Diseases and Pests of Tea: Overview and Possibilities of Integrated Pest and Disease Management

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Diseases and Pests of Tea: Overview and Possibilities of Integrated Pest and Disease Management

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Abstract

From the viewpoint of plant protection (phytomedicine), the demand for tea free from pesticide residues is in conflict with the demand for high quality from the consumer, and with the demand for high yield and low labour input, from the producer. High yield in tea has been mainly achieved with elimination of shade trees, and reduction of losses due to diseases and pests, with pesticides. Elimination of shade changed the agro-environment, with increased growth of weeds, higher input of fertilizers, and with susceptibility to certain diseases (stem canker due to sun-scorch, grey blight) and pests (mites). However, shade also can be detrimental to yield with unsuited tree species, or to much shade in the rainy season, favouring incidence of blister blight (*Exobasidium vexans*) and some insect pests (tea mosquito bug). Economic loss of tea due to diseases is higher compared to animal pests (pests), the blister blight being the main disease. Pressure of diseases and pests on tea depends also on the control strategy and the climatic environment. Reducing pesticides may be feasible by lowering pressure of diseases and/or pests through cultivation in less disease and pest prone environments (altitude, shade), in choosing disease or pest tolerant clonal tea-varieties, by choosing pesticides with low interference on natural enemies of pests & diseases, and by applying pesticides according to economic threshold. The long standing time of the tea bushes favours slow developing root diseases These are reviewed and the integrated control is discussed in detail with eradication, with pesticides, and with improvement of soil microflora. Leaf and stem diseases are reviewed. Integrated pest and disease management of blister blight and the scarlet tea mite (*Brevipalpus phoenicis*), are discussed in detail.

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1 Introduction

Tea[1] originates in the mountains of Southeast-Asia. It is a small evergreen tree, which reaches a height of 10-15 m, without cutting. In cultivation it is pruned down to 0.5 to 1.5 m in height, for allowing easier picking of the leaves. There are different tea varieties, but the most important are *Camellia sinensis* var. *sinensis* and *C. sinensis* var. *assamica*. The former has small, hard and serrated leaves, is more temperature tolerant (it can withstand -5°C), more aromatic, but lower yielding. The latter originates in southeast India (Assam), has large soft and smooth edged leaves, is mildly aromatic, high yielding and cannot withstand even the slightest frost. Nowadays, hybrids of the two varieties are mostly grown. A newer development is the selection of clones (see section „Blister blight of tea"), which are multiplied by cuttings.

Most of the tea world production[2] is produced in Asia (81.4%), second is in Africa (15.5%), which is being followed by Latin America (2.0%) (FAO, 1999). Growing of the tea is best with deep and well drained acidic soils (pH 4.5-5.0), well distributed rainfall of 1500-2000 mm per year, mild average temperatures of 18°-20°C and sufficient sunshine. These ecological conditions are prevalent in the tropics at higher altitudes of 800-2000 m (1400-2100 near equator). According to CARR (1972) minimum rainfall for commercial yields is 1150-1400 mm/year, depending on how it is distributed. Temperature should not fall below 13°C and not exceed a mean maximum of 30°C. In the subtropics, tea has a dormancy period during winter and also in dry periods. The optimum sunlight intensity for tea is 50% to 80% from full radiation (EDEN 1976; PURSEGLOVE 1968). The suppression of weeds is essential. Tea is sometimes interplanted in a nurse crop or with green manure. Deep cultivation, which would damage the surface roots, should not be done. Shade was common. The plucking interval depends on the length of time needed for production of new shoot (flushing) and, depending from altitude, varies from 70 to 90 days.

The biggest challenge for tea growers nowadays, is to produce tea without pesticide residues. There is a growing demand for residue free tea, or at least low pesticide residue tea, in the highly industrialised countries and this property of tea is being well paid off. From the viewpoint of plant protection (phytomedicine) it should not be to difficult to grow tea without the aid of pesticides in some regions, if it was not for the phytomedical incompatible demand of the market for quality and the demand of the producer for high yield and low labour imput. Reduced labour intensity has been achieved, starting in the seventies, by replacing manual weeding with herbicides, hereby introducing the risk of herbicide residues in the plucked tea. High yield has also been established by eliminating shade trees, which increased the weed problem, the need of synthetic fertilizers and increased the incidence of some pests and diseases. However the need of shade in tea is controversial (EDEN, 1976). The economic loss of tea due to diseases is generally

[1] Tea, *Camellia sinensis* (L.) O. Kunze, of the family Theaceae

[2] Tea world production was 2 963 000 metric tons in 1998

higher compared to losses due to animal pests (pests). The pressure of diseases and pests on tea depends on the disease and pest control strategy of the plantation and also on the agro-ecological environment, which is different in specific tea growing regions and which varies at different altitudinal levels within the regions. Therefore one way of reducing pesticide application is to escape excessive pressure from specific diseases or pests by growing tea in environments less favourable to pests and diseases, which may not be always possible. Other alternatives will be addressed below. Tea is a plantation culture, being a single tea bush for a very long time (> 50 years) at the same site. This might be desirable from an economic viewpoint, but not so from a phytomedical viewpoint. The healthy survival of the tea bush for a long time at the same site requires a strong equilibrium (degree of integration) with the environment, which due to the management practices is not possible in highly efficient plantations.

Shade in tea through shade trees was common in the past. However, cultivating tea in full sunlight or with reduced shadow is more common now, since yield is higher and disease severity of the main leaf disease in Asia, the blister blight (*Exobasidium vexans*), is lower, this applies also to the attack of the tea mosquito bug (*Helopelthis* sp.). On the other hand, leaves falling from shade trees (acting as a nutrient pump) have a favourable impact on organic matter in the soil, which is important for the diversity and population density of the soil micro flora and fauna. Spreading and incidence of root diseases and also nematodes is favoured by a disturbed soil micro flora with a low species diversity and a low population density of antagonists to the fungal root disease agents.

The lack of equilibrium with the environment shows up in a number of diseases and pests, being an important disease group the decline diseases. The long standing time of the tea bushes is favouring slow developing root diseases spreading from one bush to another by root contact. In time, big dead patches or clearings due to these diseases, appear in the plantations. The most important fungal diseases of tea, besides blister blight of leaves, are root diseases (table 2).

2 Overview tea diseases

Since the leaves are the harvest product in tea, leaf diseases play an important role. The most important disease being the blister blight (table 1) found in Asia, followed by the worldwide present root diseases (table 2 and section 2.1).

Information of tables 1 and 2 have been recompiled from various sources, mainly HAINSWORTH (1952); EDEN (1976); SEMANGUN (1983); WALLER & HOLDERNESS (1997), and supplemented by the author’s experience in Java, Vietnam, Peru, and Bolivia.

