outbreaks | *Brevipalpus* spp. transmits citrus leprosis virus in affected regions |
| Litchi | *Aceria litchi* | Erineum formation, leaf curling | Up to 80% under severe attack | Associated with the algal/fungal erineum complex rather than direct pathogen transmission |
| Guava | *Brevipalpus phoenicis*, *Tetranychus* spp. | Leaf bronzing, fruit scarring | 10–35% | *Brevipalpus* species are vectors of several plant viruses on other hosts |
| Apple | *Panonychus ulmi*, *Tetranychus urticae* | Defoliation, chlorosis | 30–50% | No major disease transmission |
| Pear | *Epitrimerus pyri* | Rusting, reduced photosynthesis | 20–40% | None confirmed |
| Grapes | *Colomerus vitis*, *Tetranychus urticae* | Blistering, leaf bronzing | 25–50% | None confirmed |
| Pomegranate | *Tenuipalpus punicae* | Leaf and fruit bronzing | 20–40% | None confirmed |
| Banana | *Raoiella indica*, *Tetranychus* spp. | Leaf yellowing and reduced vigor | 15–40% | No established virus transmission |
| Papaya | *Polyphagotarsonemus latus*, *Tetranychus urticae* | Leaf curling, distortion | 20–60% | Broad mite injury may predispose plants to secondary infections |

**Figure 3. Representative symptoms caused by the principal mite pests of Mango (1) *Oligonychus mangiferus* (2) *Aceria mangiferae* (Image sourced from Plantix, PEAT GmbH) (3) *Cisaberoptus kenyae***

**Figure 4. Representative symptoms caused by the principal mite pests of Citrus (1) *Eutetranychus orientalis* (Image sourced from Plantix, PEAT GmbH) (2) *Panonychus citri damage* on mature fruit (3) *Panonychus citri* male & female**

**Figure 5. Representative symptoms caused by the principal mite pests of Apple (1) *Aculus schlechtendali* From Pavel Šinkyřík (2021) (2) *Bryobia rubrioculus* From Wa'el Almatni (2008)**

**Figure 6. Representative symptoms caused by *Aceria cernuus* on Ber (Dhileepan, 2017)**

**Figure 7. Representative symptoms caused by the principal mite pests of Pear by *Eriophyes pyri* (1) Leaves (CABI, 2022 *Eriophyes pyri.* CABI Compendium) (2) Fruits (3) *Eriophyes pyri* mites under microscope (NY State Ag Experiment Station)**

**Impact of Mite Infestation on Plantation Crops**

In Indian agriculture, plantation crops hold a unique position. Unlike the annual field crops that dominate most pest-management literature, tea (*Camellia sinensis*), coffee (*Coffea* spp.), coconut (*Cocos nucifera*), rubber (*Hevea brasiliensis*), arecanut (*Areca catechu*) and cashew (*Anacardium occidentale*) are perennial, spatially extensive and tied to export earnings and rural incomes across several agro-climatic zones. That permanence is precisely what makes them hospitable to mites. A canopy that never resets each season, combined with the buffered microclimate beneath it, gives phytophagous mites an uninterrupted habitat in which to establish and several species have consequently become entrenched, chronic pest problems rather than occasional visitors.

The pest complex in these crops mainly includes four families: Tetranychidae, Eriophyidae, Tarsonemidae, and Tenuipalpidae. Their members share several traits that are striking compared to their size. They have short generation times, produce many offspring, and disperse easily through wind or by hitching rides on other animals. This allows their populations to grow quickly when temperatures increase and humidity decreases (Jeppson et al., 1975). Their mode of feeding compounds the problem. Rather than removing tissue outright, most species use stylet-like mouthparts to puncture epidermal and mesophyll cells and withdraw the chloroplast-rich contents, leaving the cell wall intact. The result is a slow, cumulative bleaching and browning of tissue that is easy to dismiss in its early stages and difficult to reverse once it has spread (Singh & Raghuraman, 2011).

