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Occurrence, Distribution, Consequence, Biology and Management of Tea Blister Blight (Exobasidium vexans Massee): A Review

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Abstract
Tea (*Camellia sinensis*) is one of the most commonly consumed beverages next to water by a wide range of age groups in all levels of society in the world. Tea blister blight caused by *Exobasidium vexans* is a devastating disease that causes severe damage to tea in major Tea producing countries of Asia. The disease causes a crop loss as high as 50% and adversely affects the quality of made tea. It is reported throughout the tea growing countries of Asia, especially in India, Sri Lanka, Indonesia, Malaysia, Thailand, Philippines, Taiwan and Japan. It infects the young leaves of tea bush. In the field, Blister blight appear as circular blisters pale yellow spots first and turned to circular white spot later on tea leaves. Basidia of *E. vexans* are clavate to cylindrical, 88.6-164.5 × 3.8-5.1 µm with ellipsoid to ovoid, 11-16 × 4-6 µm, hyaline, smooth, one-septated basidiospores. The increased disease severity on tea decreases yield, deteriorates quality and declines total phenols, catechin, total nitrogen, amino acids, chlorophylls and polyphenol oxidase activity in tea. Use of improved cultural practices (Pruning of tea bushes), biological control by use of parasitic bacteria (*Pseudomonas fluorescens*), use of resistant tea clones and chemical control by use of fungicides Hexaconazol, Copper Oxychloride, Propiconazole, Bitertanol, Carbendazim, Hexaconazol, Tridemorphs, Triazoles and Nativo play a role in the disease management.
Keywords: Asia, brown spot, crop loss, white velvet, young leaves, Tea bush
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INTRODUCTION

Tea (*Camellia sinensis*) is one of the most important non-alcoholic cheapest beverages in the world [1]. It originated in the lower montane forest of mainland Asia from southwest China to northwest India [2]. *C. sinensis* is grown in more than 50 countries lying between 43° N and 42° S latitudes and situated at 2300 meter above sea level [3]. The primary center of origin is presumed to be near the source of the Irrawadi river in north Burma [4]. Early human interest in stimulating properties of tea may have been instrumental in its wide dispersal in Asia. The tea grown in China and Japan is *C. sinensis* var. sinensis (China tea) which has smaller leaves and greater cold tolerance but grows less vigorously than *C. sinensis* var. assamica (Mast.) Kitamura (Assam tea) discovered in the forests of north-eastern India in 1823 [5].

The productivity is declining due to unusual weather and large number of insect pests and diseases. Tea being a monoculture crop is susceptible to a number of destructive diseases and provides a stable microclimate for various diverse phytopathogens [6]. Diseases are very problematic in tea bushes and can cause death of the bush. Diseases in tea have been classified as Primary diseases (the diseases which can cause death of healthy tissues or bushes even under the best conditions) and Secondary diseases (the diseases which is harmful if the health of the bushes is damaged due other cause) [7]. A number of tea diseases along with their causal pathogens have been identified and documented on tea (Table 1 and 2). Tea crop loss due to these diseases has been increasing, which is as high as 15-25% worldwide [8]. Pest damage in China decreased the yield by 10-20% in an average a year [9]. Up to 10-15% yield loss in normal condition and as high as 100% loss in severe cases was reported [10].

Table 1. Plant parts affected, names of diseases, causative pathogen and symptoms of Primary diseases identified in tea [11]

