



Red Spider Mite (*Oligonychus Coffeae*): Bio-Ecology And Its Infection Cause Metabolic Changes In The Tea Plant (*Camellia Sinensis*).

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Abstract:

The tea plant, *Camellia sinensis* (L.) O. Kuntze is an evergreen leafy plant that is used in the manufacturing of beverages. The production and consumption of tea worldwide have continually increased over the decades. All parts of the plant, leaf, stem, root, flower, and seed, are fed upon by at least one pest species. In this study induced physiological and biochemical changes in tea with different levels of resistance against the red spider mite, have been studied. Red Spider Mites are the important pests of tea causing damage in respect of both quantity and quality.

The quantity of tea leaf waxes and the Phyto hormones like salicylic acid, jasmonic acid, Ethylene and the The secondary Metabolites like Terpenes, Phenolic Compounds and Nitrogenous Compounds activities have enhanced due to the infection by Red Spider Mite. Whereas a decrease in chlorophyll, carotenoids, superoxide dismutase, phenylalanine ammonia-lyase, catalase enzyme activities, amino acids, Glutathione are clear in above pests infested tolerant tea plants.

Keywords: *Camellia sinensis* (L); Green Leafhopper, Red spider mite (RSM), Phyto hormones, secondary metabolites, Enzyme activities, resistance, damage, susceptible.

Introduction:

Tea (*Camellia sinensis*) has been considered a strong nutraceutical, non-alcoholic, and widely consumed beverage after water (Hajra, 2019). Tea is a major part of the Indian agricultural cash crop. India is the world's largest producer, consumer, and exporter of tea. It is a rural-based agro-industry. (Das, 2014:1). Annually 5 million tonnes of tea are produced by 58 countries in the world. (Hajra, 2019). The major contributing countries are India, Sri Lanka, and China, along with Indonesia, Japan, Kenya, Malawi, Uganda, Georgia, Turkey, Iran, and Argentina. In India, tea is grown in Darjeeling, Assam and Nilgiris (Tamil Nadu), Himachal Pradesh, Kerala, Karnataka, Uttaranchal, Sikkim, Orissa, Bihar, Arunachal Pradesh,

Tripura, Manipur, Nagaland, Mizoram, Meghalaya and in the adjacent plain areas of Doors and Terai of the northern part of West Bengal. (Kumar, Badal, Singh, & Singh, 2008). Above India, States produced a total of 1.38 tonnes (2021) (Statista research department; 2022).

Pests are constantly attacking the tea as well as other plants on their foliage, sap, and roots causing a reduction in the net productivity by around 20% (Agrawal, 2011). All over the world, 1034 species of arthropods and 82 species of nematodes are recorded in tea plants (Chen and Chen, 1989). Among them, major tea pests are tea mosquito bugs, red spider mites, termites, aphids, jassids, thrips, flush worms, and nematodes (Mamun and Ahmed, 2011). Annually around 5-10% of the crop has been lost due to pest-related damage. (Sinha, 2010). Mites are the major pests of the tea plant almost all over the world (Cranham 1966b; Hazarika et al. 2009a; Sana, 1989). The red spider mite which was discovered in 1868 in Assam, India (Watt, 1903) is a pest of coffee, tea, rubber, indigo, grape, cashew, citrus, mango, camphor, mulberry, oil palm, and many other tropical plants (Jepson et al., 1975). Red spider mites feed on the sap of the leaf and damage to the chlorophyll contain causes hindrance in photosynthesis resulting in immature defoliation (Ahmed, 2005).

Plants have both physical and chemical defences against pests. Physical defence is hairs, trichomes, thorns, waxy cuticles, and spines (War et al., 2012). Chemical defences include toxic, repellent, and the plant parts which cause digestion problems in the herbivore's animals (Dearing et al., 2005). Physical and chemical defences work together in most cases (Dussourd, 1991). The major chemical defence is resins, gum, lattices, mucilage, monoterpenes, sesquiterpenes, diterpenoid acids ((Phillips, 1999), and derivatives of isoprenoid, phenylpropanoid, alkaloid, or fatty acid/polyketide pathways (Ramawat, 2009; Dixon, 2001). The biochemical reaction of the host against the pest like mites, thrips, tea bugs, etc cause a decrease in the phenolic content of the plant (Murthy and Chandrasekaran, 1979; Sudhakaran et al., 2000) resulting in a decrease in tea quality (Das, 1957).

