REVIEW ARTICLE

Indigenous Plant Extracts and their Role in Pest Management in Tea Ecosystem

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Abstract

India is the world's second largest producer of black tea. Insects, mites, nematodes, and plant pathogenic diseases all damage the tea plant which severely hampered tea production causing about 10-15% crop loss every year. It would be 100% in extreme circumstances. In India, many synthetic pesticides are commonly employed to control tea pests. The use of an excessive amount pesticides could lead to a number of issues, including the development of resistance, negative impacts on non-target species such as insect predators and parasitoids, disruption of the ecological balance, and the accumulation of pesticide residues on tea leaves. In the international market, there is an increasing demand for organic tea or tea that is pesticide residue free, which influences the export price. Plant extracts having insecticidal qualities contains secondary metabolites such as alkaloids, terpenoids, phenolics, and minor secondary compounds can be used as an alternative to synthetic insecticides and these are environmentally safe, selective, biodegradable, cost-effective, and renewable options for use in IPM programmes in this context. Biopesticides are natural plant products that can be grown at a minimal cost by planters and extracted using indigenous methods.

Keywords: Botanical pesticide, Plant Extracts, Insecticidal properties, Tea Pest Management, IPM, Tea..

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INTRODUCTION

A monoculture plantation crop produced for its tea-producing leaves and buds, *Camellia sinensis* (L.) O. Kuntze (Theaceae) is a member of the family Theaceae. Tea is grown in over 50 nations, ranging in altitude from sea level to 2300 metres above sea level and latitudes from 43° north in Georgia to 42° south in Nelson, which is located on the South Island of New Zealand.[1] The annual production of tea in India is 1, 013, 30 tonnes, making it the second largest producer in the world after China.[2] As tea plantations are considered a "single-species forest," the only way for arthropod species to survive is through either intra-tree dispersal or stratification and the creation of ecological niches.[3] The climate and soil of the tea biosphere work together to keep the biological processes of the biotic community in check.[4] Pests are responsible for 15-40% crop loss in the tea industry.[5] In the North-Eastern and southern regions of India, the red spider mite (*Oligonychus coffeae*), the tea mosquito bug (*Helopeltis theivora*), and the tea thrips (*Scirtothrips dorsalis*) are three of the most destructive types of tea pests. The importance of loopers (*Buzura suppressaria, Hyposidra talaca,* and *Hyposidra infixaria*) in northeast India has increased over the past ten years as a result of damage to tea crops and a decrease in productivity.[6] *Caloptilia theivora, Eterusia magnifica, Andraca bipunctata, Euwallacea fornicatus, Cydia leucostoma*, Darjeeling black hairy caterpillar (*Euproctis latifascia*), and black caterpillar are some of the species of caterpillars that can be found in India. Historically, the majority of pests were controlled through the use of insecticides. The continued use of these chemicals, despite the fact that they are effective, has resulted in the reintroduction of primary pests that had been eliminated in the past[7] the proliferation of secondary pests[3], the development of resistance to the chemicals[8]. As tea is a consumable good, the pesticides left behind in made tea are bad for people's health. Integrated pest management (IPM) of insect pests has not worked well when pesticides are used a lot. It is important to find some environmentally friendly ways to get rid of tea pests.[9] In many places, people are trying to reduce the number of harmful insecticides they use by using natural plant products, IPM methods, biodegradable products[10], and insect growth regulators[11]. In this situation, biopesticides are being looked at as safe for the environment, selective, biodegradable, cheap, and renewable alternatives that could be used in the IPM programme.[12] Some plant extracts are interesting because they contain pesticides like alkaloids, tannins, quinones, coumarins, phenolic compounds, and phytoalexins. Recently, it has been said that different plant extracts and plant parts can kill insects.[13] Some plant extracts make certain tea pests lay eggs differently, stop them from eating, or kill them.[14] In this review, we tried to bring together relevant parts of the basic and applied sciences of natural pesticides and new ways that natural products are being used to keep pests away from tea.