Site of Attack	Name of the Diseases	Causal Organism	Identifying Characters
Leaf	Blister blight	*Exobasidium Vexans*	First pale yellow translucent spots, the circular blisters on leaves underside. Then white velvety and later circular brown spot
	Thread blight	Corticium koleroga	Leaves and twigs turn brown. Dead leaves are hanging on thin thread from the branches
Stem	Poria Disease	*Poria Hypobrunnea*	Yellowish encrustation forms on the collar region which changing to dull gray, corky.
	Nectria	*Nectria Cinnabarina*	The stems of the bush die backed and the new shoots which arise lowers down are generally thin and weak. The bush looks like at the point of death.
	Black root rot	*Rosellinia arcuata*	The collar region of the bush without encrustation but with mycelia growth and wooly, grayish stocking of mycelium sometimes extending to the base of the branches.
	Brown root rot	*Fomes lamaoensis*	The collar region of the bush without encrustation but with mycelia growth and brown soft mycelium extending up the main stem to several inches.
Root	Red root rot	*Poria hypolateritia*	Roots with encrustation of soil, sand, stone particles and mycelium white to chocolate red or black cords or sheets. Thin white films of mycelium present beneath the peeled bark.
	Tarry root rot	*Hypoxylon asarcodes*	The collar region of the bush with black, effused, hard encrustation and surface of crust smooth, dried black point.
	Purple root rot	*Helicobasidium compactum*	The collar region of the bush without encrustation but with mycelia growth. Thick pad of velvety, purplish brown mycelium surrounding the collar. Cords of mycelium purplish brown, cords branched, giving a general purplish brown color to the root.
	Charcoal stump Rot	*Ustulina zonata*	The surface undulated, brittle and charcoal like when broken. Dull white, silky and fan like film of mycelium present beneath the peeled bark.

Table-2 Plant parts affected, names of diseases, causative pathogen and symptoms of Secondary diseases identified in tea [11]

Site of Attack	Name of the Diseases	Causal Organism	Identifying Characters
Leaf	Leaf red rust	*Cephaleorus mycoidae*	Small brownish and circular shaped warts develop on the leaf surface.
	Brown blight	*Colletotrichum camelliae*	Old leaves are generally affected by these diseases. Yellowish green spots developed on young leaves. Circular irregular spots develop on the leaves with red and dray mycelium.
	Grey blight	*Pestalozzia Theae*	Light brown or dark brown, circular or oval shaped patches observed on the leaves.
Stem	Stem red rust	*Cephaleuros parasiticus*	Small water soaked green spots and yellow hair appear on green twigs.
	Jew's ear fungus	*Auricularia auricula*	Brown, soft, gelatinous, pronounced bracket like growth resembling to human ears observed at the collar region of the bush.
	Thorny blight	*Aglaospora aculeata*	Small, black, thorn like, pointed projections singly or in group observed at the collar region of the bush. White strands of mycelium are seen on the surface underneath the bark
	Ganoderma	*Ganoderma applanatum*	The collar region of the bush with pronounced bracket like growth. Brackets are thick, dull, upper surface marked with grey and brown concentric zones.
Root	Violet root rot	*Sphaerostilbe repens*	The roots become inky black or light violate colored.
	Thorny blight	*Aglaospora sp.*	Small, black, thorn like, pointed projections singly or in group observed at the collar region of the bush.

Among the leaf diseases, blister blight disease caused by a fungus Exobasidium vexans Massee is one of the most damaging diseases of tea bushes in tea producing countries of Asia [12]. It attacks young leaves and shoots, which made it the most important foliar disease of tea in all tea growing countries of Asian continent [13]. The disease is the major foliar disease of tea which causes a crop loss as high as 50% and adversely affects the quality of made tea in many countries [14]. Therefore, the objective of this paper is to review the occurrence, distribution, consequence, biology and management options of Blister blight disease in tea caused by *Exobasidium vexans*.

Occurrence and Distribution of Blister Blight Disease

The disease occurs all year in almost all tea growing areas of Asia. The disease is not present in Africa and Americas. Among the leaf diseases, blister blight disease caused by a fungus Exobasidium vexans is one of the most damaging diseases of tea plants worldwide [12]. It is an important foliar disease incapable of causing enormous crop loss throughout the tea growing regions of Asia, especially in Malaysia [15], Thailand [16], India [17], Sri Lanka, Japan [18], Indonesia [19] and Philippines [20]. It is also an important disease in Japan and Taiwan [13].