The main objective of this review is to study the Bio ecology of the red spider mite (*Oligonychus coffeae*) and its relation with the tea plant host and its tolerance. The information on the RSM is less so further research is required to improve the host tolerance against the Red Spider Mites (RSM).

Biology of the pest:

The life cycle of the RSM includes egg, larva, protonymph, deutonymph, and adult. The adult stage is the longest stage which occupies 56% of the total life cycle of the mite. (Hu and Wang 1965).

Eggs

Eggs are laid on the area near the midrib and veins on the dorsal surface of the leaf. Eggs that are blood red to chrome red in color, ovoid, or spherical in shape have a flat lower surface and depression on the anterior part (Das 1959a; Rao 1974a). before hatching the egg's colour changed to light orange. The egg is provided with a small filament on the anterior side which act as a hook to anchor on the leaf surface. (Das and Das 1967; Sudoi 1997; Gotoh and Nagata 2001; Sudoi et al. 2011; Das et al. 2012). At optimum temperature (20-30°C) and humidity, the female lays maximum eggs, egg-laying decreases with the decrease in temperature and humidity. (Das and Das 1967). The rainfall decreases the breeding behaviour but the eggs which are already present had a minimal effect. The maximum oviposition is recorded at dawn and dusk and maximum hatching is influenced by red light (Ahmed et al, 2012).

Larva

Egg hatched to a rounded cream coloured larva having three pairs of legs. After feeding it colour changes to pale green colour. The larval period is followed by first quiescent stage (Roy, Mukhopadhyay, & Muraleedharan, 2014).

Nymph

Larva stop feeding and changes to protonymph and is followed by Deutonymph (Kachhawa & Kumawat, 2018). The duration of quiescent stage is different for male and female. The *protonymph* comes out after the moulting of larval skin. the protonymph is identified by dark colour and four pairs of legs. The larval two pairs have been lost during moulting. (Siddhapara & Virani, 2018).

After the second quiescent stage the protonymph moults into deutonymph stage. The sexes can be differentiated from this stage; the male has an elongate abdomen and small body size where as females are larger and rounded abdomen. After the third quiescent stage the adult emerges. (Roy, Mukhopadhyay, & Muraleedharan, 2014).