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Plant Extracts as Botanical Insecticides in Tea

Crude plant extracts typically contain multiple active compounds.[15] The synergistic mixtures of bioactive plant compounds are more effective than using any one of them alone when it comes to pest management. Neem (*Azadirachta indica* A. Juss.), a plant native to India, is commonly recommended and used for controlling a wide range of tea pests.[7] Neem seed kernel aqueous extracts (NKAE) were tested for their antifeedant effect against the *H. theivora*, at different concentrations.[16] The oviposition and nymphal phases of *H. theivora* are shortened and the hatching success rate is decreased.[17] Several additional local weeds and wild plants have also been found to be efficient insecticides against *H. theivora.*[16] Moderate suppression of *Clania cramerii* and *Microcerotermes sp.* has

been achieved with the use of NKAE.[18] The antifeedant properties of NKAE and its impact on the development and mortality of *E. magnifica* (red slug) larvae were investigated in the laboratory. The results demonstrated a negative correlation between NKAE concentration and larval weight. The antifeedant activity increases with increasing concentration.[19] Similarly effective in controlling the red spider population in the field for *O. coffeae* were water extracts of *Clerodendrum viscosum* (68-95% effective) and *Melia azedarach* (56-95%). *Coriandrum sativum* may serve as a useful insecticide; NKAE at 5% has been demonstrated to be efficient in reducing red spider mites in tea as well as other spider mite colours (pink, purple, yellow, and Scarlet).[20-21] Crude aqueous extracts of the dry pericarp of fruits of *Sapindus mukorossi* have been shown to be effective against low to moderate infestations of thrips and jassids in tea fields.[22] Aqueous extracts of *P. hydropiper, Annona squamosa, C. viscosum, Argyreia speciosa*, and *Leucas aspera* have all been found to suppress the *H. talaca*, to varied degrees.[16] Among the species tested, *P. hydropiper* had the highest LC_{50} value, while *L. aspera* had the lowest. With a 4% concentration, the LC_{50} values were lowest in *P. hydropiper* and highest in *L. aspera*, whereas the LT_{50} values were lowest in *A. squamosa* at 2%. For example, *C. infortunatum* has been found to exhibit insecticidal activity of 45-84% and antifeedant activity of 84-100% against the bunch caterpillar, *A. bipunctata*.[18] The percentages of antifeedant action against *A. bipunctata* recorded for *P. hydropiper* (20-64%), *Artemisia indica* (62-93%), *Eupatorium glandulosum* (35–62%), *Urtica dioica* (42-68%), *Polygonum runcinatum* (56.87- 72.64%), and *Artemisia vulgaris* (62-78%) all vary. According to Gurusubramanian *et al.*[18], aqueous extracts of unripe *Carica papaya* fruit (17-22%), whole plant of *Tagetes erecta* (10-15%), and leaves of *C. sinensis* (20-24%) had low levels of control of the soilborne pest, *Microcerotermes sp*., but aqueous extracts of *Ipomoea carnea*, *Cleome viscose*, and *Pavonia*.[23] Some researchers have suggested that aqueous plant extracts could be useful in organic tea production and could even be considered as alternative products for crop protection, particularly in the management of resistance development.[7] However, continuous exposure of herbivores to the extract of the same plant species lowers response.[7]

Neem (*Azadirachta indica*)

When it comes to managing insects, mites, fungi, nematodes, and even viruses, neem has surpassed all other botanical insecticides. The neem tree offers an organic, environmentally friendly alternative to traditional insecticides, pesticides, and agricultural chemicals.[24] Neem tree products are safe for both humans and animals to use, and they cause no long-term damage to crops. Azadirachtin, an oxygenated triterpenoid, is produced in the seed kernels of the neem tree, *Azadirachta indica*. This chemical is extremely effective against pink and purple mites as well as several leaf-folding caterpillars. The neem tree has yielded over a hundred different types of terpenoids, including proto-limonoids, limonoids, tetranor-triterpenoids, pentanoor tripenoids, hexanor-tripenoids, and various nonterpenoids. These compounds and neem extracts display virtually every type of biological action imaginable against a diverse range of insects. According to research, compounds contained in neem trees destroy over 400 distinct types of insects.[25] Additionally, neem has been demonstrated to have antifungal effects. The neem tree, both its leaves and seeds, contain insecticides such as azadirachtin, miliantriol, and others. These components are more concentrated in the plant's seeds than in any other part of the plant. Neem can repel pests in a variety of ways, including neem seed kernel extracts (NSKE), neem decoction, neem oil, neem cake, and so on. An aqueous plant extract of *A. indica* considerably reduced the feeding of the tea mosquito bug.[26] Insects such as tea mosquito bug, red spider mites, thrips, flushworm, scales, ants, termites, looper caterpillars, and nematodes, among others, can be controlled by neem. Spraying one hectare of tea requires approximately 25 kg of neem seeds. The spray solution, at its current concentration of 5%, can be used to repel any insect problem.[27] To ensure that the spray solution is distributed uniformly to all of the leaves, an emulsifier must be used. The least price emulsifier option is soap powder, which is widely accessible at local supermarkets. In the knapsack sprayer, thoroughly mix 15 to 20 teaspoons (or around 50 g) of the soap powder. Use this treatment to prevent an infestation from occurring. The extract should be used in a formulation no later than 24 hours after preparation for maximum efficiency. By thoroughly soaking the entire plant, the spray's efficiency can be increased. Because many insects and mites lay their eggs on the underside of the leaves, the spray must be applied to both sides of the plant. It is suggested that the extract be taken at least twice over the period of 10-15 days. To inhibit the spread of nematodes, use 50 gms. of neem cake per planting pit before planting tea seedlings. Neemcake at a rate of 2 kg. per bush has been shown to be effective against the root knot nematode *Meloidogyne brevicauda* in plants.[28]

