

STUDIES ON THE BLISTER BLIGHT
(*EXOBASIDIUM VEXANS* MASSEE, HYMENOMYCETES,
KOBASIDIALES) DISEASE AFFECTING TEA IN SOUTHERN INDIA

THESIS
SUBMITTED TO THE BHARATHIAR UNIVERSITY
FOR THE AWARD OF THE
DEGREE OF DOCTOR OF PHILOSOPHY IN BOTANY

BY
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UNDER THE GUIDANCE OF
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INDIA
1992

C E R T I F I C A T E

This is to certify that this thesis entitled **"STUDIES ON THE BLISTER BLIGHT (EXOBASIDIUM VEXANS MASSEE, HYMENOMYCETES, EXOBASIDIALES) DISEASE AFFECTING TEA IN SOUTHERN INDIA"** is the original work of the candidate **Mr.B.CHANDRA MOULI**, carried out under my supervision and guidance in the Division of Plant Pathology, United Planters' Association of Southern India (UPASI) Tea Research Institute, Valparai - 642 127, Coimbatore District, India and that the matter entered herein has not formed the basis for the award of any other degree to the candidate.



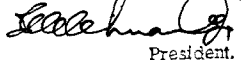
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D E C L A R A T I O N

I hereby declare that the thesis entitled "STUDIES ON THE BLISTER BLIGHT (*EXOBASIDIUM VEXANS* MASSRE, HYMENOMYCETES, EXOBASIDIALES) DISEASE AFFECTING TEA IN SOUTHERN INDIA", submitted to the Bharathiar University, Coimbatore - 641 046, in candidature for the award of the Degree of Doctor of Philosophy, is a record of original research work done by me in the Division of Plant Pathology, under the supervision and guidance of Dr.K.K.Krishnamurthi, former Director, United Planters' Association of Southern India (UPASI) Tea Research Institute, Valparai - 642 127, Coimbatore District, India and that it has not formed the basis for the award of any Degree / Diploma/Associateship/Fellowship or other similar title to any candidate of any university.

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(B.CHANDRA MOULI)



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CONTENT

CONTENTS

	PAGE NO.
1. INTRODUCTION	1
1.1. Review of literature	9
1.2. Scope of the present study	28
2. MATERIALS AND METHODS	31
2.1. Laboratory studies	31
2.2. Field studies	35
3. THE PATHOGEN	44
3.1. The disease cycle	44
3.2. Crop loss	46
3.3. Influence of climatic factors on disease	50
3.4. Physiology of basidiospore germination of the causal fungus	52
4. HOST TOLERANCE	53
4.1. Highly tolerant clones	53
4.2. Clones moderately tolerant	56
4.3. Clones least tolerant and susceptible	58
4.4. Studies on tolerance of blister blight in some clones selected by tea gardens	60

	PAGE NO.
5. DISEASE CONTROL IN TEA RECOVERING FROM PRUNING	62
5.1. Evaluation of agricultural antibiotics in combination with copper oxychloride	62
5.2. Evaluation of therapeutic inorganic fungicide formulations	69
5.3. Assessment of oil based copper formulations	71
5.4. Studies on the efficacy of organic fungicides	74
6. DISEASE CONTROL IN TEA UNDER PLUCKING	81
6.1. Performance of inorganic protectant fungicides	81
6.2. Antisporulant action of systemic fungicides	95
6.3. Systemic fungicides and mite pests	101
6.4. Studies on the interaction of dosage and spray interval	106
6.5. Studies on certain formulations of triazoles in disease control	111
6.6. Integrated application of protectant, therapeutant and systemic fungicides	124
6.7. Evaluation of Ultra Low Volume spraying equipment	129
6.8. Role of spray adjuvants in enhancing disease control	129