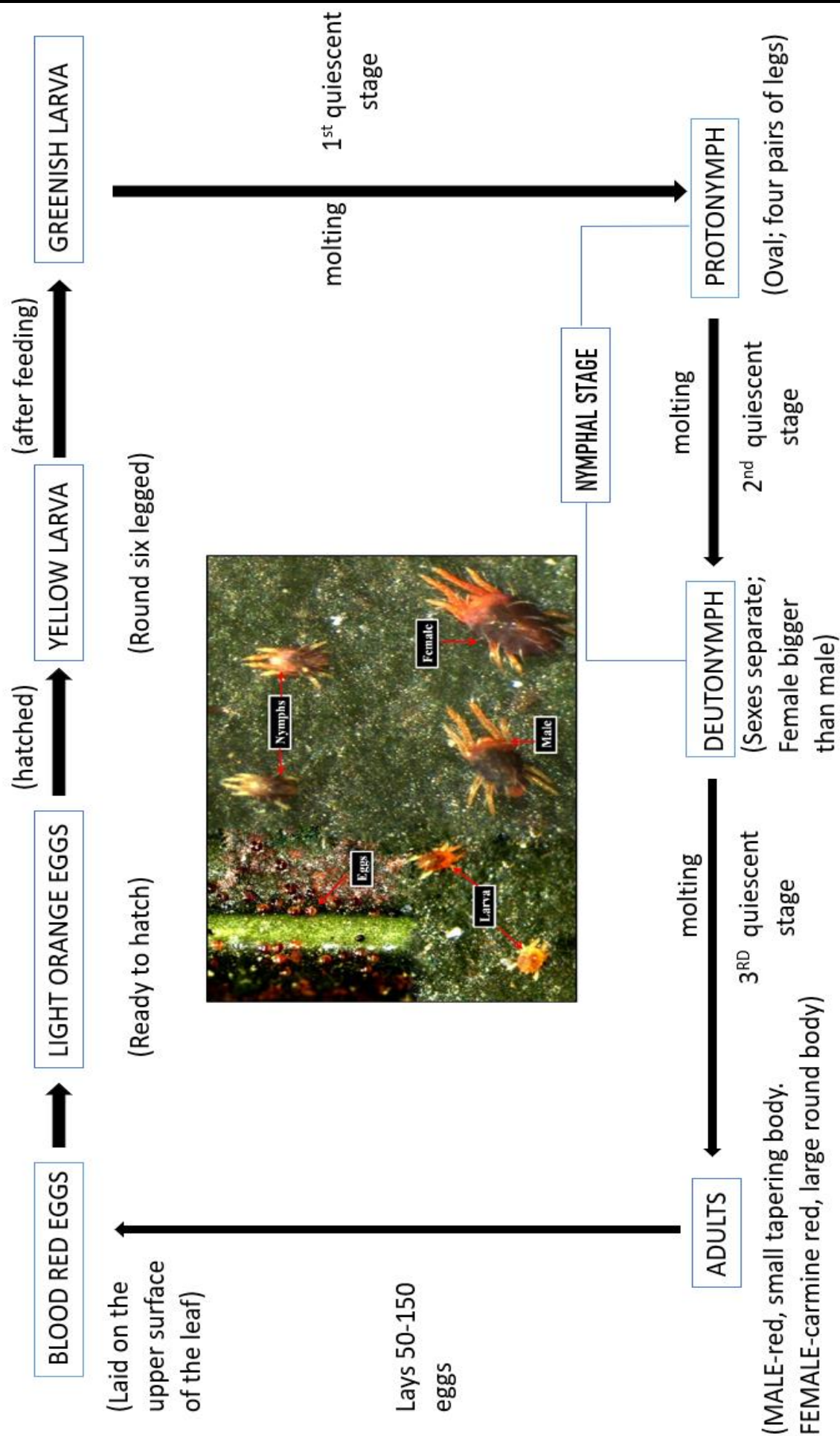
Adults

The male characterised by reddish green or pale red body colour with small tapering body whereas females are carmine red after mating changed to dark colour with larger rounded body and setae over the body and legs. (Roy, Mukhopadhyay, & Muraleedharan, 2014)

Sexually mature Adult comes out after the third quiescent stage. (Das, 1959). Male emerge first and wait for the female to emerge from deutonymph for mating. (Das 1959a). Female has longer life span than male. Female life is longer in winter than summer. (Das 1959a). in China the life span of female ranges from 34 to 72 days. But in the Indian climatic condition it survive for 20 to 30 days. (Roy, Mukhopadhyay, & Muraleedharan, 2014). Survival of female depends on the absence of shade. So, the shade has been recommended to control the RSM (Kachhawa & Kumawat, 2018). In absence of male female goes for parthenogenesis (Siddhapara & Virani, 2018). The parthenogenetic eggs develop into males only (Roy, Mukhopadhyay, & Muraleedharan, 2014).

Life cycle

The Red Spider Mites (*Oligonychus coffeae*) completes 15 to 16 generations per year in natural conditions. No diapause is recorded in winter (Hu and Wang, 1965). 30°C is the maximum temperature required for an egg to hatch. Beyond this, it fails to hatch. (Das and Das, 1967). In North Indian summer temperature i.e., May to June life cycle (egg to adult) takes only 9-12 days. Where as in winter takes around a month (Das, 1959). If the eggs are managed to hatch at 35 °C then they take only 8-9 days instead of 9-12 days to complete their life cycle (Das et al, 2012). In south India, it takes 21 to 25 days to complete the life cycle (Rao et al, 1974).



Host plant of Red Spider Mite:

Red Spider Mite (*Oligonychus coffeae*) was discovered in Sri Lankan Coffee plant (*Coffea arabica*) by Nietner in 1861. (Roy, Mukhopadhyay, & Muraleedharan, 2014). In India it was discovered in Tea Garden of Assam in 1868 (Watt and Mann, 1903). The RSM distributed world-wide from South America to Asia and from Europe to Australia. It was discovered in coffee, but it is now found in around 133 crops (Meyer 2001; Borror et al. 1989).