Ghora-neem (*Melia azedarach*)

The plant can be used to keep pests away from tea plants. According to some study, the insecticides azadirachtin and salanin may be derived from the *M. azedarach* plant. According to the work of multiple experts, oil cakes from the *M. azedarach* tree have been proven to be relatively successful in controlling root knot nematode infestation in cowpeas.[29] The seed contains mono- and sesquiterpene terpenes as well as lactones, which are both potent nematicides. As a result, it could be employed as a component of biopesticides to eliminate nematodes in tea. The seed extract has been shown to have an antifeedant action against tea mosquito bug.

Mahogoni (*Swietenia mahagoni*)

Mahogoni seeds are extremely toxic to insects and other parasites. As a result, extracts can be created by crushing the seed kernels and blending them with water. Tea extracts have been discovered to be particularly effective in fighting tea mosquito bug, or red spider mites.[27]

Karanja (*Pongamia pinnata*)

Karanja is a shrub with deadly seeds for insects. Extracts from the seeds of this plant can efficiently eradicate tea mosquito bug, red spider mites, and other microscopic insects of tea. When treated with an aqueous seed extract of karanja, tea mosquito bug infestation (43%) in tea was reduced by 10%.[30] Oilcakes of *P. pinnata* aid in the suppression of root-knot nematode populations.

Exodus (*Sophora flavescens*)

Exodus, a formulation made from extracts of the leguminous plant *S. flavescens*, has been shown to be particularly efficient against red spider mites in tea.[22]

Adathoda (*Adathoda vasica*)

The plants contain ovicidal and antifeedant effects against tea mosquito bug.[18] One kilogramme of fresh leaves is crushed, mixed with 6 L of water, and left to soak for one day. The liquid

is subsequently filtered and a suitable adhesive, such as soap, is added. The optimal time to submit an application is in the evening, after sunset. This will effectively minimize tea mites. This should be used daily for three days in a row. It is antifeedant, insecticidal, and acaricidal in effect.

Sweet flag (*Acorus calamus*)

The rhizomes of sweet flag (*A. calamus*) contain calamus, which has insecticidal effects. Saponins and tannins are the most important active ingredients. By drying and powdering the rhizomes and preparing aqueous extracts, pest control formulations are created. It decreases red spider mite infestation by 60-88% and kills red spider mite eggs by 33–70% in tea.[18]

Rotenone (*Derris elliptica*)

The roots of *D. elliptica*, a leguminous plant that contains 4-11% rotenone, can be utilised by drying, powdering, or combining with water. The liquid spray should contain between 0.002% and 0.004% active component. It is effective against sucking insects, caterpillars, and some beetles as a contact and gastrointestinal poison. One hectare of Derris produces 1.5 L of roots containing 5% rotenone, sufficient to cure 500 to 700 hectares of tea crop.

Annona (*Annona squamosa*)

The leaves and seeds of this plant contain insecticidal lanolin and anonaine. For application, the seeds must be dried, ground, and combined with water or alcohol to form a solution. It is effective against stem borer, sucking pests, and scale insects, among others. The aqueous leaf extract of annona possesses between 66 to 82% antifeedant action against tea mosquito bug.[18]

Smartweed (*Polygonum hydropiper*)

For extract preparation, the plant's leaves and succulent stems are collected, dried, powdered, and soaked for 24 hours. With antifeedant and ovicidal effects, 10% concentrations of aqueous extract of *P. hydropiper* diminish red spider mite by 60–80%.[18] Additionally, it decreases tea mosquito bug to an acceptable level.