Tea demonstrates this trajectory most clearly. India is the world's second-largest tea producer, and the red spider mite, *Oligonychus coffeae* Nietner, is consistently identified as its most damaging mite pest, capable of completing as many as 22 overlapping generations a year under favourable conditions, with parthenogenetic reproduction ensuring that all life stages are present simultaneously (Roy et al., 2014). Coconut presents a structurally different challenge. The eriophyid *Aceria guerreronis* Keifer colonises the concealed space beneath the perianth of developing nuts a refuge that shields it from contact acaricides and delays detection until the nut surface is already fissured (Navia et al., 2013; Lima et al., 2015). Coffee shares *O. coffeae* with tea and is additionally attacked by the cosmopolitan *Tetranychus urticae* Koch, both producing chlorosis and premature leaf fall that curtail the canopy's photosynthetic capacity (Roy et al., 2014). Rubber foliage in India is affected by *Calacarus heveae* Feres and *Tenuipalpus heveae* Baker, whose damage is translated less into visible leaf symptoms than into a quiet reduction in the carbohydrate supply available for latex synthesis (Daud et al., 2012; Nuvoloni et al., 2014); the great bulk of the biological and management literature on these two species, however, originates from Brazilian plantations, and India-specific data remain notably scarce. Arecanut and coconut also face the red palm mite, *Raoiella indica* Hirst first described from India and possibly native to South Asia or the Middle East while cashew is more often troubled by the broad mite, *Polyphagotarsonemus latus* (Banks) (Taylor et al., 2011; Dowling et al., 2012). What unites these otherwise dissimilar crop pest pairings is a shared recent history: outbreaks have intensified as climatic variability, expanding monoculture and indiscriminate insecticide use have eroded the natural-enemy populations that once kept mite numbers in check (Van Leeuwen et al., 2015).

**Damage Symptoms**

Despite differing biology, symptom progression across species follows a broadly conserved sequence: chlorotic flecking appears first, coalesces into larger discoloured patches, and in advanced infestations gives way to bronzing, curling and premature senescence that erodes the plant's functional canopy. In tea, *O. coffeae* punctures mature leaves, which take on the reddish-bronze cast from which the pest's common name derives, accompanied by a decline in shoot elasticity and flush production (Roy et al., 2014). *Aceria guerreronis* departs from this pattern altogether, since its feeding site is hidden from view: the earliest sign is a pale, triangular patch beneath the perianth that only later develops into the corky, longitudinally fissured lesion associated with deformed, undersized nuts and gummy exudation (Navia et al., 2013; a description corroborated by field surveys from Kerala and Karnataka e.g., the coconut pest database maintained by ICAR-NBAIR). Rubber foliage infested by *C. heveae* or *T. heveae* shows chlorosis and marginal scorch that, under sustained pressure, culminates in defoliation and reduced clonal vigour, with the severity and seasonal timing of damage varying markedly by clone (Daud et al., 2012). *Polyphagotarsonemus latus*, by contrast, targets actively expanding tissue rather than mature leaves, producing the characteristic thickening and downward curling associated with broad-mite injury on young flushes (Jeppson et al., 1975). Across all of these presentations, the underlying physiological consequence is the impaired photosynthesis, transpiration and nutrient translocation and because the host is perennial, this damage compounds across seasons rather than resetting with each new flush.

A B C

**Figure 8. Representative symptoms caused by the principal mite pests of Indian plantation crops. (A) Bronzing of tea leaves caused by the tea red spider mite, *Oligonychus coffeae* (Roy et al., 2014). (B) Surface scarring and necrotic lesions on young coconut nuts caused by the coconut eriophyid mite, *Aceria guerreronis* (Howard et al., 2007). (C) Yellow stippling and chlorosis of palm leaflets caused by the red palm mite, *Raoiella indica* (Giliomee et al., 2016).**

The role of mites in spreading diseases is well known in other cropping systems, but it is only somewhat relevant to Indian plantation crops. Eriophyid mites are recognized worldwide as carriers of viruses in the genera Emaravirus and similar groups. Species of *Brevipalpus* (Tenuipalpidae) spread kitaviruses like citrus leprosis virus and coffee ringspot virus. These are non-systemic diseases marked by yellowing and dead tissue at feeding sites (Ramos-González et al., 2023). None of this, however, has been demonstrated for the principal Indian plantation mite pests: the economic impact of *O. coffeae*, *A. guerreronis* and *R. indica* is attributed almost entirely to direct feeding injury rather than pathogen transmission (Roy et al., 2014; Navia et al., 2013). The microscopic wounds left by continuous feeding compromise the epidermal barrier and create infection courts for opportunistic fungi and bacteria documented for coconut lesions damaged by *A. guerreronis* (Navia et al., 2013) and inferred, though less directly quantified, for tea bushes weakened by prolonged *O. coffeae* infestation. Given the increasing movement of planting material between regions and the range shifts already documented for related mite-virus systems elsewhere, this comparatively benign status is not guaranteed to persist, which argues for continued surveillance rather than complacency.