Crop Losses Due to Blister Blight Disease

The disease attains epidemic proportions during monsoon months (June to December) during which tea flushes are frequently plucked [21]. The pathogen infects young succulent harvestable shoots leading to severe crop loss. The crop loss varies with the geographical locations and nature of tea clones and seedlings. The disease causes a crop loss as high as 50% and adversely affects the quality of made tea [14]. It was estimated to be 33% in Sri Lanka [22], 20-25% in Indonesia and as high as 35% in India [17]. In addition to crop loss the disease adversely affects the quality of made tea [23].

Consequence of Blister Blight Disease on Tea

The fungus *Exobasidium vexans* feeds from tea leaves which is the primary source of carbohydrate and center of photosynthesis [22]. Increased severity of blister blight on young tea leaves and shouts has a great effect in chemical composition and quality of tea at green leaf stage and in orthodox made tea. The study on Analysis of quality-related parameters at the green leaf stage and in orthodox made tea indicated marked quality deterioration with increasing blister blight severity [24]. With increased blister blight severity, the total phenols, theaflavins, thearubigins, catechin, caffeine, total nitrogen, amino acids, chlorophylls, total liquor colour, brightness and briskness and polyphenol oxidase activity declined in tea leaves and shoots [24]. Aroma components, particularly hexene-1-ol, phenyl acetaldehyde, linalool, methyl salicylate, geraniol, indole, b-ionone, nerolidol, and several unassigned components were also lower in the disease affected teas [24].

Biology of *Exobasidium vexans*

The disease, being polycyclic in nature, assumes epiphytotic conditions within few days to cause huge crop loss. The disease perpetuates in the form of viable basidiospore in the necrotic lesions [25] during dormant season.

Symptoms of Blister Blight of Tea

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 water soaked 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 [26].

Figure 1. Symptoms of blister blight on young tea leaves A) circular blisters pale yellow spots [27], B) circular white spot [26].

Sporulation of Exobasidium vexans

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 and the lesion sporulates for about 1 week [28]. 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. Basidia of *E. vexans* are clavate to cylindrical, 88.6-164.5 × 3.8-5.1 µm [29]. Basidiospores were ellipsoid to ovoid, 11-16 × 4-6 µm, hyaline, smooth, one-septated [29].

Source of Infection:- Source of primary infection, the pathogen remain in the infected tea bush on the collateral host or form the soil. Secondary infection is made by air, rain splash [27].

Growth Factor Requirement Exobasidium vexans

Many studies by different scholars indicated that *Exobasidium vexans* is an obligate parasite [30] of tea and as such cannot be cultured on artificial media. However [31] first reported successful cultivation of pure cultures of the pathogen on maltsalep agar. Cultivation and maintenance of cultures of *E. vexans* on home-made Potato Sucrose Agar (PSA) is also successfully reported [32]. The pathogen formed a colony after 20 days incubation on the home-made PSA [32]. Some heterotrophic *Exobasidium* strains required thiamine in order to successful cultivation on artificial media [33].

Favorable Environmental Condition for Blister Blight

Cloudy, wet weather, cool-humid climate [27] and microclimatic conditions such as higher relative humidity, lesser temperature and longer duration of surface wetness in the ravine favored the disease throughout the year [20]. With the onset of rainy season from July to September, the disease starts appearing as whitish blister of basidiospore mass on pluckable shoots of self-grown tea seedlings under mother tea bushes to serve as initial foci for further disease spread [26].

Taxonomy and Ecology of *Exobasidium vexans*

The causal agent *Exobasidium vexans* Massee belongs to the division Basidiomycotina, class Hymenomycetes and here in the order Exobasidiales of the subclass Holobasidiomycetidae. *Exobasidium vexans* is an obligate parasite with no other host; hence its life cycle is completed on the tea plant itself [34].

Host Range:- the pathogen does not have alternate or collateral host [34].

Survival of Exobasidium Vexans, During Offseason

The disease attains epidemic proportions during monsoon months (June-December) and virtually disappears during the drier months by mid-January or early February [21]. The survival of Exobasidium vexans during off season (January to May) was investigated by [21]. Basidiospores of the pathogen was present in the atmosphere throughout off season and it was very low (<10 spores/m3 air) during the months of April and May. During this period, pathogen produced thick walled spores which failed to germinate in vitro indicating specific nutrient/ environmental requirement for its germination. These spores may help in over wintering of the pathogen [21].