Drumstick (*Moringa oleifera*)

This also a beneficial bio-pesticide plant. The insects and weevils that attack grains can be deterred by combining powdered drumstick seeds with preserved pulses. In addition, an aqueous extract of the tree's bark is a highly effective repellent.

Albizzia (*Albizzia procera*)

The crude extracts of the seeds of *A. procera* are extremely effective against coleopteran insects such as beetles and weevils. After the mixture has cooled, 1 L of water and a small amount of soap are added. Additionally, the entire plant should be pulverised and soaked in 2 L of water overnight. Small particles of soap may be added to the solution and then sprayed. For the control of aphids, cutworms, and termites in tea, the solution functions as an insecticide.

Xanthium (*Xanthium strumarium*)

It is a weed with insecticidal and miticidal effects. It is repellent (84–100%), ovicidal (47–60%), and antifeedant (27–3%) against tea mosquito bug.[31] This plant's aqueous extract at doses of 5–10% also reduces red spider mites (60–80%) in tea.[32] Additionally, it has high ovicidal action (44–87%) against red spider mite.[18]

Castor bean (*Ricinus communis*)

Oilcakes are recognised for their nematicidal characteristics.[29] 500 gm of shelled castor seeds or 750 gm of unshelled castor seeds can be crushed. The crushed seeds should be cooked for ten minutes in two litres of water. A small amount of soap and two teaspoons of kerosene are added. The solution is then filtered, and 10 L of water are added.

Coriander (*Coriandrum sativum*)

200 gm of crushed seeds are boiled in one litre of water for 10 minutes, strained, and diluted at a ratio of 1:2 with hot water. This will serve as a spider mite repellant in tea.[29]

Lantana (*Lantana camara*)

These plants contains flavanoids, triterpenoids, and alkaloids such as lantanine are the insecticidal ingredient. To control root grubs and termites, cut 5 kg of lantana leaves, flowers, and fruits into small pieces and partially crush them. After drying, the leaves and blooms can be removed with water and utilised to control numerous insects, including tea mosquito bug and aphids.[12] The plant's leaf extract exhibits good acaricidal activity (23–95%) against the red spider mite in tea.[18]

Chrysanthemum (*Chrysanthemum cinerariafolium*)

It is derived from Chrysanthemum's dried blossoms. Six distinct chemicals make up pyrethrum or natural pyrethroid. The principal active ingredient is the alkaloid stachydrine. It is capable of paralysing bugs upon contact. Pyrethrum is effective against sucking pests such as tea mosquito bug, thrips, aphids, and scale insects, among others.

Artemisia (*Artemisia vulgaris*)

This herb has 60–78% antifeedant effects.[18] Cut the leaves and stems of the *Artemisia vulgaris* plant into small pieces before it blooms. Place 1 kg of chopped leaves and stems in a bucket, add 10 L of water, and let sit for 16 to 24 hours. The liquid should be then filtered and spray against typical tea mosquito bug infestations.

Aegle (*Aegle marmelos*)

Boil 20 to 25 *Aegle marmelos* fruits in 10 L of water to extract the juice. Then, add 1 kg of turmeric powder and let the mixture sit for 12 hours. To manage thrips, dilute 1 L of extract solution with 10 L of water and spray it over the entire crop.

Marigold (*Tagetes erecta*)

Two kgs of marigold flowers can be ground into a paste with 5–10 L of water. The paste is then mixed with 5 L of water after being combined. This solution may be sprayed on the plants after being combined with 200 L of water.

Clerodendrum (*Clerodendrum inerme*)

Clerodendron inerme Linn. is the popular name for Ghetu, a herb belonging to the family Verbenaceae. The plant also exhibits repelling characteristics. The most significant weed species surrounding tea plantations is *C. inerme*, which has both insecticidal and miticidal properties. The 10% aqueous extracts of *C. inerme* decrease the infection of tea mosquito bug by 49%.[30] Aqueous extract of *C. inerme* reduced red spider mite (23–100%) and tea mosquito bug (32–60%) populations in tea.[18]

Wild sunflower (*Helianthus sp*.)