Table-1 list of Major Host plants of Red Spider Mite

Scientific Name	Common Name	Reference
Anacardium occidentale	Cashew nut	(Baker and Pritchard 1960)
Cinnamomum camphora	camphor laurel	(Ohno et al. 2011)
<i>Citrus limon</i>	Lemon	(Gupta and Gupta 1994)
Camellia arabica	arabica coffee	(Aranda and Flechtmann 1971)
<i>Camellia sinensis</i>	Tea	(Watt and Mann, 1903)
Corchorus capsularis, Corchorus olitorius	jute	(Gupta and Gupta 1994)
Elaeis guineensis	African oil palm	(Baker and Pritchard 1960)
Eucalyptus globulus	Tasmanian blue gum	(Gutierrez and Schicha 1985)
Gossypium sp.	Cotton	(Gupta and Gupta 1994)
Hevea brasiliensis	rubber	(Gutierrez and Bonato 1994)
Indigofera	Indigo	(Misra 1913)
<i>Malus sylvestris</i>	European crab apple	(Considine, 1982; Aziz et al., 2013)
Mangifera indica	Mango	(Baker and Pritchard 1960)
Manihot esculenta	Cassava	(Rodrigues 1968)
Morus alba	Mora	(Gupta and Gupta 1994)
Persea americana	Avocado	(Srikumar, Kumar, & Radhakrishnan, 2015)
Ricinus communis	Castor bean	(Gupta and Gupta 1994)
Terminalia catappa	Singapore almond	(Garrett and Haramoto 1967)
Vitis vinifera	grapevine	(Sayed 1946; Jeppson et al. 1975)

Infection identification mark and mode of damage

The dorsal surface of the mature leaf of the Tea plant is infected by Larvae, nymph and adult Red Spider Mite. Starting infection causes a reddish-brown mark which turns red which can be identified from the distance (fig-1a and b). when the infection is chronic causing around 50% crop loss (Das, 1959). When the infection become chronic, the Mites produces webbing on the leaf surface. Through this web, mites move from one leaf to another with the help of wind, called “ballooning” (vikaspedia, 2022). The mites mostly feed on the sap of the leaf, when the plants are in the drought stress, the mites cause secondary infection in the tender leaf, due to the presence of reserved sap in it. (Rao, 1974a).

The mites feed on leaf sap from the veins, under high population density they feed on petioles too. (Jeppson et al. 1975). The long needle-like mouthparts pierce the parenchyma cells of the dorsal leaf surface, inject saliva helps in digestion (Tomczyk and Kropczynska, 1985; Bensoussan et al., 2018). Infection makes a visible spot on the leaf surface (Kant et al., 2004; Bensoussan et al., 2016). The mites feed on the chlorophyll-containing part of the leaf, resulting in the reduction of photosynthetic rate, increase transpiration, and moisture loss leading to wilting leaves, abscission and defoliation (Peto et al.,

1981; Demiral and Türkan, 2005). It is believed that high rhodoxanthin contains in the tea leaf are susceptible to RSM, it act as a feeding stimulants (Muraleedharan 1999).



fig:1 a) Red Spider Mite infested single leaf, b) infected Tea Garden.

Defensive phytohormones and Secondary metabolites of tea plant

The insects (>1000000 species) are more diverse than plant (>300000 species), but also the ecosystem is dominated by plants (Futuyma, 2009). The plant dominance in the ecosystem is due to the production of Secondary metabolites and presence of phytohormones, which act as either toxic or impala tables to the herbivores (Wink, 2008; Ramawat, 2009).

Phytohormones

The list of phytohormones mostly produced by Tea Plants are jasmonic acid (JA), salicylic acid (SA), and ethylene (ET) in addition auxin, abscisic acid (ABA), gibberellin (GA), brassinosteroid (BR), and cytokinin (CK) may also helps in defence responses in tea plant (Yang et al., 2015). Jasmonic acid mostly produced against necrotrophic and herbivorous insects whereas salicylic acid produces against biotrophic and hemi biotrophic organisms. (Bari and Jones, 2009).

Secondary Metabolites

Plants' secondary metabolites which play a role are broadly divided into three groups. They are terpenes (or terpenoids), phenolic compounds (such as flavonoids, isoflavonoids, anthocyanins, lignins, and tannins), and nitrogen-containing compounds (such as alkaloids, cyanogenic glycosides, glucosinolates, and nonprotein amino acids) (Bahmani et al, 2014). In tea plants special metabolites of polyphenols are present. They are L-theanine, catechins, caffeine, and volatile compounds, they not only protect plants from pest and pathogens it also improves the quality of the tea (Koornneef and Pieterse, 2008).

