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Exploring Sustainable Approaches to Tea Pest Management: A Comprehensive Review

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ABSTRACT: The tea ecosystem provides an ideal environment for various insect pests and diseases to thrive, with the red spider mite emerging as a significant concern, especially in the Terai, Dooars, and Assam regions. This growing issue has garnered the attention of numerous scientists, and the repeated use of chemical pesticides has adverse effects on made tea, deteriorating its quality and creating a significant challenge in the tea market. To address this challenge, there is a renewed focus on employing non-chemical methods for biological control of tea pests and diseases, including the use of botanicals, Indigenous Technical Knowledge (ITKs), and microbial antagonists. The authors have conducted a comprehensive analysis, revisiting the effectiveness of botanicals in managing tea diseases and pests, with a particular emphasis on the red spider mite. Our efforts aim to bridge the gap between current non-chemical pest management approaches and the evolving requirements of the tea industry, especially in the context of organic tea production. By incorporating bioactive compounds and conducting field studies, we hope to offer innovative and sustainable solutions for pest management in tea plantations.

Keywords: Botanicals, Tea, Pest, Red Spider Mite, Management.

INTRODUCTION

The tea plant, scientifically known as *Camellia sinensis* (L.) O. Kuntze, is a valuable evergreen crop that commands a multi-billion-dollar industry. It belongs to the Theaceae family and Gordonaceae tribe (Wight, 1962). This woody perennial crop is widely cultivated both on large-scale plantations and small farms, with its tender leaves and buds being essential for the production of "made tea". The cultivation of tea spans across more than 50 countries, ranging from Georgia at 43°N to Nelson in New Zealand's South Island at 42°S. Remarkably, tea thrives at altitudes of up to 2,300 meters above sea level (Hajra, 2001). Leading tea-producing nations include China, India, Kenya, and Sri Lanka, with China holding the top position and India ranking second in terms of tea production. Notably, tea is extensively grown in 13 Indian states, with Assam, West Bengal, Tamil Nadu, and Kerala being the major contributors. The environment in which tea is cultivated presents favourable conditions for various insect pests and disease-causing microorganisms (Agnihothrudu, 1964) (Das, 1965). The tea plant is susceptible to a range of challenges, including approximately 1034 arthropod species, 82 nematode species, 1 algal disease, and 350 fungal diseases, all of which can result in significant yield losses if not managed meticulously (Chen and Chen 1989). In the North-Eastern region of India alone, over 167 pest species have been identified as threats to tea crops, leading to annual yield losses ranging from 11% to 55% (Das, 1965). This region faces a complex array of pests, including the tea mosquito bug, red spider mite, looper caterpillar, thrips, termite, and red slug caterpillar, among others. Among these pests, mites, as a collective group, consistently pose significant challenges and are considered the most serious pests in tea-producing nations (Cranham, 1966). Notably, the red spider mite, scientifically known as *Oligonychus coffeae* Nietner (Acarina: Tetranychidae), is a particularly formidable adversary. It was first identified in Assam in 1868 (Hazarika *et al.*, 2009). Reports indicate the presence of over 12 mite species that target tea plants in various countries, including Bangladesh, China, India, Indonesia, Japan, Malaysia, Sri Lanka, Taiwan, and the former USSR (Muraleedharan, 1992). India alone has documented 13 mite species spanning eight families (Gupta, 2001). China and Kenya have added to this list with *Daidalotarsone musspecies* (Tarsonemidae) and *Brevipalpus californicus* (Banks) (Tenuipalpidae), respectively (Lin and Liu 1995) (Rattan, 1992).