Regarding leaf diseases, the black blight or thread blight (*Corticium invisum*), the pink disease

Table 1: Leaf and stem diseases of tea

Common name	Causal agent & geographic distribution	Symptoms
blister blight (E) Blasenbrand (D) cacar teh (BI) quema de ampolla (S)	*Exobasidium vexans* Massee (Basidiomycotina, Ustomycetes, Exobasidiales) Asia only	First, pale yellow translucent spots, then circular blisters on leaf underside. Then white velvety and later circular brown spot
black blight, thread blight (E) Fadenbrand (G) mal de hilachas (S)	*Corticium koleroga, C. invisum syn. Pellicularia koleroga* (Basidiomycotina, Hymenomycetes, Aphyllophorales, Corticiaceae). World-wide	Leaves and twigs turn brown. Dead leaves are hanging on thin threads from the branches. Under humid conditions in the tropics
grey blight (E) Grauer Brand (D) quema gris (S)	*Pestalotiopsis theae* (Deuteromycotina, Coelomycetes) World-wide	Round, irregular, grey and necrotic leaf lesions. In the centre of older spots black fruiting bodies (acervuli). Mostly attacks weak or damaged tea bushes
red rust (E) Roter Rost (D) roya roja (S)	*Cephaleurus parasiticus* Karst, *C. virescens* (Algae, Heterokontophyta [=Chrysophyta]) World-wide	Red film covering leaves and branches
pink disease (E) Rosarote Zweigkrankheit (D) mal rosado (S)	*Corticium salmonicolor* Berk. & Broome (Basidiomycotina, Hymenomycetes, Aphyllophorales, Corticiaceae). World-wide	Pink crust on twig and branches. The portion above the branches dies off and cause dieback. Under humid conditions in the tropics
hypoxylon wood rot, wood rot (E); Holzfäule (D) pudrición de madera (S)	*Hypoxylon serpens* (Prs. ex Fr.) (Ascomycotina, Pyrenomycetes) South India, Kenya	Stem canker. Wood with blackish patches and lines
stem canker, low-country stem canker (E), Stammkrebs (D)	*Macrophoma theicola* (Petch) (Deuteromycotina,Coelomycetes) Sri Lanka	Stem-canker
thorny stem blight (E) Stacheliger Stammbrand (D) quema espinosa del tronco (S)	*Tunstallia aculeata* Petch (Ascomycotina, Sphaeriales). India	Branches die off. Fruiting bodies (perithecia) project from bark of dead branches giving a thorny appearance. Weak wound parasite

(E): English, (D): German, (BI): Bahasa Indonesia, (S): Spanish

(*Corticium salmonicolor*) and algae on leaves causing the „red rust“ (*Cephaleurus parasiticus*) can be a severe problem in humid climates. The blister blight is discussed in detail in section 2.2.

Acute defoliation by the black blight is controlled by pruning the affected bushes, and burning the shoots on the spot. Plucking tea of the affected fields only in dry weather avoids disease transmission. New growth is protected with fungicide sprays (copper or organic fungicides, see section 2.2). *C. invisum* is also controlled by antagonists on leaf surfaces (phylloplane), such as the bacterium *Bacillus subtilis* (BARTHAKUR et al., 1993), which may provide a biological control agent for black rot. The grey blight can be controlled to a great extent with resistant varieties, such as IRB88-15 from Yakubita variety (Japan), CP-1 and TV-26 in SE-Asia, and 31/11 and 303/199 in Africa (Kenya). Red rust (*Cephaleurus virescens*) is controlled with partially resistant clones (0-10% susceptibility), such as TV-17, TV-23, TV-24, TV-25, TV-26 and TV27 (BARTHAKUR et al., 1992), and with repeated copper sprays.

2.1 Root diseases

Name and causal agents of root diseases: Several fungal species. See table-2.

Economic importance: HAINSWORTH (1950) calculates the loss involved with root diseases, concluding that with a 1% loss of bushes, the loss of the potential crop expected in the tenth year would be 10%. In Africa root diseases are the limiting factor of the tea production in many countries. In Kenya losses up to 50% of tea bushes occurred (ONSANDO et al., 1997).

Symptoms

The general symptoms of root diseases are a dieback of twigs and branches of the bushes, and a wilt of the seedlings. In tea the first symptom of root diseases is wilting, which is not always clearly visible, and shows up first at noon. Then comes sudden yellowing or bronzing of leaves, followed by dieback (tip of branches begin to die), which can also show up as a sudden death of the whole bush. A characteristic of root diseases is the sudden appearance of symptoms. Most of the fungal dieback diseases (with exemption of the seedling diseases) have an incubation period of more than one year, meaning that it takes more than one year from infection to symptom expression.

Following the first symptom of dieback (wilting, bronzing, yellowing, or dying of tip of branches), the tea bush is killed in a relatively short time. This happens especially in the drier season, in which water must be supplied at a higher rate to the leaves by the root and vascular system. Leaves and twigs wilt first and die thereafter if the water supply rate is reduced and water demand is high, due to low air humidity and high temperature. Reduced water supply may be either due to a limited uptake ability of the rotten roots, or to a reduced capacity of the vascular system, blocked by the dieback fungus.

Biology

Most of the root rotting fungi belong to the subdivision basidiomycotina and the rest to the ascomyotina, exempting *Lasiodiplodia theobromae* and *Fusarium oxysporum* (the latter not listed in table 2), which belong to the deuteromycotina (fungi imperfecti), lacking characteristic visible fruiting bodies. The best way to identify the causal agents of the root and/or wood rot is by the fruiting bodies[3]. Unfortunately these often appear when the bush is already dead, or after incubation of samples with symptoms in a moist chamber (plastic bag). But, as described on table 2, the individual fungal root rot species, can be recognised often by the symptoms on the roots and in the wood (table 2). Identification based on pure cultures isolated from diseased tissue, is recommended and necessary with fungi belonging to the subdivision deuteromycotina. The fungal disease agents of root dieback have a wide host range on roots of wooden plants and are facultative soil pathogens, meaning that they can survive in soil without a host plant.

Epidemiology

In soil, other soil-inhabiting microorganisms keep the population of the facultative pathogens low. A higher diversity and population density of the saprophytic soil microorganisms will reduce the population of the facultative pathogens accordingly, hereby lowering the chance of the facultative pathogens to attack healthy tea bushes. However, facultative root pathogens have very favourable growth conditions on root and wood residues in the soil, remaining from former trees and bushes of the site. This residues give rise to locally high populations of the facultative pathogens, meaning a high inoculum density. On such sites the facultative root pathogens can easily attack healthy roots of tea bushes.

Working on diagnostic and epidemiology of root rot on newly planted coffee, citrus and mango in Central America (Costa Rica, Nicaragua, El Salvador) at altitudes up to 800 m, the author found that dieback by black root rot (*Rosellinia* sp.) on coffee, and diplodia root rot (*Lasiodiplodia theobromae)* on citrus and mango, originated invariably through contact with buried residual wood or roots (mostly with visible mycelia). In older coffee plantations, infection occurred through the growth of mycelia or rhizomorphs from roots of infected neighbouring coffee bushes. Frequent downhill spread of the disease in up to 5 years old coffee, may be due to inoculum (mycelia, spores?) spread by water (LEHMANN-DANZINGER, 1990, 1997). Dieback on rubber (*Hevea brasiliensis*), attacked by the black root rot (*Rosellinia* sp.) in South Kalimantan (Indonesia), was also due to root contact with wood debris. All this cases had, besides wood and root residues in the soil, other features in common: Soils with low pH, low content of organic matter, and previous clearing from more or less degraded forests.