Role of Phytohormones against Red Spider Mite (*Oligonychus coffeae*) infection

The chemical or physical signaling in the plants to identify the stimulation of spider mite is still unknown. It is only believed that mechanical given by RSM initiates plant responses (Mithöfer et al., 2005; Duran-Flores and Heil, 2016). Jasmonic acid is identified as the major phytohormone against defense signalling pathways against the necrotrophic pathogen like Red Spider Mite and it also initiates secondary metabolites defence signalling (Krisa et al 1999). The ethylene hormone is released against wound or stress response (Hyodo and Yang, 1971; Abeles, 1973).the jasmonic acid and selisylic acid are antagonistic to each other (Thaler et al, 2012). RSM induces the production of Jasmonic acid and nagetivel induces to salicylic acid dependent gene expression (Zhang et al, 2009).

Role of secondary metabolites against Red Spider Mite (*Oligonychus coffeae*) infection

Some plants, around 10% of the body weight contain defensive chemicals (Ramawat, 2009). The production and storage of chemical needs energy in the form of ATP (Wink, 2010). when plants are attacked by herbivores or by pests, they need to produce chemicals for their defence purpose. The chemicals make the plant's parts impalatable or toxic to the attackers (Wink,2008; Ramawat,2009).

The list of secondary metabolites and their action on RSM are as follows:

1. Terpenes or Terpenoids:

Terpenes are the diverse and largest secondary metabolites of plants (Ashour et al, 2010; Cox-Georgian et al, 2019). It is produced by plants for both defensive and internal chemical signalling (Silva, 2016). linalool, (*E*)- β -ocimene, myrcene, (*E*)-nerolidol and (*E, E*)- α -farnesene are the volatile terpenes produced by tea plant due to herbivore invasion (Cai et al., 2012, 2014). The volatile terpenes may play a direct defence by repelling the pest or attracting the natural enemy (Li et al, 2019).

2. Phenolic compounds

Phenolic compounds in tea act as reducing agents so has important antioxidant properties (Wu and Wei 2002). Tea produces their phenolic compounds mostly by the following two pathways: (Dar et al, 2014). Firstly, the amino acid phenylalanine is converted into phenolic compounds, a pathway called phenylpropanoid pathways (Cheynier et al, 2013). Secondly, called polyketide pathways in which polymerization of phenolics and other modifications give rise to a diverse variety of phenolic compounds (Kant, 2015; Quideau et al, 2011; Balasundaram, 2006). The phenolic compounds are mostly confined to the epidermal region of the plant, accumulation increase with the increase in pathogen/ pest load (Cle, 2008; Kefeli, 2003). Phenolics are toxic to the pest (Lindroth, 1988) as well as to the plant so it stores in an inactive form (Pourcel, 2007).

3. Nitrogenous compounds

Tea leaves are rich in amino acid, fibers, vitamins, minerals, etc. (Ramdani, 2013) and alkaloids (e.g. caffeine) (Chen, 2008). Caffeine has important disease resistance (Kim, 2008; Kumar 1995) and acts as a defensive chemical in tea plants (Wang, 2016). Caffeine makes the plant's parts bitter so it is an impala table for the insects to feed on (Kim 2011). Caffeine also inhibits the insect's phosphodiesterase activity and induce intracellular cyclic adenosine monophosphate activity (Nathanson, 1984). Study suggested that most of the tea pest has caffeine detoxification system in their body, but further exploration and verification is needed (Ceja, 2015).

Conclusion

This review summarizes the important research progress regarding the life cycle and the action of Phytohormones like Jasmonic acid, Salicylic acid and Ethylene and secondary metabolites like Terpenes, Phenolic compounds and Nitrogenous Compounds in the tea plants against the Red Spider Mites infection. The red spider mites infection not only damages the tea production, it also effects the physiological and biochemical contents of tea. The metabolic suppression of the pest is the primitive adaptation of the plant, so it generally has negative and less efficient consequences also. Pests also develop tolerance against the internal defence of the plant. Production of metabolites is costly and decreases the quality and competitive ability of the plant.

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