**Yield Losses**

Because mite damage accumulates gradually, its economic cost is often recognised only after substantial loss has already occurred, and the precision with which that cost has been quantified varies considerably by crop. Tea has the most consistent evidence base: sustained *O. coffeae* infestation has been linked to green-leaf yield reductions widely cited in the range of 17-46% across tea-growing regions (Roy et al., 2014), with individual field studies in India reporting losses as high as 35-55% and associated declines in made-tea quality (Kachhawa & Kumawat, 2018). Coconut shows a comparably strong evidence base: losses attributable to *A. guerreronis* have been reported from 20% up to 60-80% of copra yield in severely affected, unmanaged palms in different Indian states, with the wide range reflecting differences in infestation intensity, cultivar and assessment method rather than a single agreed figure (Navia et al., 2013). Coffee and rubber losses are not as well measured. The logic is the same. A smaller leaf area limits carbohydrate supply for filling beans in coffee and for making latex in rubber. However, neither crop has an India-specific, peer-reviewed yield loss estimate like those available for tea or coconut. Data on arecanut and cashew are even scarcer. This disparity is telling. Tea and coconut, the two crops with dedicated reviews focused on mites, have the bestsupported loss estimates. In contrast, coffee, rubber, arecanut, and cashew need long-term, India-specific, replicated yield-loss studies before accurate figures can be provided.

**Management**

Plantation mite management requires integration rather than dependence on a single method. Regular field surveillance, timed to warm and dry periods when most of these species build up fastest, remains the first line of defence, as it allows intervention before populations surpass economic thresholds (Roy et al., 2014). Cultural measures complement this: sanitation, canopy-opening pruning, and moderating nitrogen inputs (which favour the succulent growth mites prefer) all reduce the conditions under which outbreaks develop. Conservation of naturally occurring predators is a cornerstone of biological suppression across every crop in this group that is phytoseiid mites such as *Neoseiulus longispinosus* on tea and *Neoseiulus baraki* beneath the coconut perianth, alongside predatory coccinellids and lacewings, are directly undermined by indiscriminate broad-spectrum spraying (Taylor et al., 2011). Entomopathogenic fungi offer a genuinely complementary, lower-risk option: *Hirsutella thompsonii* has been documented causing substantial natural mortality in *Calacarus heveae* populations on rubber, with infection rates shaped by the presence of native vegetation and local microclimate (Nuvoloni et al., 2014), a finding that argues for landscape-level conservation alongside chemical control rather than instead of it. Botanical formulations, particularly neem-based products, have shown suppressive activity against coconut perianth mite populations in Indian field trials, although efficacy has generally been lower and slower-acting than that of conventional acaricides. Where acaricides remain necessary, rotation across distinct IRAC mode-of-action groups is essential, since repeated reliance on a single mode of action accelerates the resistance for which tetranychid mites in particular are already notorious (Van Leeuwen et al., 2015). Precision-agriculture tools are beginning to sharpen this process further: UAV-based hyperspectral imaging has achieved high classification accuracy in detecting spider-mite infestation in tree crops before symptoms are visible to the naked eye, pointing towards spatially targeted rather than blanket acaricide application as a realistic near-term goal for Indian plantations (Wu et al., 2023).

**Table 4. Principal Mite Pests of Indian Plantation Crops: Taxonomic Placement, Feeding Site, Reported Yield Impact and Core IPM Components**

| Crop | Principal mite species | Family | Feeding site | Core IPM components |
|---|---|---|---|---|
| Tea | *Oligonychus coffeae* | Tetranychidae | Upper surface of mature leaves | Warm/dry-season surveillance; shade and pruning management; conservation of *Neoseiulus longispinosus*; acaricide rotation across IRAC groups |
| Coffee | *Oligonychus coffeae*, *Tetranychus urticae* | Tetranychidae | Mature and expanding leaves | Same surveillance and biological-control principles as tea; India-specific loss data needed |

| | | | | |
|---|---|---|---|---|
| Coconut | *Aceria guerreronis* | Eriophyidae | Concealed zone beneath the perianth of developing nuts | Sanitation and nutrient management; conservation of *Neoseiulus baraki*; neem-based botanicals (moderate efficacy); targeted acaricide application given the perianth refuge |
| Coconut / Arecanut | *Raoiella indica* | Tenuipalpidae | Underside of leaflets | Field surveillance; conservation of phytoseiid and coccinellid predators; caution against broad-spectrum sprays |
| Rubber | *Calacarus heveae*, *Tenuipalpus heveae* | Eriophyidae, Tenuipalpidae | Foliage (leaf undersurface) | Clonal resistance screening; conservation of *Hirsutella thompsonii* via native-vegetation retention (Nuvoloni et al., 2014); acaricide rotation |
| Cashew | *Polyphagotarsonemus latus* | Tarsonemidae | Actively expanding young leaves and shoots | Sanitation and canopy management; predator conservation; India-specific loss data needed |

**Mites as Biocontrol Agents**

Biological control is a key ecosystem service and an underlying pillar of Integrated Pest Management (IPM) (Naranjo et al., 2015). In many parts of the world, augmentative biological control of insect and mite pests is common practice as part of the IPM strategy. 80% of the revenue created by commercial biological control is created in protected cultivation (Pilkington et al., 2010). Predatory mites, mainly from the family Phytoseiidae and Laelapidae play the leading role among the biocontrol agents used against devastating pests of crops.