[3] The only reliable way of identifying fungal species is in taxonomy by fruiting bodies

Table 2: Serious root diseases of tea

Common name	Causal agent	Symptoms on tea
red root rot (E) Rote Wurzelfäule (D) akar merah (BI) raíz roja (S)	*Ganoderma pseudoferreum* (Wakef.) van Overh.et Steinm; *G. philippi* (Basidiomycotina, Hymenomycetes, Aphyllophorales, Ganodermataceae)	Wilt of the plant and dieback. Roots with white surface mycelium which later turns red, to which soil adheres. Rot pale brown and hard, later pale buff and either dry or spongy
brick-red root rot (E) Ziegelrote Wurzelfäule (D) akar merah buta (BI) pudrición de rojo ladrillo (S)	*Poria hypolateritia* Berk. (Basidiomycotina, Aphyllophorales, Polyporaceae). Also *Ganoderma pseudoferreum* (see above),	Root surface white speckled with mycelial strands. These turn into a smooth sheet hardening into plates or ropes of red colour. They show up with scraping or washing
black root rot (E) Schwarze Wurzelfäule (D) akar hitam (BI) pudrición negra (S)	*Rosellinia arcuata* Petch; *R. bunodes* (Berk.et Broome) Sacc. (Ascomycotina, Pyrenomycetes, Sphaeriales, Xylariaceae)	Rot of root and stem base, black wood discolouration. White mycelia on roots, later grey to black. Stem ringing. *R. bunodes* wide host range
charcoal stump rot, charcoal root, ustulina charcoal rot (E) Wurzelhalsfäule (D) leher akar (BI) pudrición de cuello (S)	*Ustulina deusta* (Hoffm.) Lind; *U. zonata* (Lév.) Sacc. (Ascomycotina, Pyrenomycetes, Sphaeriales). World-wide	No surface mycelium. Under bark of roots white fan-like patches. Wood at base of stem with irregular double lines. Wide host range
diplodia root rot (E) Diplodia-Wurzelfäule (D) akar Diplodia (BI) pudrición radicular de diplodia (S)	*Lasiodiplodia theobromae* (Pat.) Griffon et Maubl. (syn. *Botryodiplodia theobromae* Pat.) (Deuteromycotina. Coelomycetes). Pantropical	Dieback. Root and stem-base rot. Blackened vascular system and black discolouration of wood. Large number of host plants
armillaria root rot, root splitting disease (E) Hallimasch Wurzelfäule(D) pudrición de armillaria (S)	*Armillariella mellea* (Vahl:Fr.) (syn. *Armillaria mellea*) (Basidiomycotina, Hymenomycetes, Agaricales). Severe in Africa and Indonesia, in India rare	Sudden browning of leaves. Root splitting. White mycelial mat under the bark of stem base and roots, Shoe-string rhizomorphs
white root rot (E) Weiße Wurzelfäule (D) akar putih (BI) pudrición blanca (S)	*Rigidoporus lignosus* (Klotzsch) Imazeki (Basidiomycotina, Hymenomycetes, Aphyllophorales, Polyporaceae)	Dieback, white mycelium (rhizomorphs) on root. Roots rotten and white. Living wood decaying fungi
brown root disease (E) Braune Wurzelfäule (D) pudrición radicular café (S)	*Phellinus noxius* (Corner) Cunn. (syn. *Fomes noxius* Murr.) (Basidiomycotina, Aphyllophorales, Hymenochaetaceae). Africa, SE Asia, Australasia	Adherence of a crust of earth and gravel round the entire root. White or brown mycelium under the bark. Pale dry rot of wood
rhizoctonia seedling blight (E) Rhizoctonia Sämlingsbrand(D) quema de plántula por rizoctonia (S)	*Rhizoctonia bataticola* (Taub.) Butl. (Deuteromycotina, Agonomycetes); teleomorph probably *Tanatephorus cucumeris* (Basidiomycotina, Hymenomycetes)	Seedlings wilt and dieback. Wide host range. Soil inhabiting fungi
seedling disease (E) Sämlingskrankheit (D) penyakit pesemaian (BI) enfermedad de plántula (S)	*Cylindrocladium ilicicola* (Deuteromycotina, Hyphomycetes); teleomorph *Calonectria* (Ascomycotina, Hypocreales)	Seedlings wilt and dieback. Pantropical, wide host range

(E): English, (G): German, (BI): Bahasa Indonesia, (S): Spanish

Fungi such as *Macrophoma theicola* and *H. serpens* also in tea responsible for attack by stem canker, cause disequilibria with the environment and/or, in the case of *Hypoxylon serpens,* wounded stems. Low organic matter leads to low diversity and density of soil micro-organisms, meaning a desequilibrium of the soil environment.

A good example for disequilibria of the environment causing diseases, are the cork oaks: The Marmora forest in Morocco is composed of cork oaks (*Quercus suber*) as the dominant species. In the last decades this forest has been overgrazed severely, damaging and stressing the oaks and hindering the renewal of the forest. The result was over-aging of the cork oak population. These oaks were severely attacked by the charcoal disease (*Hypoxylon mediterraneum,* Ascomycotina: Sphaeriales), causing stem canker and killing an appreciable number. The dead wood was then colonized by soilborne saprophytic and facultative pathogenic wood decaying fungi: *Heterobasidion annosum, Armillariella mellea* and the propagules of these fungi accumulated in the soil. As a result newly planted acacias (*Acacia mollissima*) on part of the former forest, were attacked so heavily by root rot, that after 4 years over 50% of the trees had died (LEHMANN-DANZINGER, 1986). Similar high losses occurred in Kenya on tea attacked by Armillaria root rot, transmitted by buried wood or root residues (ONSANDO et al., 1997).

Control

From the biology and epidemiology of root diseases two preventive control strategies emerge: First, removal of stumps, other wood residues and large roots of woody plants from the soil prior to planting, this applies also to shadow trees removed from the plantation. The second strategy is increasing the diversity and population density of the soil microflora, by augmenting the organic matter of the soil either with green manure, with appropriate shadow trees, or by adding organic manure such as compost. Woody plant residues should be destroyed by burning or burying them beyond reach of roots in the soil.

Controlling the root and dieback diseases appearing in the plantation is done by first removing the diseased bush and all neighbouring tea bushes together with their roots and destroying them by burning or burying them outside the plantation. Replanting is possible only after a two year fallow with non host plants, such as grass. If after two years there are still appreciable wood residues remaining in the soil, a one year treatment of the replanted tea bushes with systemic fungicides is recommended. Suitable systemic fungicides are the group of demethylation inhibitors (DMI)[4], such as bitertanol, flusilazole, propiconazole, penconazole, hexaconazole and others, and in the group of morpholines tridemorph[5]. In Sri Lanka good results have been obtained by drenching systemic fungicides in 3-4 month intervals for a period of one year (ARULPRAGASAM, 1987). Applying fungicides of the same group consecutively should be

[4] The mode of action of the DMI's is inhibition of sterol biosynthesis

[5] For an overview and an application oriented description of fungicides see LEHMANN-DANZINGER, 1994. A detailed description of fungicides is given by LYR, 1995

avoided as to not promote resistance of the fungus against the fungicide. The two year waiting period can be shortened to one month, if soil fumigants are applied. The disadvantage of the available soil fumigants, such as chloropicrin (tear gas), the now banned methyl bromide, and formalin (formaldehyde), is that they are rather expensive (exempting formaldehyde), that covering of the site with a plastic sheet is necessary and that they have to be applied with the necessary precaution as not to harm the personnel involved. Formaldehyde is not as effective as methyl bromide. However, it is less costly, easier to apply and a good fumigant when treated surfaces or products are wet. It acts in the gas phase and comes as a liquid with 36% or 40% formaldehyde. The dose for soil fumigation is 1.5 litres of a 40% product for each 10 m^2. Application is by diluting the formaldehyde in water and then spraying it with a can over the soil. Afterwards sealing with a plastic sheet for 77 hours is necessary (LEHMANN-DANZINGER, 1994). Following fumigation a waiting time of 3 weeks should be observed, before replanting. In any case application of organic manure (compost) is recommended before replanting.

2.1 Blister blight of tea

Name of the disease: Blister blight (E), cacar teh (BI), quema de ampolla (S), Blasenbrand (G).