Within three days, 2–10% concentrations of the aqueous extract of wild sunflower (*Helianthus sp*.) diminish red spider mites by 60–100%. To produce the solution, bring 2 kg of *Helianthus* leaves and 10 L of water to a boil. 1-L of this solution should be diluted with 10 L of water. In addition, the herbal mixture of a particular plant is highly efficient against all types of insects, mites, and diseases in the sustainable control of tea pests. The mixture can be created using the following straightforward steps. About 500 g of dried tobacco leaves, 1-kg of neem seed kernel, 500 g of lime powder, 500 g of Datura leaves, and 500 g of olender (*Nerium oleander*) pods and seeds are pulverised and combined, then soaked for 15 days in 15 L of water. Every other day, the mixture must be stirred with a stick. After fifteen days, one litre of the filtrate is combined with 15 L of water and sprayed on the crop. It is sufficient for 2.5 ha and is designed to repel all types of pests.

Plant Formulations and Essential Oils as Insecticides in Tea

Significant effort has been placed into using plant extracts for pest management, and in recent years, research has shifted towards selecting biorational pesticides, which are safer than synthetics.[33] Several studies have shown the usefulness of plant-based oils and powders against insect pests.[34] Botanical pesticides are innovative in pest management. Botanical pesticides are safer for humans and the environment than synthetic insecticides due to complex combinations of monoterpenes, biogenetically related phenols, and sesquiterpenes.[35] Tea can be protected from sucking and chewing pests with botanical formulations, like other agriculture and organic gardens.[7] Central Insecticide Board (CIB) has certified many neem formulations with varying azadirachtin concentrations as insecticides. Assam, West Bengal, and Darjeeling employ 5% azadirachtin to treat tea pests.[36] A formulation containing 50,000 ppm azadirachtin effectively controlled tea mosquito bug (65%). Under the laboratory conditions, neem formulations with varied concentrations of azadirachtin killed *H. theivora, S. dorsalis*, and *E. formosa* with LC_{50} values of 0.09-0.24, 0.07-0.16, and 0.07-0.18 ppm, respectively.[15] 50,000 ppm azadirachtin is best for suppressing three important sucking tea pests: *H. theivora, S. dorsalis*, and *E. flavescens*. The bioactivity of azadirachtin at different concentrations and dilutions may vary depending on the insect.[36] *S. dorsalis* was most sensitive to neem, with LC_{50} values between 0.09 and 0.20 ppm, slopes between 1.99 and 2.54 ppm, and mean percentage decreases between 46.2% and 75.8%. *E. flavescens* and *H. theivora* followed. Additional azadirachtin could lower neem's $LC_{50.}$[36] Few commercial neem formulations displayed effective antifeedant activities in lab experiments on *A. bipunctata* and *C. cramerii.*[37] 300 ppm azadirachtin can reduce the population of various tea pests by 50-75% within 7 days, with *E. flavescens* being the most sensitive, followed by *O. coffeae* and *S. dorsatus*. For the purple mite, *Calacarus carinatus*, a 70% reduction was noted.[38] Econeem showed 100% pest mortality 10 days after treatment at 4 mL/l.[39] Majumder *et al.*[40] found that neem-based pesticides' efficiency against *Hyposidra spp*. was inconsistent, with reductions of 31-49% after the first application and 9–17% after the second. 0.15% EC azadirachtin killed *O. coffeae* at all three doses tested.[41] Hazarika *et al.*[7] found neem formulations ineffective against *H. theivora*, perhaps because *A. indica* A. Juss. is a secondary host. Red spider mites in tea were defeated using *S. flavescens* extracts[22]. Small-scale investigations suggest that plant essential oils are as effective as botanical medications in repelling tea pests. Roy *et al.*[16] and Barua *et al.*[42] tested horticultural oil and clove oil against *O. coffeae*. *O. coffeae* is affected by acaricidal, anti-ovipositional, repellent, and ovicidal actions. Pesticide exposure varies *O. coffeae* mortality rates. After 48 hours, petroleum-based horticultural oil was more effective than clove oil at all three intensities, showing it was designed for adults. Essential oils from plants kill insects and mites on touch and in the air and repel garden pests.[43] Neem-based formulations and oils provide a current paradigm for the creation of botanical insecticides, and many of the insights learnt about neem in the past decade can be utilised to produce new botanicals in tea. No other plant-based product offers as many benefits as neem, but there are others for which a constant supply, commercial standards, and regulatory criteria can be met without compromising earnings.[44]