Management of Blister Blight Disease of Tea

Blister blight disease has been known on tea bushes in countries in Asia for many years [20; 16; 15; 18; 12] but few studies have been conducted on its management since the potential threat of the disease to production. The disease is widespread on tea bushes with high rates of incidence and severity in the tea growing countries of Asia since most farmers have limited knowledge about the disease and were therefore indifferent towards its control resulting in increasing disease incidence and severity [34].

Host Resistance

Different tea cultivars react differently to blister blight and they significantly vary in their degree of resistance and susceptibility to the disease severity [35]. Moreover, the nature resistance in tea cultivars to blister blight is due to defense response mechanism. Ideal plant architecture can optimize canopy architecture, improve photosynthetic efficiency and prevent lodging, thus resulting in overall high yield [36].

Biological Control Method

Biological control of plant diseases is increasingly receiving attention, not only to reduce the dependence on chemicals having hazardous effect in ecosystem [37] but to adapt it to the conceptual scheme of integrated pest management as an acceptable ecosystem approach [38]. Biocontrol has been most successful against diseases of woody plants [39] because traditionally little breeding work has been done for resistance in trees and that very few pesticides have developed specifically for tree diseases. It appeared to be a promising strategy for managing

foliar and fruit diseases in number of crops [40]. The study indicated that the use of *Pseudomonas fluorescens* is helpful in preventing tea crop loss due to Exobasidium vexans [41].

Chemical Control

The disease can be effectively controlled by copper fungicides. The systemic tridemorphs and triazoles group of fungicides have been found to be effective against the disease [34; 42]. Nativo 75 WG at 125 g/ha was recommended against blister blight of tea [43]. Indiscriminate usage of fungicides to control BB may lead to resistance development and may exceed the acceptable maximum residue limits of residue (1–2 ppm for systemic fungicides) [24]. In addition [44] recommended about six fungicides to control the disease (Table 3).

Table 3. Blister blight disease in tea bush, control measures by use of fungicides and their dose of application [44]

Name of the diseases	Fungicides used	Dose
Blister blight	Hexaconazol 5% EC	200ml/200*l* water/acre
	Copper Oxychloride 50% WP	350g/200*l* water/acre
	Propiconazole 25% EC	100g/200*l* water/acre
	Bitertanol 25% WP	200g/200*l* water/acre
	Carbendazim 50% SC	200ml/200*l* water/acre
	Hexaconazol 5% EC	200ml/200*l* water/acre

Cultural Control

Pruning of tea bushes after 4-5 years, depending upon the nature of tea cultivars and climatic condition is an effective method of controlling blister blight disease of tea which gives rise to new healthy shoots [45]. Tea bushes are pruned to attack many pests and diseases [45]. After 4-5 years, depending upon the nature of tea cultivars and climate, tea bushes undergo pruning which gives rise to new shoots.

In conclusion Blister blight caused by *Exobasidium vexans* is a devastating disease that causes severe damage to Tea bushes in major tea producing countries in Asia. The occurrence and distribution of the disease is reported in India, Sri Lanka, Indonesia, Malaysia, Thailand, Philippines and Japan**.** The pathogen does not have alternate host. In the field, Blister blight disease appear as circular blisters pale yellow spots first and turned to circular white spot later on tea leaves. *Exobasidium vexans* is identified by its basidia and basidiospors. Basidia of *E. vexans* are clavate to cylindrical, 88.6-164.5 × 3.8-5.1 µm. Basidiospores were ellipsoid to ovoid, 11-16 × 4-6 µm, hyaline, smooth, one-septated. The disease can be controlled by use of improved cultural practices (pruning out blighted and old tea bushes); use of resistant and tolerant clones and biological control by use of parasitic bacteria (*Pseudomonas fluorescens*). Chemical control with Hexaconazol, Copper Oxychloride, Propiconazole, Bitertanol, Carbendazim, Hexaconazol, Tridemorphs, Triazoles and Nativo were recommended against blister blight of tea in extreme cases.

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