Causal agent: *Exobasidium vexans.*

Geographic distribution: Indian subcontinent, South-East Asia and East Asia.

Economic importance: Losses due to blister blight extend up to 43% on annual crop basis. Heavy attack can result in death of the whole plant. Even with fungicide control 11.3% yield loss occur in Sri Lanka, in the peak attack at the altitudinal range of 1500m - <1800 m (FUCHS, 1989).

Symptoms

Symptoms appear first on young leaves and later on the older leaves, but only young leaves can be infected. First, pale yellow translucent spots appear, then circular blisters on the leaf underside with a dark green watersoaked zone around. Finally the blister becomes white velvety (spore release). Following sporulation, the blister turns into a circular brown spot. Infected young stems are bent, distorted or girdled and may break off and die.

Biology

The causal agent *Exobasidium vexans* Massee belongs to the division Basidiomycotina, class Hymenomycetes, and here in the order Exobasidiales of the subclass Holobasidiomycetidae. The first symptoms appear following a 9-10 day incubation period. This period starts with the arrival of the spores on the leaf (inoculation). The first symptoms are irregular pale yellow translucent (watersoaked) spots which are clearly distinguishable on the underside of young leaves. Following 16 days after inoculation the spots become circular and the epidermis at the center becomes indented, forming a blister on the underside of the leaf. At 18-20 days after inoculation, the blister becomes first grey and then turns white and velvety. Here the lower epidermis of the blister is ruptured and spore bearing upright filaments (4-spored basidia) appear. Ripe spores are ejected with force from the basidia (GADD, 1949) and the lesion sporulates for about 1 week. Later on, the blisters turn brown and break up. The lesions appear then as circular spots with a dark brown centre surrounded by a light brown (tan) zone. The spores are thin walled, susceptible to desiccation, and direct sunlight. Therefore they can survive only a short time in dry air, and spread of the disease is difficult in the dry season. Surviving of *E. vexans* in the dry season is probably with immature lesions on leaves protected from direct sunshine.

Epidemiology

The blister blight was first reported from the Assam valley in 1868, at the border to Myanmar, where it caused little damage. Then it spread in 1908 to Darjeeling and from there in 1946 to south India and Sri Lanka. It also appeared in 1912 in Japan and 1930 in Vietnam. In 1949 the blister blight jumped over to Sumatra and from there in 1950 to neighbouring Java (Indonesia). Now it is endemic throughout most tea-growing areas of Asia, where it has reached epidemic proportions. It has not been reported in Africa or America. How spreading occurred in India and Asia still remains an unresolved problem. On opinion of the author this must have happened by leaves with immature lesions, probably with transport of tea seedlings.

Depending on climatic conditions, the full reproduction cycle (from inoculation and infection to release of spores) of *E. vexans* varies from 16 to 25 days. The disease occurs mainly in the rainy season. Cool, moist, still air favours infections, as do higher elevations. According to FUCHS (1989), more than 4-5 hours of sunshine/day keeps attack below danger level. In Sri Lanka severe attack of blister blight occurs mainly above 600 of altitude, with the most heaviest attack at 1500m - <1800 m. A similar sharply increasing incidence of the yellow Sigatoka[6], a banana and plantain leaf disease, occurred in the Andes mountain range[7] at >800-<1800 m, with a peak at 1100m (LEHMANN-DANZINGER, 1987). In this altitudinal range, condensing air leads to frequent fog, high humidity, and drizzling rain. These conditions lead to a dramatic decrease of sunshine and altogether favour fungal leaf diseases and, at the same time, lower the resistance to diseases in crops not adapted to the environment. This being the case with tea and bananas/plantains. Tea cultivated in the above range of altitude in South America is affected by losses due to diseases, such as algae, grey blight and pink disease[8]. However, if blister blight is introduced there, losses are going to be very heavy.

[6] The causal agent of the yellow Sigatoka disease is *Mycosphaerella fijinensis* (Ascomycotina)

[7] The survey was conducted in Venezuela, Colombia, Peru and Bolivia, from which the latter two had tea plantations

[8] diseases observed near Tingo Maria (Peru) at 1000 m of altitude

SUGHA (1997) found that blister blight was enhanced by the minimum and average temperatures and the relative humidity, but was negatively influenced by the average rainfall or hours of sunshine. Survival of the fungus in the off season was on necrotic blisters. The disease appeared then (end of May in Himachal Pradesh, India) on volunteer tea seedlings under mother bushes, and here the inoculum for infection in the following wet season was certainly build up. On opinion of the author of the present paper, *E. vexans* survives the dry season with slow developing or dormant immature lesions, which can develop further and sporulate when favourable environmental conditions appear.

Blister blight is more serious in plants recovering from pruning, since they are debilitated and have mainly young leaves. This susceptible period may extend up to 2 years after pruning. Pruning in the dry season avoids attack of the extremely susceptible leaves in the first period of recovery. Of course dry-weather pruning delays recovery and may cause sun-scorch of the stems (frame) and make them susceptible to stem cankers (caused by *Hypoxylon* and *Macrophoma*) and insect pests. The remedy to this drawback is providing shade during the dry season, which may be reduced (by pruning) afterwards in the rainy season, in order to reduce blister blight incidence. An alternative is pruning tea in the wet season and protect the bush from blister blight with systemic fungicides (see control).

Control

The most important factor contributing to the incidence and severity of blister blight is, besides temperature, humidity. Therefore the main attack on tea is in the rainy season. Newer tea clones, such as GMB-1, GMB-2 and GMB-3 show some resistance to the disease in comparison to older clones (TRI 2025). Clone PS1 is highly resistant to blister blight in Indonesia (MARTOSUPONO, 1991). The resistance transduces to a lower control level with fungicides, or even with no fungicide control. Therefore more attention should be paid to resistance against blister blight when planting tea at higher altitudes and breeding new clones.
Light pruning only in dry weather (addressed above) and reduction or removal of shade assist control with fungicides. The main strategy of control is prevention from infection. A second strategy is to start the wet season with a inoculum as low as possible and suppress sporulation of the fungus. The tea leaves are traditionally protected from infection of *E. vexans* by application of copper-oxichloride at 125g a.i./ha, or at higher concentration after pruning. Since only the young leaves and tender twigs can be infected by the fungus, only these have to be sprayed with the fungicide. The layer of copper on the leaves will kill the germinating spore of *E. vexans*. However, this protection is sometimes not enough during the rainy season. Here the cupric oxides give better results. Nickel chloride is superior to copper fungicides, since it has a curative action. To control the blister blight in India, a mixture of copper fungicide and nickel chloride is sprayed at 7-10 day intervals throughout the rainy season. However, copper fungicides stimulate the increase of the population of tea mites, especially the scarlet tea mite (Tenuipalpidae), which