**Which Mites Act as Biocontrol Agents**

Mesostigmata is one of the ecosystem's important and effective predatory mite families. Their primary feeding behaviour is predation, which is considered one of the most primitive feeding habits. They feed mostly on other mites, small insects, nematodes and Collembola. These mites have been widely studied because of their possible use as biological control agents against agricultural pests and parasites (Castilho et al., 2015). The predators most often used for that purpose belong to the Phytoseiidae (Gerson et al. 2003; Beaulieu & Weeks, 2007), especially because these are usually by far the most common plant-inhabiting group of predatory mites and help in the control of above-ground agricultural pests (Rueda-Ramírez et al., 2022). Mites, such as *Phytoseiulus persimilis* and *Amblyseius cucumeris*, are well-known for their voracious appetite for pests like spider mites, thrips, and whiteflies. On the other hand, Soil-dwelling predatory mites, in particular, are at the top of the trophic web in the soil agronomic system. Most species are mobile predators feeding on collembolans, nematodes, insect larvae, insect eggs, and other microarthropods. They also feed on the edaphic stage of some above-ground pests (Berndt et al., 2004b; Wiethoff et al., 2004; Beretta et al., 2022). Their effectiveness as biological control agents in regulating soil pest populations have contributed to their use both in the field and in the greenhouse. Despite their known diversity and predatory capacity, soil-dwelling below-ground predatory mites so far less used in biological control. Only a few soil mite species are used in the biological control of pests, even though Below-ground pests, in particular plant-parasitic nematodes, are responsible for severe crop damage in agricultural systems (Rueda-Ramírez et al., 2022). All of them can feed on a wide range of prey, however, few studies have been conducted to validate their effectivity in field experiments and results are not consistent (Manners et al., 2013; Pozzebon et al., 2015). Mainly laelapids and macrochelids are used as soil-dwelling biocontrol agents. For example, the laelapid predators *Hypoaspis* (*Geolaelaps*) *aculeifer* (Canestrini) and *Stratiolaelaps* (*Hypoaspis*) *scimitus* (*miles*) (Womersley), as well as *Macrocheles robustulus* (Berlese) of the Macrochelidae family are used to control various species of edaphic pests (Gerson and Weintraub 2007; Messelink and Holstein-Saj 2008). Currently, more than 60% of the market is accounted for by phytoseiid predatory mites with *Amblyseius swirskii* (Athias-Henriot), *P. persimilis*, *Neoseiulus californicus* (McGregor), and *N. cucumeris* as the major species. *Amblyseius swirskii* (Athias-Henriot), was the first predatory mite available that was effective against whiteflies (Nomikou et al., 2001). The majority of the predatory mites commercially available are belonging to the family Phytoseiidae.

**Different Predatory Mites Used in Biocontrol**

The majority of the predatory mites commercially available in world market are belonging to the Phytoseiidae, followed by Laelapidae and one species each of Macrochelidae and Cheyletidae. Important mite families as commercially available biocontrol agents are (Knapp et al., 2018).

*Amblydromalus limonicus* is predatory on Thrips, whiteflies.
*Amblyseius andersoni* →Mites, small insects
*Amblyseius swirskii* →Thrips, whiteflies
*Euseius gallicus* →Thrips, whiteflies
*Iphiseius degenerans*→ Thrips
*Neoseiulus barkeri* →Thrips
*Neoseiulus californicus* →Spider mites
*Neoseiulus cucumeris* →Thrips

**Laelapidae**

*Androlaelaps casalis* →Poultry red mite
*Gaeolaelaps aculeifer* → Fungus gnats, thrips
*Stratiolaelaps scimitus* →Fungus gnats, thrips, Nematodes

**Macrochelidae**

*Macrocheles robustulus* → Fungus gnats, thrips

**Cheyletidae**

*Cheyletus eruditus* →Poultry red mite, stored product pests

Apart from these, there are also few families who can feed on pest insects like- Laelapidae (*Cosmolaelaps*, *Gaeolaelaps*, *Ololaelaps*, *Hypoaspis*, *Stratiolaelaps*), Ascidae (*Lasiosius* sp.), Blattisociidae, etc., feed on nematodes. Some are also associated with water mites (Hydrachnidae, Hydryphantidae, Pionidae etc.) (Fathipour, 2016; Gupta & Kumar, 2018).