POPULATION AND LIFE CYCLE OF RED SPIDER MITE

Among these mites, the red spider mite (*Oligonychus coffeae* Nietner) is a major scourge for tea (*Camellia sinensis*). Its widespread distribution across tea-growing

nations has garnered significant attention from entomologists and acarologists since its initial discovery. Both adults and nymphs of this mite cause visible damage by puncturing cells, leaving distinct reddish-brown marks on matured leaf surfaces, which can escalate to extensive reddening in severe infestations, resulting in crop losses ranging from 17% to 46% (Das, 1959). The impact can be severe, ultimately leading to leaf defoliation and weakening of the tea bush (Radhakrishnan, 2014). This pest thrives in conditions of high temperature and low humidity, with its growth and development favouring temperatures around 30°C (Das and Das1967; Gotoh & Nagata 2001). The minimum threshold for its life cycle is 10°C, requiring approximately 23.26°C to complete the egg-to-egg cycle (Gotoh & Nagata 2001). The population of the red spider mite typically begins to surge in early March, reaching peak densities by late March and early April. The most severe damage occurs during May and June, subsiding with the onset of monsoon rains, which wash away the active forms. From July onwards, the pest significantly diminishes, except for a few mites that persist in the lower parts of tea bushes. Occasional mild attacks may resurface in September or October. Rainfall plays a role in dislodging mites residing on upper leaf surfaces. Moreover, leaf temperature and light penetration within tea bushes shape mite distribution, with the mites preferring the middle zone of the bush due to optimal temperature conditions provided by plant shading (Banerjee, 1979).

INFESTATION OF RED SPIDER MITE

Infestation by the red spider mite exerts a profound impact on plant growth and leaf productivity. Its damaging effects are particularly pronounced in Indian tea cultivation, with Assam and North Bengal tea plantations facing heightened vulnerabilities due to changing environmental conditions. Tea plantations in the North Eastern region of India confront a significant challenge in managing pests, often resorting to the extensive use of pesticides. However, this reliance on synthetic pesticides has resulted in adverse effects such as environmental disturbances, pest resurgence, variations in pest susceptibility, residues in processed tea, disruption of natural pest control mechanisms, and harm to non-target organisms, including humans (Bora *et al.,* 2007). Furthermore, the tea industry faces concerns from developed importing countries that impose restrictions on tea due to pesticide residue levels. This situation has spurred the need for alternative approaches that rely on non-chemical methods, which should be practical, cost-effective, and easily accessible. Consequently, an integrated pest control strategy has become imperative.

NEED FOR NON-CHEMICAL SUSTAINABLE MANAGEMENT OF TEA PESTS

Recent times have witnessed a growing global demand for organic tea or tea with minimal pesticide residues. This shift has led to the enforcement of new regulations for internationally traded foods, including the implementation of the Plant Protection Code (PPC) specifically tailored for tea by the Tea Board of India. These developments necessitate a re-evaluation of prevailing synthetic pesticide usage patterns in tea cultivation. The focus is shifting towards exploring sustainable, compatible, and environmentally friendly non-chemical interventions for managing tea pests. This proactive shift is essential to ensure the tea industry's long-term viability and to meet the demands of the ever-evolving international market. The utilization of plant extracts with insecticidal properties presents an alternative to synthetic pesticides. Research has demonstrated the potential of 67 plant species as botanical insecticides against tea pests. The application of neem-based products has also made a moderate impact on tea pest control. Additionally, researchers have recommended the use of cow urine fortified with leaf extracts of various botanicals, such as neem, ipomea, Annona, and jatropha, as an eco-friendly alternative to hazardous pesticides. Studies have shown the effectiveness of this practice in reducing insect populations on different crops. Many tea growers have adopted these practices as they are locally available, cost-effective, and environmentally friendly. Traditional practices similar to these are also in use in Assam.

APPROACHES ADOPTED BY FARMERS

A comprehensive survey was undertaken to examine the non-chemical approaches employed by small tea growers in Dibrugarh district, Assam, for controlling the red spider mite. The findings revealed that an impressive 95% of farmers were familiar with indigenous practices. These Indigenous Traditional Knowledge (ITK) practices emerged from the farmers' own experiences and could potentially serve as valuable inputs for scientific investigation, offering the possibility of broader applications in insect pest management (Hazarika *et al.,* 2005).