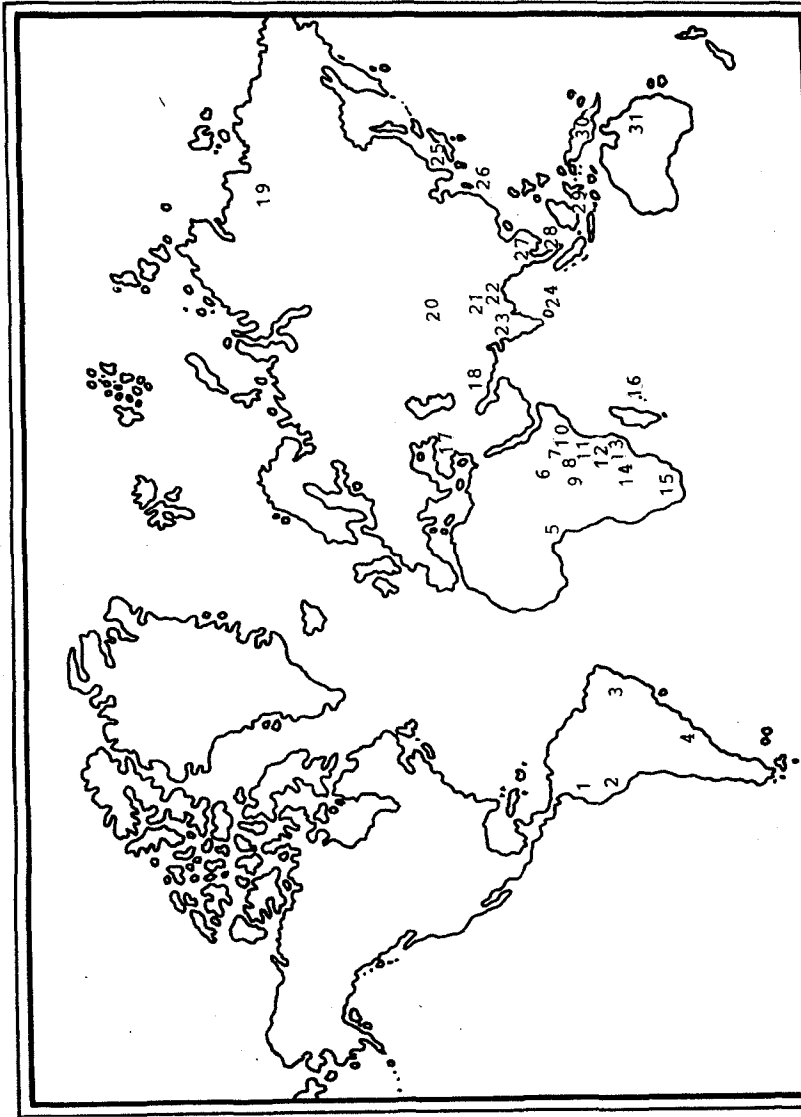
		PAGE NO.
7.	DISEASE CONTROL : EVALUATION OF ALTERNATIVE CHEMICALS	133
7.1.	Effect of dilute solutions of nitric, sulphuric and phosphoric acids on blister blight infection	133
7.2.	Role of acid water in arresting infection by <i>E. vexans</i>	134
7.3.	Studies on blister blight control with dilute nitric acid water sprays	137
7.4.	Effect of acid water sprays on quality during non-disease season	143
8.	8.1 Discussion	144
	8.2. Summary	156
	8.3. References	161

INTRODUCTION

Tea is one of the most important commercial crops, grown for its stimulating beverage, both for internal consumption and for the valuable foreign exchange it earns in many developing countries. Cultivation of tea as a beverage crop has been for so long that its home as a wild plant is a matter of speculation. The Chinese discovered that the infusion of the leaves of tea plant produced a very palatable drink. In the south-east China, tea has been used as a beverage for 2000 to 3000 years (Ukers, 1935). It is also very likely that the people in the Shan states of Burma and Siam had used the leaves of tea plant, initially for medicinal purposes, then as a beverage as early as the Chinese. Tea was mentioned in the Chinese dictionary in 350 B.C. and the first book on the preparation of tea leaf and manufacture was published by Lo-Yu in 780 A.D. (Willson and Clifford, 1992).

China continued to be the only supplier of tea until the eighth century when Buddhist priests brought it to Japan. From the seeds obtained from China, Japan began to cultivate tea from the 12th century. Tea as a beverage became known to Europe during the 16th century. Tea trade with China was started by Dutch around 1600 A.D. In 1793 a British delegation was sent to China to open up tea trade with the Chinese. Seeds from tea growing areas of China were procured and sown in the Botanical Garden, Calcutta.

Fig. 1. Tea growing areas in the world



Unfortunately, none of the plants raised from those seedling survived. The enthusiastic adventurers continued to make a relentless search to locate the wild tea plant in the north-east India, in the foot hills of the Himalayas. It was around 1823 that the Bruce brothers discovered the wild tea plant in Sadiya in Assam.

In India, commercial cultivation of tea was taken up first in Assam and later extended to Darjeeling and Cachar (Griffiths 1967).

In southern India a few tea plants were put out as a trial in 1832 by Dr.Christie, in the Nilgiris (Griffiths, 1967). Large coffee areas in the southern India had to be replaced due to the onslaught of leaf rust disease and as a sequel the first commercial tea cultivation appeared to have started around 1875.

At present, tea is grown in more than 30 countries, mostly in the continents of Asia and Africa (Fig. 1). In China the area under tea cultivation is around one million hectares (Chen and Chen 1989). However, India with an area of 400,000 hectares of tea is the major producer, consumer and exporter of this commodity. It is cultivated in Assam, West Bengal and Tripura in the north-east and Himachal Pradesh and Uttar Pradesh in north India (Fig. 2). In southern India this crop is grown in the states of Tamil Nadu, Kerala and Karnataka over an area of 82,000 hectares (Fig. 3).