In India, there are also some examples of biological control using predatory mites mainly Phytoseiidae. Several other families of plant inhabiting mites are considered potentially important predators. Gupta (2002) reviewed the literature on the taxonomy and bioecology of those mites, discussing their potential as biocontrol agents. They reported the following numbers of species of the most important of those families in India: Anystidae, Ascidae, Bdellidae, Cheyletidae, Cunaxidae and Stigmaeidae (Karmakar & Gupta, 2011).

**Table 5. Important Mites Used as Biocontrol Agents**

| Family | Genus | Species | Target organism | Crop | Year |
|---|---|---|---|---|---|
| Phytoseiidae | *Amblyseius* | *Amblyseius bhadrakaliensis* | *Tetranychus cinnabarinus* | Cucurbits, Brinjal | Gupta (1986) |
| | | *A. bindrai* | *T. cinnabarinus* | Brinjal | Dhooria (2007) |
| | | *A. channabasavannai* | *Raoiella indica,* Scale insect, Mealybug, *T. urticae* | Arecanut, Jute | Karmakar & Gupta (2011) |
| | | *A. cucumeris* | *T. cinnabarinus* | Brinjal | |
| | | *A. californicus* | *T. urticae* | Vegetables | Abdallah et al. (2012) |
| | | *A. swirskii* | *Polyphagotersonemus latus,* Whitefly, Thrips | Vegetables, Brinjal, Potato, Tomato | Onzo et al. (2012) |
| | | *A. fallacies* | *Schizotetranychus andropogoni* *T. cinnabarinus* *T. urticae* | Paddy, Carrot, Bean | Gupta & Dhooria (1972) |
| | | *A. largoensis* | *P. latus* *Tetranychus sp.* | *Amaranthus*, Brinjal, Cowpea | Maheswary et al. (2015) |
| | | *A. paraaerialis* | *T. macfarlanei* *T. truncates* *P. latus* | Cucumber, Snake gourd, Snapmelon, bitter gourd | Maheswary et al. (2015) |
| | *Euseius* | *Euseius alstoniae* | *Eutetranychus orientalis* *T. macfarlanei* | Citrus, Cotton | Dhooria (1981) |
| | | *E. astrictus* | *E. Orientalis* *P. latus* *Oligonychus mangiferus* *Brevipalpus phoenicis* *B. obovatus* *T. urticae* | Pear, Mango | Biswas et al. (2022) |

| | | | | | |
|---|---|---|---|---|---|
| | | *E. finlandicus* | *T. cinnabarinus* | Brinjal, *Bauhinia* sp., cowpea | Karmakar & Gupta (2011) |
| | | *E. ovalis* | *P. latus*<br>*Brevipalpus phoenicis*<br>*E. orientalis*<br>*Oligonychus* spp<br>*Panonychus* sp.<br>Thrips, Mealybug, | Chilli, fruit trees, greenhouse ornamental crops | Biswas et al. (2022) |
| | *Neoseiulus* | *Neoseiulus longispinosus* | Spider mite pest complex:<br>*T. ludeni*, *T. macfarlanei* and *T. urticae*<br>*T. truncates*<br>*P. latus* | Vegetables, Brinjal, Chilli, Banana, cowpea, jute, okra, pointed gourd, weeds | Karmakar & Gupta (2011) Biswas et al. (2022) |
| | | *N. barkeri* | *T. urticae*<br>*Brevipalpus phoenicis* | Rice, Cotton, Vegetables | Biswas et al. (2022) |
| | *Paraphytoseius* | *Paraphytoseius multidentatus* | *P. latus*<br>*T. macfarlanei* | Jatropha, Jute, Brinjal | Karmakar & Gupta (2011) |
| | | *P. orientalis* | *P. latus*<br>*T. urticae*<br>*T. evansi*<br>*Brevipalpus* sp. | Weeds, Brinjal, Tomato, *Terminalia* arjuna | Biswas et al. (2022) |
| | *Typhlodromips* | *Typhlodromips syzygii* | *P. latus*<br>*T. urticae*<br>*T. macfarlanei* | Chilli, jute, pointed gourd, Cucumber, | Karmakar & Gupta (2011) |
| | *Phytoseiulus* | *Phytoseiulus persimilis* | *T. urticae* and other *Tetranychus* sp. except *T. evansi* | Cucumber, Capsicum, Brinjal | Gupta & Kumar (2018) |
| | *Transeius* | *Transeius tetranychivorus* | *Tetranychus* spp. | Vegetable crops | Gupta & Kumar (2018) |
| Anystidae | Walzia | *Walzia indiana* | *Brevipalpus* sp.,<br>*P. latus,*<br>*Bemisia tabaci*<br>Coccids, *Aleurodes* sp., Thrips | Betelvine, Chilli | Karmakar & Gupta (2011) Gupta & Kumar (2018) |
| *Bdellidae* | *Bdelloides* | *Bdelloides* sp. | *Brevipalpus* sp.,<br>*P. latus,*<br>*B.tabaci* | Arecanut, Mango | Karmakar & Gupta (2011) |
| Chelytidae | *Cheletogenes* | *Cheletogenes ornatus* | *A. mangiferae,*<br>*P. latus*<br>*A. cernuus* | Jatropha, Mango, Ber | Karmakar & Gupta (2011) Gupta & Kumar (2018) |