is the main pest of tea grown at altitudes below 1400 m, and also the purple mite and pink mite, belonging to the family Eriophyidae (table 3).
An alternative to copper fungicides are the well established protective organic fungicides which are Calixin® (a. i. tridemorph)[9], and Sicarol® (a. i. pyracarbolid)[10]. These are applied at considerably lower doses at 14 day intervals and do not seem to enhance the multiplication of mites. A disvantage of piracarbolid is that it enhances the population of the mosquito bug (*Helopeltis* spp.) (table 3). A curative effect is reported for tridemorph, meaning that it can stop further development of still non sporulating lesions to sporulating lesions (see „biology"), another advantage is that it does not stimulate mites. A disadvantage, at least of Calixin® is, that it can be rapidly washed of by heavy rainfall during monsoon. Therefore this fungicide should be applied (at 14 day interval) at the beginning of the rainy season (2-3 applications), to lower the spore inoculum, and the end of the rainy season (3-4 applications), to keep the mite population down before the starting dry season (VENKATA RAM, 1980). A curative effect is achieved by the newer (and more expensive) group of organic fungicides with systemic action in the plant, and belonging to the group of the benzimidazole fungicides, especially Benlate® (a.i. benomyl), and to the demethylation inhibitors (DMI), especially Bayleton® (a.i. triadimefon), Tilt® (a.i. propiconazole) and, Anvil® (a.i. hexaconazole), which can be applied up to 21 day intervals. These can also be mixed with copper oxychloride. Being systemic, these fungicides cannot be washed off by heavy rain, with the provision of having enough time for penetration before rainfall, following application. The curative treatment is important to reduce the spore inoculum by suppressing sporulation (by stopping lesion development), when control is not possible with the available protective fungicides. This is the case when the inoculum originates from heavily infested disease nests („hot spots") in the plantation, these should then be treated selectively with curative fungicides. Selectively treating only the hot spots is an alternative to treatment of the entire tea plantation, if disease incidence is not too high (for instance at lower altitudes). This strategy would have less impact on benefical entomopathogenic fungi, in comparison to a broad application of copper or other fungicides in the plantation. Generally, the copper fungicides require application at rather high dosification in comparison to organic non systemic fungicides and organic systemic fungicides. Applying copper fungicides frequently results in accumulation of copper in the soil, which, at higher concentration becomes phytotoxic, especially in soils with low content of organic matter.

Setting up a disease forecast model for blister blight should be possible by relating bio climate with disease development. Bio climate includes continuous measurements (at the height of the tea bushes) of temperature, relative humidity, leaf wetness, sunshine and rainfall. Disease development includes lesion density, spore density in the air, and follow-up of lesion development. Encouraging results have been achieved by SUGHA (1997) (see epidemiology).

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9 a. i. = active ingredient of the commercial product
10 Pyracarbolid is no longer manufactured or marketed according to TOMLIN (ed.), 1997

Having set up the forecast model, blister blight severity forecast should be possible by measuring only the relevant parameters.

Conclusion: Controlling blister blight at higher altitudes in climates with a strong rainy season, is not possible without fungicides. However, the number of applications and the amount of the applied fungicide can be lowered, as shown above. A problem is the enhancement of pests, mainly mites, by the sprayed fungicides. Enhancement of mites can be reduced or abolished by the selections of non interfering fungicides, and application of cuprous fungicides only in the middle of the rainy season, when mites are not active. The outlined integrated control strategy could further reduce or even abolish fungicide residues in tea.

3 Overview tea pests

An overview of the main animal pests (pests) of tea is given in table 3 and table 4. Natural enemies in Asia are listed in table 4. Information of tables 3 and 4 have been recopiled from various sources, mainly HAINSWORTH (1952); KRISHNA & WEESNER (1970); EDEN (1976); DAS (1974); SARMA (1979); KALSHOVEN & VAN DER LAAN (1981); DHARMADI (1988); and MURALEEDHARAN (1992), and supplemented by the author’s experience in Java (Indonsia), Vietnam, and Peru (south America).
From the pests in the overview, phytophagous mites are considered one of the most limiting factors in tea production. The second most damaging pest are the *Helopeltis* bugs, which are also of economic importance in Africa. The third most important group of pests, listed in table 4, are leaf feeding caterpillars of the lepidoptera order, here Geometridae and Limacodidae feed mainly on maintenance leaves.

In Africa the mosquito bug *Helopeltis schoutedeni* is capable of causing annual losses up to 55% (RATTAN, 1992). The main pest of tea in Java and other regions of south-east Asia, from 400-1400 m altitude, is *H. antonii*. The adult bug is only 5 mm long and at a first view, resembles a mosquito[11], however it is a bug having 2 pair of wings and belonging to the order Heteroptera. In the frame of integrated control a wide range of measures have been applied in Java to control the mosquito bug (DHARMADI 1990a, 1990b). These measures include shortening of the plucking cycle, reducing nitrogen application, pruning in the correct time, control of broadleaved weeds, mechanical elimination of bugs with plucking, and use of released mantid predators (table 4). Application of insecticides becomes necessary, when the above techniques are not sufficient to keep the pest below the economic threshold level of 8 adult *Helopeltis* bugs/2 sqm. This level reduces 78.75% of the leaf production within 8 weeks.

[11] A true mosquito has only one pair of wings and is classified therefore in the the order Diptera (flies)

Table 3: Important pests of tea

Common name	Scientific name, order and family & geographic distribution	Symptoms, part of plant attacked
mosquito bug	*Helopeltis schoutedeni* Reut., E-Africa; *H. orophila* Ghesq., W-Africa. (Heteroptera: Miridae)	Brown centred black lesions followed by holes in the leaves. Scorching of leaves with heavy attack. Some species cause stem canker with black lesions on stems. The mosquito bug (probalby *Helopeltis* sp.) is also present on tea in Peru (South America)
mosquito bug, tea bug	Heliopeltis antonii Signoret (Heteroptera: Miridae). Sri Lanka, India, Indonesia, Vietnam. Occurs from 200 to 1400 m altitude	
tea mosquito bug, cocoa mirid	*Helopeltis theivora* Waterhouse (Heteroptera: Miridae). Sri Lanka, India, Bangladesh, Indonesia). Occurs up to 600 m	
scarlet mite, red-and-black-flat mite, red-crevice mite	*Brevipalpus phoenicis* Geijskes (Acarina: Tenuipalpidae). World-wide (tropics)	Attack of tea flushes and leaves, corky area on leaf undersides, leaves dry up. Attack below 1400 m of altitude. Distortion of young leaves
carinate tea mite, purple tea mite	*Calcarus carinatus* Green, (Acarina: Eriophyidae). Sri Lanka, India, Indonesia, Malaysia, China	
yellow tea mite	*Polyphagotarsonemus latus (*syn. *Polytarsonemus latus)* (Acarina: Tetranychidae, Tarsonemidae). World-wide	Flush leaves are cupped or otherwise distorted, corky brown area between main veins on leaf underside. Browning of flushes
red coffee mite	*Oligonychus coffeae* Nietner (Acarina: Tetranychidae). Practically world-wide, tropics	Yellowish-brown, rusty or purple discolouration of leaves. Fully developed leaves are mostly attacked
pink tea rust mite	*Acaphylla theae* (Watt) (Acarina: Eriophyidae). Bangladesh, India, Malaysia, Indonesia, China , former USSR	
red coffee borer	*Zeuzera coffeae* Nietner (Lepidoptera: Cossidae). India, Sri Lanka, Malaysia, Indonesia	Larva red to violet brown, often with yellowish rings. Larvae bore inside stems and branches. Dieback
live wood termites	*Glyptotermes dilatatus* Bug. & Pop., *Postelectrotermes militaris* (Des.). (Isoptera: Kalotermitidae) Sri Lanka	Attack of stems. Dieback. Colonies in the trunc region. Breeding and colony maintenance is more succesfull by *P. militaris* in tea stems
	Microcerotermes spp., (Isoptera: Termitidae). Fungivorous termites. India, Malaysia, Java	
ground termites	*Macrotermes gilvus* (Hag.) (Isoptera: Termitidae). Indonesia, Malaysia, Vietnam, Philippines	Nest in the ground. Attack of tea seedlings
tea shoot hole borer (stem borer)	*Xyleborus fornicatus* (Eichoff) India, Sri Lanka, SE Asia. *Xyleborus morigenus* (Blanford), Indonesia. (Coleoptera: Scolytidae)	Attack of stems. Dieback. Shoot holes in stem