Between 2000 and 2004, a survey encompassing three districts of Assam. Golaghat, Sivasagar, and Jorhatunearthed insights into the traditional techniques used by tea growers to manage two major tea pests, namely the red spider mite (*Oligonycus coffeae*) and the tea mosquito bug (*Helopeltis theivora*). The necessity to manage these pests through traditional means stemmed from the high costs and lack of timely availability of chemical pesticides. Farmers relied on an array of local resources including cow urine, Neem (*Azadirachta indica*), Pothoruabihlongoni (*Polygonum hydropiper*), Water hyacinth (*Eichhornia crassipes*), Chilli (*Capsicum annum*), Ghora neem (*Melia azedarach*), Dhopatteta (*Clerodendrum infortunatum*), Bahektita (*Adhato davasica*), Jarmoni bon (*Chromolaena odorata*), Garlic (*Allium sativum*), Amla (*Phyllanthus emblica*), Tobacco (*Nicotinna tabacum*), and Karanj (*Pongamia glabra*). All these resources were locally abundant, consisting of plant or animal-based products (Saikia *et al.,* 2008). Furthermore, a survey conducted spanning eight major tea districts, investigating various indigenous practices and their combinations for tea pest management. Their study revealed that 56.41% of

growers employed cow dung and cow urine, followed by neem (48.71%), *Pothorua bihlongoni* (*Polygonum hydropiper*), (43.58%), and fish waste (30.78%) among other practices (Bhuyan *et al.,* 2016).

EFFICACY OF DIFFERENT APPROACHES AGAINST TEA PESTS

Unlike traditional insecticides that rely on a singular active ingredient, botanical insecticides consist of a variety of chemical compounds that work in synergy, minimizing the likelihood of resistance formation. *Pongamia glabra*, commonly known as karanj, has been reported as effective against insect pests in various crops. More than 19 active components have been identified in this plant, showing oviposition deterrent, antifeedant, and larvicidal properties (Kumar *et al.*, 2002). However, its effectiveness at the farmer's level is limited compared to neem due to the less efficient aqueous suspension (Kumar *et al.,* 2002). The key furano flavonoids in karanj seed oil, such as karanjin, are responsible for its biological activities. Different parts of the karanj tree possess insecticidal properties, including furano flavonoid derivatives, antifeedants, and nitrification inhibitors (Kumar *et al.,* 2002). Shukla *et al.* (2003) demonstrated that combining cow urine with various botanical extracts improved insecticidal properties against sucking pests, offering an eco-friendly alternative to hazardous pesticides. Verma *et al.* (2003) also reported reduced insect populations on different crops using cow urine and botanicals.

Nutritional assays revealed that neem compounds deterred feeding in insects, leading to reduced growth and development of larvae (Koul *et al.,* 2004). Botanical insecticides containing compounds with ovicidal, repellent, antifeedant, and toxic effects have been recommended as alternatives to chemical pesticides (Isman, 2006).

Compost tea as foliar spray in case of potato and as soil drenching in tomato may be the best alternative approach to control late blight of potato and tomato with higher economic return. However, the suitability of compost tea as a technology to control plant diseases needs to be evaluated against wide range of pathogens in other crop plants as compared to other biological means of plant disease control (Islam *et al.,* 2013).