| | | | | | |
|---|---|---|---|---|---|
| Cunaxidae | *Cunaxoides* | *Cunaxoides* sp. | *P. latus*, *T. urticae*, *B. tabaci* | *Datura*, *Mikania* sp., pointed gourd sp. | Karmakar & Gupta (2011) |
| | *Cunaxa* | *Cunaxa setirostris* | *E. orientalis* *O. iseilemae* *O. mangiferus* | Citrus, Mango, Coconut | Karmakar & Gupta (2011) Gupta & Kumar (2018) |
| Stigmaeidae | *Agistemus* | *Agistemus* spp. | *Brevipalpus* sp., *P. latus, T. urticae, Panonychus citri, B. tabaci, T. ludeni, T. neocalidonicus* mealybug | Betelvine, chilli, citrus, green gram, guava, mango, pointed gourd, cowpea, Calotropis, Tea, Mullberry | Karmakar & Gupta (2011) Gupta & Kumar (2018) |
| Erythridae | *Balastium* | *Balastium* sp. | *Tetranychus* sp. | Brinjal | Mukherjee & Somchoudhury (1979) (1981) Gupta & Kumar (2018) |
| Tydeidae | *Pronematus* | *Pronematus* sp. | *E. orientalis* *B. phoenicis* | Citrus, Guava | Gupta & Kumar (2018) |

**Table 6. Examples of Predatory Mites Feeding on Different Stages of Insects from India**

| Family | Species | Target insects | Remarks | Year |
|---|---|---|---|---|
| Phytoseiidae | *Amblyseius delhiensis* | *Amrasca biguttula biguttula* (cotton jassid) | From Delhi | Somchoudhury (1981) |
| | *A. channabasavannai* | Scale insects, Mealybug | Arecanut from Kerala | Daniel (1979), Daniel (1981) |
| | *E. alstoniae* | Whitefly | Citrus from Delhi | Dhooria (1981) |
| | *E. ovalis* | *Bemicia tabaci* | From Odisha | Borah & Rai (1989) |
| Laelapidae | *Dinogamasus* sp. | *Mesotrichia confusa* *Xylocopa* sp. | Almost 50% population infestation | Mohansundaram (1989) |
| Anystidae | *Tencateia* sp. | Whitefly, hopper, Thrips | Feed on eggs and development stages of mentioned insects in Betelvine | Raut & Bhattacharya, (1989) |
| Bdellidae | *Bdella* sp. | Aphids | | Ghosh et al. (1987) |
| Erythraeidae | *Bochartia* sp. | Cotton jassid, cabbage painted bug, pigeonpea pod borer, mirid bug, mealybug | Collected from Delhi and MP, feeds on both nymph and adult | Sridhar et al. (2013) |

| | | | | |
|---|---|---|---|---|
| Stigmaeidae | *Eryngiopus coimbatorensis* | Sugarcane scale | Feeds on eggs | Gupta & David (1990) |

**Table 7. Reports about predation on nematodes by mites**

| Family | Species | Target organisms | Remarks | Year |
|---|---|---|---|---|
| Xylobatidae | *Xylobates seminudus* | Nematodes | Completely devoured the nematodes | Raveendran & Haq (1993) |
| Galumnidae | *Galumna flabellifera* | Nematodes | Cuts its nematode prey into pieces | Raveendran & Haq (1993) |
| | *Pergalumna* sp. | *Rhabditis* sp. *Peloderma* sp. | Efficiently control soil nematode population | Haq et al. (1992) |

**Mass Rearing Techniques**

Practical use of predatory mites for augmentative biological control, involving periodic releases, is highly dependent upon the availability of efficient mass production systems for the selected species. That means that regardless of the efficiency of a given candidate, its practical use may not be possible unless it can be produced in large numbers at competitive cost. Widely used substrate for the mass rearing are live corn plants, live ornamental pepper plants (*Amblyseius Swirskii* against Chilli Thrips), cut foliage (*Neoseiulus californicus* or *Amblyseius swirskii* against corn mites) and commercially available pollens (*Neoseiulus californicus* and *Amblyseius swirskii* predatory mites can be reared on any number of commercially available pollens (peach, kiwi, pear, almond) or field collected crape myrtle and cattail pollen).