Mosquito bugs have been controlled with the organo-chlorine insecticide gamma-HCH (γ-HCH) (= lindane). Nowadays the pyrethroid insecticide cypermethrin and permethrin (Ambush®, Torpedo®), the organo-phosphorous insecticides fenitrothion (Sumithion®, Folithion®), and formothion (Anthio®) are preferred. However, formothion stimulates the scarlet mite (DHARMADI, 1988). A study of DEKA et al. (1998) found that plant extracts of pongam (*Pongamia pinnata*) and wild sage (*Lantana camara*) have antifeedant and repellent effects on the tea mosquito bug *H. theivora*. Tea shoots sprayed with a 5% chloroform extract of *P. pinnata*, showed 72 hours after treatment only 43 spots on tea leaves caused by tea mosquito bug, in comparison to the untreated control with 653 spots. This finding shows that an integrated control of mosquito bugs may be feasible by replacing insecticides with plant extracts. The further description and discussion of the mosquito bug might be desirable here, but must be postponed in favour of an in depth treatment of the mite problem in tea.

The natural enemies of the lepidopteran pests in tea are parasitoids[12] belonging either to the order hymenoptera (wasps), or Diptera (flies) (table 4). This opens the possibility for control of the lepidopteran pests selectively with insecticides affecting only Lepidoptera, such as the *Bacillus thuringiensis* (B.t.) based insecticides. B.t. insecticides have the advantage of not leaving residues on tea, if applied properly.

From the phytophagous mites, the scarlet mite is considered one of the most damaging and most difficult to control. It is dealt with in a separate section. Mites are active during dry weather. In south India 4 rounds of spraying acaricides were the minimum for mite control. Severe infestations require even 6 applications (SARMA, 1979). Acaricides employed worldwide on tea are usually the organo phosphorous insecticide-acaricide dimethoate, and the organo chlorine acaricide-insecticide dicofol (see also table 7). Both are broad spectrum acaricides-insecticides, meaning that they kill other mites and also insects besides the target mite. Therefore most of the natural enemies of mites (Table 5) and the other insect pests (table 4) of the tea are killed by broad spectrum insecticides/acaricides, which promotes damage of tea by the other insect pests controlled by natural enemies (table 4). SARMA (1979) reported that predator populations tended to decline after only one spray of the organochlorine insecticide chlorobenzilate[13], and nearly disappeared after several sprays.

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[12] Parasitoid is an animal (insect) that feeds and lives for a long time in or on another living animal (host insect), consuming all or most of his tissues and eventually killing it

[13] The insecticide chlorobenzilate has been removed from the marketplace in the USA in 1989 and the registration suspended in Germany. Now chlorobenzilate has been replaced in tea by the organo phosphorous insecticide trichlorphon (Dipterex®)

Table 4: Serious insect pests of tea and natural enemies in Asia

Common name	Scientific name (order: family) geographic distribution	Natural enemies present on tea & remarks
tea tortrix	*Homona coffearia* Nietner *Tortrix dinota* (in Malawi) (Lep.: Tortricidae). India (subcontinent), China	Larval parasitoid *Macrocentrus homonae* (Hym.: Braconidae). Introduced from Java succesfully in Sri Lanka, controlling there *H. coffearia*
tea flushworm	*Cydia leucostoma* Meyrick *(*syn. *Laspeyresia leucostoma)* (Lep.: Tortricidae). India, Bangladesh, Indonesia	Ectoparsite *Asympiesiella india*, *Elasmus homonae* (Hym.: Eulophidae); *Apanteles* sp. (Hym.: Braconidae)
tea leaf roller	*Caloptilia theivora* Walsingham *(*syn. *Gracillaria theivora)* (Lep.: Gracillariidae)	*Asympleia india* (Hym.: Eulophidae) *Bethylus distingma* (Hym.: Bethylidae)
tea leaf miner	*Tropicomyia theae* (Cotes) (Diptera: Agromyzidae)	India and Sri Lanka
bunch caterpillar	*Andraca bipunctata* Wlk. (Lep.: Bombycidae)	Parasitoid tachinid fly on 1st and 2nd larval instar. *Bacillus* sp. on late instars
tea looper	*Buzura suppressaria* (Guen.) *(*syn. *Biston suppressaria).* (Lep.: Geometridae). From Sri Lanka to China	Indian subcontinent, Indonesia, China
lobster caterpillar	*Staurops alternus* Walker (Lep.: Notodontidae)	*Apanteles taprobanae* (Hym.: Braconi-dae), *Carcelia guava, Zenillia sumatrensis, Z. casumatrensis, Tricholya sorbillens* (Dip.: Tachinidae)
nettle grubs	*Darna (Macroplecta) nararia* (fringd nettle grub), *Thosea sinensis, T. cervina, Setora nitens, Parasa sp.* (Lep.: Limacodidae)	*Bacillus thuringiensis*, granulosis virus *Fornicia ceylonica* (Hym.: Braconidae), *Neoplectrus maculatus, Platyplectrus natadae, Metaplectrus thoseae, Euplectrus* sp. (Hym.: Eulophidae); *Trichoglya sor-billans* (Dip.:Tachinidae)
jelly grub	*Cheromettia apicata* (Moore) (Lep.: Limacodidae)	*Batotheca nigriceps* (Hym.: Braconidae)
hemipteran pests	*Helopeltis* spp. (Heteroptera: Miridae) *Empoasca flavescens* (Auchenorrhyncha: Cicadellidae)	*Sycanus collaris* (Het.: Reduviidae), *Hierodula* sp. and *Tenodera* sp. (Man.: Mantidae). Wasp (Hym.: Drynidae)
tea aphid	*Toxoptera aurantii* Boyer (Hemiptera: Sternorrhyncha)	*Aphilinus* sp. (Hym.. Aphelenidae), *Trioxys* sp. (Hym.: Braconidae), *Syrphus balteatus* (Dip.: Syrphidae)
tea shot-hole borer	*Xyeborus fornicatus* (Eichoff) (Coleoptera: Scolytidae)	*Atherigona orientalis* (Dip.: Muscidae)
red coffee borer	*Zeuzera coffeae* Nietner (Lep.: Cossidae)	*Bracon zeuzerae*, *Microbracon* sp. (Hym.: Braconidae). *Isoturnia chatterjeeana, Carcelia kockiana* (Dip.: Tachinidae)

All listed pests, with exemption of the tea shot-hole borer and the red coffee borer, feed on tea leaves

Lep. = order Lepidoptera (moths, butterflies); Hym. = order Hymenoptera (wasps); Dip. = order Diptera (flies); Man. = order Mantodea (praying mantids) (superorder Blattopteriformia)

Phytophagous mites have a number of natural enemies listed in table 5, which under „normal“ conditions (without use of pesticides) control these mites on tea. The fungi acting as entomopathogens (table 5) are, with exception of *Hirsutella*, not specific entomopathogenic, but have been repeatedly isolated from dead phytophagous mites on tea. These and other fungi certainly play an important role in reducing the mite population in humid weather.

The numerous predacious natural enemies of mites in table 5 and 8 show, that these together with the listed pathogenic fungi, should be able to keep the mite population below the economic threshold level. It seems that this was the case before indiscriminate use of insecticides in tea, because before this time, and according to a number of authors, phytophagous mites have never been a serious problem in tea. Of course, fungi are controlled by fungicides. So when unspecific broad action fungicides, such as copper based products, are applied to control the blister blight disease, the fungi acting as natural enemies are also killed. This effect has been well documented in south India (SARMA, 1979), where the use of residual copper sprays has increased the incidence of the red spider mite (*Oligonychus coffeae)* in tea, probably by killing the naturally occurring entomopathogenous fungi (described in table 5).