The application of cow urine has been suggested to minimize synthetic pesticide harm (Ambwani *et al.*, 2006). In a trial against red spider mites, herbal products and combinations showed varying levels of control effectiveness (Roy *et al.,* 2008). Plant extracts with alkaloids, tannins, phenolic compounds, and phytoalexins possess pesticidal activity (Hazarika *et al.*, 2008). Sarmah *et al.* (2009) found that extracts from *P. hydropiper* caused significant egg mortality in red spider mites. Various botanical extracts, including neem and garlic, have been evaluated for their effects on red spider mites (Roobakkumar *et al.,* 2010). Kumar *et al.* (2010) reported 100% mortality in adult red spider mites using Derrimax. Different plant extracts, including Vitex negundo, *Gliricidia maculata*, and *Pongamia glabra*, exhibited acaricidal activity against red spider mites (Vasanthakumar *et al.*, 2012).Stored or fermented cow urine is preferred due to its reduced phytotoxicity compared to fresh urine (Gahukar, 2013). Cow urine contains components like halogenated phenols with antifungal properties and manganese and carbolic acid with anti-bacterial and pesticidal properties (Gahukar, 2013). *Terminalia chebula* extract exhibited adult mortality and oviposition deterrence in red spider mites (Roy *et al.,* 2014). *Leucas lavandulifolia* extracts demonstrated bio efficacy against red spider mites (Das *et al.,* 2015). Naturally available indigenous plants like Polygonum hydropiper, Vitex negundo, and *Sapindus mukorossi* exhibited ovicidal and acaricidal activity against red spider mites (Handique *et al.,* 2015). Mamun *et al.* (2015) evaluated various plant-based biopesticides against red spider mites in tea, observing significant reduction in mite populations. Fish extract, *Polygonum hydropiper*, and *Azadirachta indica* demonstrated acaricidal effects (Bhuyan *et al.,* 2017). The toxicity of neem kernel powder was enhanced when combined with *Prosopis julifora* seed powder (Deka *et al.,* 2020). Banerjee *et al.,* (2021) found *Vitex negundo* and garlic bulb extracts effective against red spider mites in tea plantation.

CONCLUSIONS

The current research highlights the potential use of botanical substances, either individually or in conjunction with cow urine, for tea pest control. This study suggests that non-chemical approaches, which are already in use by tea growers, could be significantly improved if they are rigorously examined, scientifically validated, and standardized. The continuous reliance on synthetic chemicals and the implementation of ineffective pest control methods have led to a range of adverse consequences, including outbreaks of secondary pests, the possible emergence of pesticide resistance, pest resurgence, environmental contamination, harm to non-target organisms, and the presence of unwanted residue in processed tea. Additionally, this approach can help reduce input costs. Given the present global context, adopting organically-based and environmentally friendly pest management practices represents a viable alternative to mitigate the adverse impacts associated with chemical pesticides.

FUTURE SCOPE

The latest research trends in tea plantation health emphasize the shift from focusing solely on individual microbes to understanding the entire microbiome in the rhizosphere. Utilizing metagenomics, researchers are exploring bioprospecting methods to ensure the long-term health of tea plantations. This includes developing microbial consortia that harness the interaction between different microbes to prevent pathogen colonization. These consortia are derived from both the rhizosphere and end sphere of tea plants, with promising results in pest and disease management. One particularly noteworthy approach involves the creation of a rhizosphere-specific microbial consortium based on arbuscular mycorrhizal fungi (AMF). This consortium has the potential to enhance the tea plant's immune system, bolstering its ability to combat pathogens and

pests. Tailored core microbiome transfer therapy is also gaining traction as a versatile method for managing various economically significant plant diseases. To fully realize the potential of microbial antagonists, a comprehensive evaluation process is essential. This includes assessing microbial pathogenicity through physiological, biological, and genetic studies, as well as field applications and considerations for bio-safety. While progress has been made in developing effective bioformulations for other crops, further validation in tea plantations is needed. Unlike plant-based products commonly used in tea disease and pest management, microbial antagonists have shown greater efficacy. To enhance the performance of botanicals, researchers are exploring the fortification of these compounds with microbial antagonists. Another avenue of research involves screening for novel bioactive molecules with antimicrobial and pesticidal properties, which could pave the way for greener pesticide design. In the pursuit of chemical-free solutions, the development of bio fungicides and nano-technology assisted microbial bioformulations is emerging as a cutting-edge strategy. These advancements align with the goal of establishing a modern tea industry that is residue-free and capable of meeting the challenges of international trade. Overall, these forward-looking perspectives are poised to establish a strong foundation for the tea industry's evolution, catering to the demands of sustainable agriculture and export-oriented trade.

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Conflict of Interest. None.

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