The following methods are used as most standardised methods for mass rearing of predatory around the world.

**Rearing of Phytoseiid Mites**

Morales-Ramos & Rojas, 2014 developed a new stackable modular system for continuous *in vivo* production of phytoseiid mites. The system consists of cage units that are filled with lima beans, *Phaseolus lunatus* or red beans, *P. vulgaris* leaves infested with high levels of the two-spotted spider mites, *Tetranychus urticae*. The cage units connect with each other through a connection cup, which also serves for monitoring and collection. Predatory mites migrate upwards to new cage units as prey is depleted. In this particular study, the whole cage system was evaluated over a six-month time period, using *Phytoseiulus persimilis* as main predator. Average production is approx. 20,895 mite/week, more than 95% are adult, showing high productivity. This has also been shown to be a consistent and robust method to produce phytoseiids mites. The system is mainly suitable for medium-large scale rearing of *P. persimilis*. This system provides a good alternative for mite rearing and potentially can be scaled up for mass production.

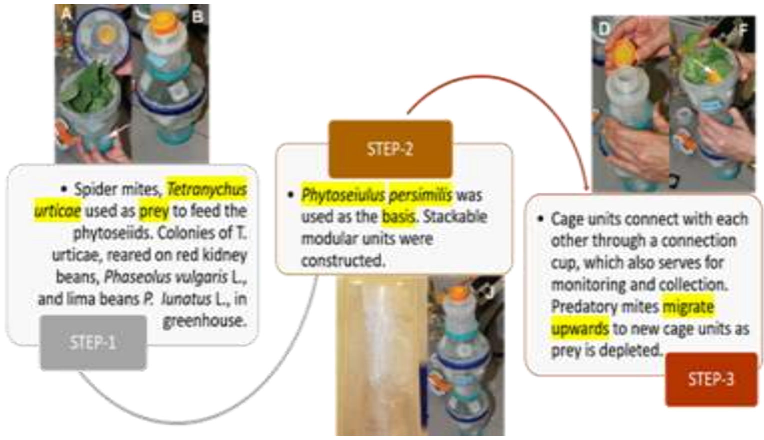


**Figure 9. Flowchart showing mass multiplication method of predatory Phytoseiid mite, *Phytoseiulus persimilis* following Morales-Ramos & Rojas, 2014**

In India, some scientists also derived some mass culture techniques under laboratory conditions. They developed a rearing system in which the predatory mite was successfully cultured on the factitious prey astigmatid *Tyrophagus putrescentiae*. *T. putrescentiae* mass-reared on a wheat bran and yeast medium. rearing units consisted of ventilated plastic containers with vermiculite, pollen, castor leaves, cotton, and moisture-maintaining arrangements that promoted oviposition, predator development, and minimized mite escape. The protocol ensures continuous production of *Neosieulus indicus* for over four years under laboratory conditions at the ICAR-NBAIR, Bengaluru, India. Each container yields approximately 800-1000 predatory mites a week. One small rearing facility is capable to produce about 20,000 mite per week using minimal labour and investment. This rearing protocol can be adopted by commercial units and also by farmers/polyhouse growers as an on-farm production system. A simple release methodology has also been developed for the mass reared predatory mites. (Ballal et al., 2021). Under laboratory condition, banana leaf with *Oligonychus sapienticolus* can also be used for the mass culture of *Neoseiulus longispinosus*.

**Figure 10. Rearing units for *Tyrophagus putrescentiae*. (1) The rearing container with a mesh-fitted lid, (2) Inner contents with a black cloth lining as lid, (3) The whole set-up of the rearing containers in a tray placed inside another tray with water, (4) Rearing containers, (5) Inside of the rearing container, (6) *T. putrescentiae* nymphs and adults, (7) rearing containers inside water tray, (8) stacked up rearing containers and (9) adult *Neoseiulus indicus*.**

**Rearing Laelapid Mites**

Hwang et al., 2019 also established a simple mass-rearing technique for a soil-dwelling predatory mite *Gaeolaelaps aculeifer*. The rearing container consists of two (inner and outer) plastic boxes (Double box system). The inner box contains rice husks, and is placed inside the outer box which contains a small amount of water to keep high humidity within the inner box and to prevent mites escaping from the box. The prey mite *Tyrophagus putrescentiae* was also mass-reared separately in a similar way using rice bran and provided to *G. aculeifer* once in seven days. Rice husks served as effective shelter for *Gaeolaelaps aculeifer*, while rice bran provided a substrate for the prey mite culture. In this double box system, under controlled conditions (25 ± 1°C and 95 ± 5% RH), *G. aculeifer* increased rapidly, achieving a 15.55-fold increase within two weeks, which was much greater than the population growth of *Stratiolaelaps scimitus* under the same conditions which takes about four weeks. Use of relatively cheap agricultural by products like, Rice husk and Rice bran make this practice easily adoptable as well as economically efficient. This double-box technique ensures continuous supply of *G. aculeifer* and technique helps farmers improve biological control efficacy of soil pests, fungus gnats, thrips larvae etc. in greenhouse as well as open field cultivation.