The termite *Glyptotermes dilatatus* Bugnion & Popoff (table 3) is a pest of tea in Sri-Lanka at middle altitudes, below 600 m (2000 feet). It has a broad host range attacking also coffee, rubber and cocoa. The soldiers are rather small of 7 mm length and the first stage larva has the sides of the thorax extended into 'wing-like' pads. The termite excavates longitudinal galleries and form a network of communicating tunnels, giving the wood a honey comb appearance in a longitudinal section of the nest in the stem. Roots are rarely attacked (KRISHNA & WEESNER, 1970).

The termite *Postelectrotermes militaris* (Desneux) *(Neotermes militaris)* is a pest of tea in Sri-Lanka at higher altitudes occurring chiefly at 1200 to 1600 m. It destroys the tea bush, hollowing out the stem, branches, roots and even rootlets. The winged termite stage gains entry into the plant through dead snags and wood rot cavities, which should apply also to *Glyptotermes dilatatus*. Nesting occurs in the heartwood. The nest has no definite system of tunnels and chambers and the cavities appear as filled with earth. The final winged stage takes 7 years to develop and a single colony may inhabit a tea bush for over 15 years (BEESON, 1941).

Table 5: Natural enemies of phytophagous mites on tea in India

Phytophagous mite species & family	Natural enemies	Order and family	Action of the natural enemy
red coffee mite *Oligonychus coffeae* (Tetranychidae)	*Menochilus sexmaculata* (F.)	Coleoptera: Coccinelidae (ladybird beetles)	predators
	Scymnus sp.		
	Verania vinta		egg predators
	Stethorus gilvifrons		
	Jauravia sp.		
	Oligota sp.	Coleoptera: Staphylinidae (rove beetles)	predators
	Orius sp.	Heteroptera: Anthocoridae (minute pirate bugs)	
	Micromus timidus	Neuroptera: Hemerobiidae (brown lacewings)	
	Phytoseiulus persimilis	Acarina: Phytoseiidae	
carinate tea mite *Calcarus carinatus* (Eriophyidae)	*Typhlodromus (Amblyseius) ovalis*	Acarina: Phytoseiidae	
	other predatory mites	Acarina: different families	
scarlet mite *Brevipalpus phoenicis* (Tenuipalpidae)	predatory mites from different families	Acarina: Phytoseiidae, Trombiculidae, Anystidae	
	Orius sp.	Heteroptera: Anthocoridae (minute pirate bugs)	
	Semidalis fletcheri	Neuroptera: Coniopterygidae (dusty-wings)	
all mites	*Hirsutella ?, Penicillium sp., Aspergillus sp., Cladosporium sp., Botryosporium*	fungi	disease (entomo-pathogens)

Data mainly from SARMA (1979)

3.1 Scarlet tea mite (*Brevipalpus phoenicis*)

Common name: Scarlet mite, red-and-black-flat mite, red-crevice mite.

Scientific name: *Brevipalpus phoenicis* (Acarina: Tetranychoidea, Tenuipalpidae).

Geographic distribution: Pantropical in most tea producing countries.

Host plants: Citrus (*Citrus* spp.), transmission of citrus leprosis disease; tea (*Thea*); coffee (*Coffea*) transmission of ringspot disease; date palm (*Phoenix dactilifera*); rose mallow (*Hibiscus rosa-sinensis*); passion fruit (*Passiflora edulis*) and 63 other host plant genera (PITCHARD & BAKER, 1958).

Economic importance

The scarlet tea mite is one of the main pests of tea in south-east Asia during the six-month long dry season. It constitutes a serious pest problem in most tea producing countries (India, Sri Lanka, Bangladesh, Indonesia, Kenya, Malawi and Mauritius), where it often causes 13% yield losses in tea. The injury and degree of infestation decreases with increasing altitude of the tea plantation, and is much lower above 1500 m of altitude. It seems that the mite problems are in some way related to the extensive use of pesticides. Copper fungicides, which are applied in tea to control the blister blight, stimulate the scarlet mite in tea (OOMEN, 1982). Also insecticides, which are applied to control the tea bug (*H. antonii*), stimulate the scarlet mite, especially the insecticide Anthio® (a. i. formothion). This is certainly due to the elimination of the mite's natural enemies. Herbicides decrease the population of the mite, most probably by killing secondary host plants of the scarlet mite (DHARMADI, 1988).

Symptoms and injury

The scarlet mite attacks the older leaves (tea maintenance leaves), their petioles and the non-lignified twigs throughout the year. The mites prefer to stay on the main veins of the leaf underside and crevices, especially on the leaf base and petiole. These parts become covered with a necrotic shade. With heavy attack there is bronzing on the leaf underside, then the leaves fall off. Following damage to the leaves, the mites migrate upward to younger leaves. The attack is heavier on old tea bushes (>50 years) and debilitated plants. Therefore, some sections of a tea plantation might show a more severe attack than others.

The yellow tea mite *Polytarsonemus latus* attacks tea flushes in the rainy season. The flushes get brown and may die off. The economic losses are similar to those of the scarlet mite.

Table 6: Influence of the temperature on the duration of the life cycle of the scarlet mite *Brevipalpus phoenicis*

Host plant	Temperature	Egg [days]	Larva + protochrysalis [days]	Protonymph + deutochrysalis [days]	Deutonymph + teleichrysalis [days]	Total time (egg-adult) [days]
tea (1)	19-23°C	14.4	5.4	6.3	7.4	33.5
tea	20-33°C	9.4	5.6	5.8	6.9	27.7
papaya	20°C	21.6	10.4	8.4	7.3	47.7
papaya	25°C	9.4	6.5	6.5	6.9	29.3

(1) Data adapted from OOMEN (1982)

Table 7: Acaricides applied in tea to control mites (based on restrictions of tea importing countries)

Active ingredient common name	Activity	Commercial product (trade name)	Chemical group	Toxicity class EPA(4)	Maximum residue limit in tea
binapacryl	acaricide/ fungicide	Morocide®, Acricid®, Endosan®	dinitrophenol	II	0.3 mg/kg(3)
dicofol	acaricide	Kelthane®, Acarin®	organochlorine	II or III	2.0 mg/kg(2)
dimethoate	insecticide/ acaricide	Cygon®, Champ®, Perfekthion®, Rogor®, Roxion®, Tara®	organophosphate	II	0.2 mg/kg(2)
chinomethionat oxythioquinox quinomethionat	fungicide/ acaricide	Morestan®	organosulphur	III	0.02 mg/kg(3)
cyhexatin (1)	acaricide	Plictran®, Mitacid®	organotin	III	2.0 mg/kg(2)

(1) cyhexatin (Plictran®) has been removed from the marketplace in the USA as a consequence of FIFRA Amendment's Reregristration Data Requirements
(2) maximum residue limit for tea in Germany (PERKOW & PLOSS, 1999)
(3) maximum residue limit in Germany, not extra specified for tea (PERKOW & PLOSS, 1999)
(4) toxicity class equivalent to EPA (= Environmental Protection Agency, USA)

Biology

The scarlet mite is polyphagous and has many host plants such as the citrus and papaya (see section "host plants"). The adult of the scarlet mite measures only 0.28 x 0.16 mm and is therefore difficult to see with the naked eye. Adults eggs and larvae are red in colour. They feed and maintain themselves on the leaf underside. The mite has five stages which are listed in table 6. The egg and chrysalis stages are immobile and remain adhered to the leaf. The reproduction of the scarlet mite is parthogenetic[14]. From table 6 it can be appreciated that the duration of the life cycle of the scarlet mite is shortened by a higher ambient temperature. This means that multiplication is faster at lower altitudes, compared to higher altitudes. This explains the much lower infestation above 1500m of altitude. The population usually increases at the end of the dry season. The average multiplication rate (rate of increase) is 0.061, which is far less than for other spider mites.