Plant Extracts, Formulations, and Essential Oils as Synergist/Adjuvants

Using plants as synergists in pest management may have economic and environmental benefits. Botanicals can reduce the amount and frequency of synthetic pesticides while improving control.[45] Maurya *et al.*[46] found that plant extracts and synthetic pyrethroid insecticides work synergistically against insect pests. Several research have used plant extracts, formulations, and oils with synthetic insecticides to control tea insect pests. Neem formulations were efficient against *O. coffeae, H. theivora*, and *S. dorsalis* when mixed with acaricides and insecticides.[47] In a similar manner, Roy *et al.*[15] observed that combined formulations of neem and endosulfan or neem and deltamethrin reduced *H. theivora* incidence compared to neem (24.1–56.6%) or synthetic pesticide at approved levels. Roy *et al.*[36] found that combined formulations (neem and insecticide) reduced *S. dorsalis* incidence by more than 80%, even when the two components were used at lower levels individually. 1% karanj oil and 1% citronella oil show promise as adjuvants with diafenthiuron 50 WP against *O. coffeae*, even at lower doses[48]. The adjuvant mixes barely affected egg stages.

Future Thrust

Considering of pesticide's environmental risks, synthetic chemical use will be limited in the future.[49] Demand for botanicals and biological plant protection may rise.[50] According to 2011 Cal DPR data, 5.6% of all biopesticides were used, and botanicals accounted for less than 0.05% of all pesticide applications; nevertheless, botanicals might account for 25% of the home-and-garden market.[50] Botanicals and other natural pesticides should gain appeal in areas where environmental safety and insect tolerance are relevant.[44] Future botanical pesticide research should prioritise the discovery and application of new botanicals as pesticides, including the isolation, identification, and evaluation of active components, as well as the use of botanicals in agriculture, such as direct spray applications of various plant materials, soil amendments for different plant parts, and intercropping of biologically active plants with the main crop.[51] Several plants have been found as potential pesticides against tea pests, however there are limitations to their broad usage. China, India, and Japan dominate Asia's biopesticide market.[52] Only neem, *A. indica*, among India's four plant biopesticides, has the potential for large-scale agricultural use; in China, rotenone is used. Central Insecticides Board (CIB) of the Indian Ministry of Agriculture registers biopesticides. This includes microbiological and botanical products.[53] Given botanical pesticides' renewable nature, safety, and environmental and eco-friendliness, the government and business may promote their use. The government may subsidise botanical pesticides like Korea,

Japan, and other Asian countries if necessary.[53] However, market items vary widely in quality and effectiveness.

Conclusion

Despite efforts to examine the problem and develop plants with pesticidal powers against tea pests, only neem-based formulations are extensively used in commercial tea gardens. Tea plantations are increasingly using botanicals, especially neem-based pesticides, while the scientific review for wide use is incomplete. Most plant extracts are crude aqueous extracts, and their efficiency has been examined in lab and field investigations. Researchers have used botanical extracts and plant derivatives like essential oils to avoid allelopathy by restricting the germination or growth of competing plants (e.g., light, minerals nutrient, water). Secondary chemicals inhibit herbivory and protect against pathogens like bacteria and fungi. Ecosystem plants can be mined for pesticides and insect repellents that are effective, less damaging to the environment, and less expensive to produce than synthetic rivals. Plant extracts can be used to control tea pests. The Tea Board of India, the Department of Science and Technology, and the Department of Biotechnology should assist the transition of research from the lab to the end user through systematic research and coordinated efforts of stakeholders (tea planters) and end users (consumers). Despite the challenges of selling plant-based products, a more innovative and relevant strategy can be considered: screening plants for pesticide properties against target tea pests. Before applying for registration, companies must generate data on the bio-efficacy, safety to non-target organisms, phytotoxicity and related information. This aim must allow public-private partnerships to manufacture and disseminate biopesticides. Several plants have been identified and reported for their anti-mite or anti-insect properties, as well as against almost all major tea pests in India. It's time for researchers to refocus their attention on the development and application of known botanicals to accelerate scaling-up and increase the availability of eco-friendly pest management techniques. A streamlined technique for registering the pesticidal chemicals in plant-based formulations would ensure the future development, enhancement, and use of these potential biopesticides, which are part of tea estates' rich floral diversity. Pesticide users and tea plants must undergo a conceptual transformation before developing a holistic management strategy. The garden managers' guild must forgo any prejudice against synthetic pesticides and to incorporate diverse approaches and practises. Biopesticides are eco-friendly and can be used in some organic farming practices to protect against pests and reduce chemical insecticides. Inclusion of such botanical preparations in the tea industry's IPM is the way forward.

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