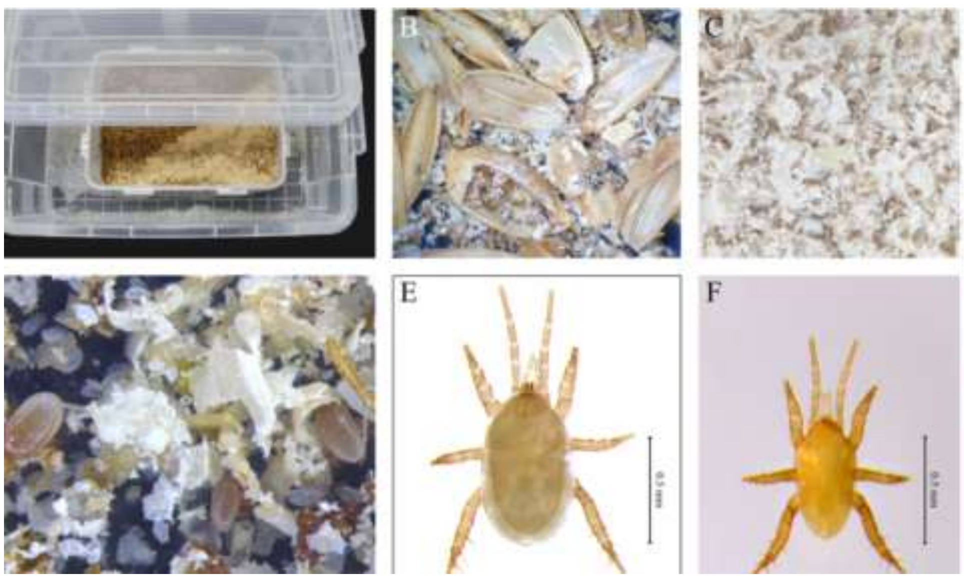


**Figure 11. Double box system for mass-rearing of *Gaeolaelaps aculeifer.* (1) *G. aculeifer* in rice husks within the inner box, (2) *T. putrescentiae* in rice brans, (3) *G. aculeifer* adults in the media after removing rice husks, (4) female mites, (5) male mite and (6) adults of *G. aculeifer.***

**Commercial Formulations**

There are some global pesticide companies that have made quite a few commercial formulations of predatory mites and marketed them. Among them, some important formulations are given in the following table-

**Table 8. Commercial Formulation of Biocontrol Mites**

| Species name | Producer | Formulation name | Target pest |
|---|---|---|---|
| *Phytoseiulus persimilis* | Biobee | BioPersi+, BioPersimilis | Spider mites, *Tetranychus urticae* |
| | Koppert India | Spidex, Spidex Vital | |

| | | | |
|---|---|---|---|
| | ARBICO organics | *Phytoseiulus persimilis* PLUS | |
| *Neoseiulus californicus* | Koppert India | Spical, Spical plus | *T. urticae, Panonychus ulmi*, *P. citri* |
| *Amblyseius swirskii* | Biobee | Bioswirski | *P. latus*, *T. urticae*, greenhouse whitefly, Chilli Thrips |
| *Neoseiulus cucumeris* | Biobee | Biocucumeris | *P. latus*, *T. urticae*, Citrus red mite, Chilli Thrips |
| *Stratiolaelaps miles* | Biobest | Hypoaspis-System | *Bradysia* sp., Thrips, Shorefly |
| *Stratiolaelaps scimitus* | Koppert | Entomite-M | Fungus gnats, Thrips |

As India is mainly a temperate country, the Acarine fauna of India is different from the faunal diversity of Europe and USA. So, the standardised method for mass rearing in Europe and USA may not be suitable in Indian conditions. It is very important to develop methods for commercial large-scale mass culture of predatory mites according to climatic conditions of in India.

**Conclusion**

Mites have proven to be invaluable allies in the sustainable management of pests in agriculture. Their diversity, adaptability, and targeted predatory behaviour make them well-suited for integrated pest management of strategies. By reducing the reliance on chemical pesticides, mites contribute to more environmentally friendly and ecologically sustainable agricultural practices. However, successful mite-based pest control requires careful consideration of environmental conditions and integration with other control methods. In conclusion, it can be said that the use of Predatory mites is a promising additional strategy for sustainable control of pests with soil-borne stages but more research initiatives need to be undertaken to fully utilize their potential.

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