Table 8: Predators which prey upon the scarlet mite *Brevipalpus phoenicis* in Indonesia

Taxonomic group	Scientific name
Acarina: Phytoseiidae (predatory mites)	*Amblyseius deleoni* Muma et Denmark *Amblyseius largoensis* *Amblyseius tamatavensis* Blommers *Amblyseius* w (near *A. newsami*) *Amblyseius* x (*near Iphiseius*) *Amblyseius* z (*A. caudatus*)
Acarina: Stigmaeidae (predatory mites)	*Zetzellia* spp. *Zetzellia maori* Gonzalez *Agistemus* spp. *Agistemus terminalis* Quayle *Agistemus denotatus* Gonzalez *Agistemus feschneri* Summers *Agistemus arcypaurus* Gonzalez
Acarina: Podocinidae (predatory mites)	*Lasioseius* spp.
Diptera: Cecidomyiidae (gall midges)	*Lestodiplosis oomeni* Harris
Hemiptera: Anthocoridae (minute pirate bugs)	*Wollastionella testudo* Carayon

(based on data of OOMEN, 1982, HARRIS, 1982)

14 Parthogenesis: Reproduction without sexual process (fertilization)

Control

The economic threshold level of the scarlet mite is 25 eggs or adults per leaf, which cause a 13% yield loss (OOMEN, 1982). To control the scarlet mite most of the tea plantations have to be treated up to three times a year with the acaricides listed in table 7. A control based on integrated pest management (IPM) is based first on assessments of the mite damage or of the mite population (if visible) during plucking (harvest) and then on the treatment of the hot spots of the plantation, in which the damage or insect population is high, with acaricides. The following acaricides, listed in table 7, are available for control of the scarlet mite on tea. Surprisingly the pyrethroid insecticide permethrin[15] and the fungicides mancozeb and maneb are also toxic to the scarlet mite, reducing significantly their survival, oviposition and multiplication. The mite itself is not affected by copper fungicides (copper oxy-chloride, copper oxyde) and the insecticide carbaryl, belonging to the group of carbamates. As stated before, copper fungicides stimulate mites, the cause is not known exactly, but possible explanations are: copper fungicides kill predators, they stimulate the mites hormonal system, entomopathogens are suppressed, and trophobiosis influence on leaves.

OOMEN (1982) surveyed predator species and found 22 mite and 2 insect species, listed in table 8, to prey upon the scarlet mite. From these, the predatory mite *Amblyseius deleoni* is the most common and widespread predator of scarlet mites, although it seems to prefer pink and purple mites to scarlet mites. The population of *A. deleoni* is enhanced by the application of copper fungicides. The predatory mites of the subfamily Stigmaeidae show some preference for the scarlet mite, but also prey on eriophyid and phytoseid mites. They are easier to rear than phytoseid mites. The bug *Wollastoniella testudo* and the gall midge *Lestodiplosis oomeni* (table 8) have been identified as the insect predators of the scarlet mite. Nymphs and adults of *W. testudo* are rather selective against the scarlet mite and don’t prey on pink or purple mites. They prey on eggs, juveniles and adults of the scarlet mite. The larva of *L. oomeni* preys on purple and pink mites, and also on scarlet mites and its own species when hungry. So far predators have not been mass reared and liberated to control the scarlet mite, but this seems to be a promising biological control method. Control of the scarlet mite without acaricides is more promising in tea grown at higher altitudes (>1000 m) compared to tea at low altitudes.

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[15] Maximum residue limit in tea is 0.05 mg/kg in Germany

4 Zusammenfassung

Krankheiten und Schädlinge des Tees: Überblick und Möglichkeiten der Integrierten Bekämpfung

Die Forderung von Tee ohne Rückstände von Pflanzenschutzmitteln steht aus der Sicht des Pflanzenschutzes im Widerspruch zur Forderung des Verbrauchers und des Handels nach hoher Qualität, und der Forderung des Erzeugers nach hohem Ertrag und Verringerung der Arbeitskosten (manuelle Unkrautbeseitigung). Im Teeanbau werden hohe Erträge im Wesentlichen erreicht durch: Beseitigung des Schattens und Verringerung der krankheits- und schädlingsbedingten Verluste. Die Beseitigung der Schattenbäume verändert das Agro-Ökosystem mit dem Ergebnis eines erhöhten Unkrautwuchses, des Einsatzes von Düngermitteln und einer Erhöhung der Anfälligkeit gegenüber bestimmten Krankheiten (Sonnenbrand bedingter Stamm-Krebs, Grauer Blattbrand, usw.) und bestimmten Schädlingen (phytophage Milben). Schatten kann jedoch auch ertragsmindernd sein. Bei Auswahl ungeeigneter Schattenbäume oder bei zu hoher Beschattung in der Regenzeit (das Optimum des Lichtgenusses liegt beim Tee zwischen 50% u. 80% des unbehinderten Lichteinfalles). Schatten kann den in Asien auftretenden Befall des Blasenbrandes (*Exobasidium vexans*) und einiger Schädlinge (Tee-Wanze *Helopeltis*) begünstigen. Der wirtschaftliche Schaden durch Krankheiten ist an Tee höher im Vergleich zu Schädlingen, wobei der Blasenbrand u. die Wurzelfäule die wichtigsten Krankheiten sind. Der Befallsdruck von Krankheiten und Schädlingen ist auch von der Bekämpfungsstrategie und den klimatischen Bedingungen abhängig. Letztere ändern sich zwischen den Anbauregionen und mit der Höhenstufe des Teeanbaus. Eine Verringerung des Pflanzenschutzmittelaufwandes kann erreicht werden durch: Verringerung des Befallsdruckes von Krankheiten und Schädlingen, durch Teeanbau unter befallsmindernden Umweltbedingungen (z. B. Höhenstufe, Schattenregulierung), durch Auswahl krankheits- und schädlingstoleranter Teesorten (Klone), durch die Auswahl von Pflanzenschutzmitteln mit geringen Nebenwirkungen auf natürliche Feinde, und durch Anwendung von Pflanzenschutzmitteln in Abhängigkeit von der wirtschaftlichen Schadschwelle. Spezifische Schadschwellen werden aufgeführt, die meisten müssen noch für die einzelnen Schadorganismen und Anbaugebiete ermittelt werden. Die lange Verweildauer (bis 50 Jahre) des Teebusches an derselben Stelle begünstigt langsam entwickelnden Wurzelkrankheiten, welche zu großen Lichtungen im Teebestand führen und hohe Ernteverluste verursachen. Wurzelkrankheiten werden eingehend besprochen und deren integrierte Bekämpfung mittels Ausmerzung, dem Einsatz systemischer Fungizide und Bodenfungizide und der Verbesserung der Bodenmikroflora, diskutiert. Ein Überblick der Blatt- und Stammkrankheiten wird gegeben. Die integrierte Krankheits- und Schädlingsbekämpfung des Blasenbrandes und der Scharlachroten Milbe (scarlet mite, *Brevipalpus phoenicis)* werden im einzelnen behandelt.

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