Fig. 2. Tea growing areas in India

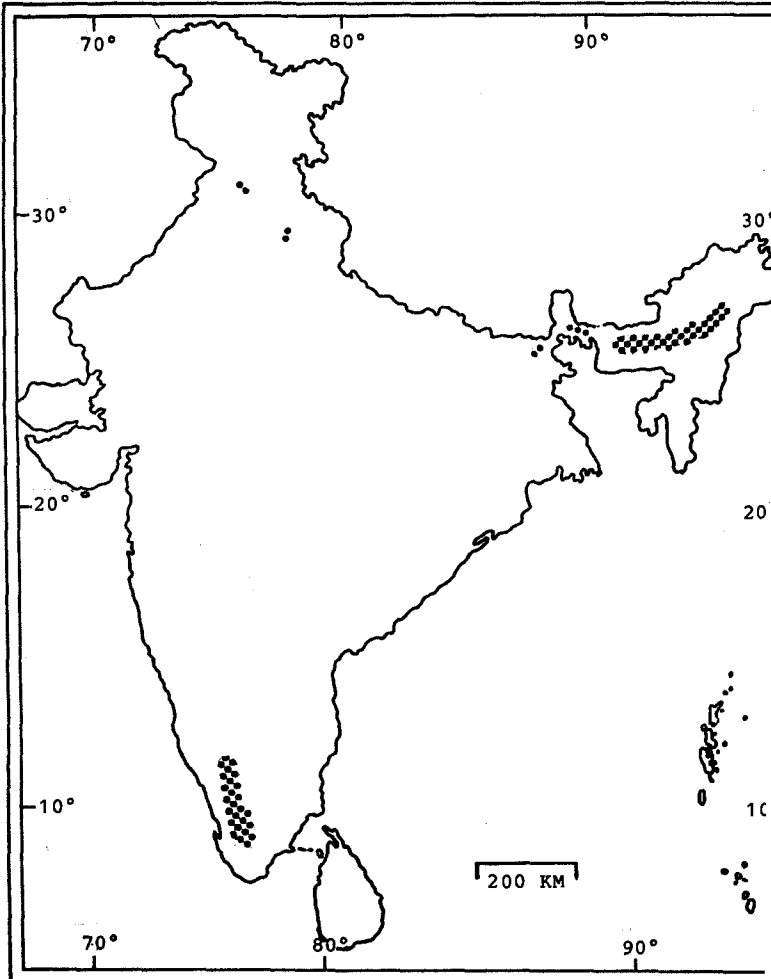
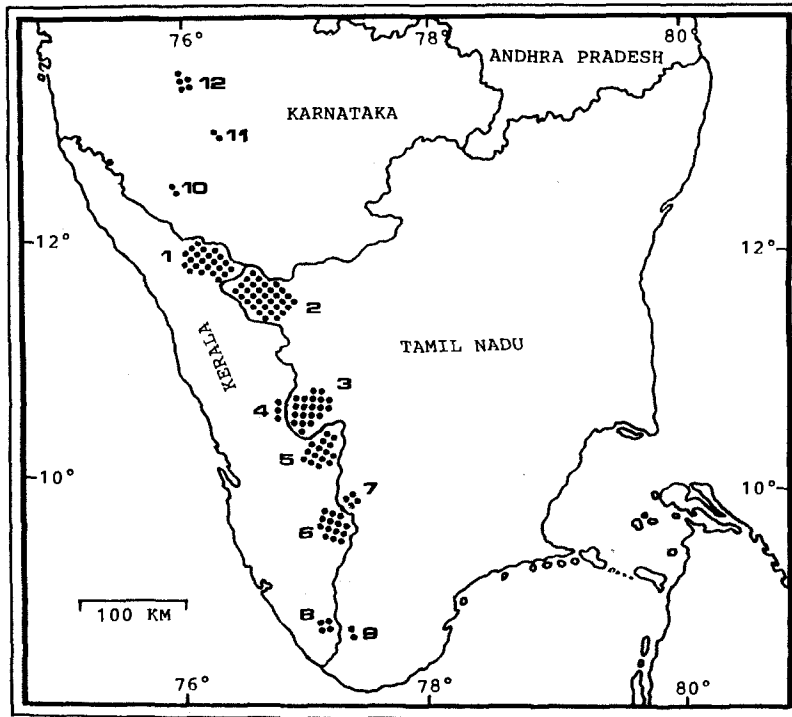


Fig. 3. Tea growing areas in southern India



- | | |
|---|-------------------------------------|
| 1. Wynaad (Wynaad Dist.) | 7. Madurai (Madurai Dist.) |
| 2. Nilgiris (Nilgiri Dist.) | 8. Trivandrum (Trivandrum Dist.) |
| 3. Anamallais (Coimbatore Dist.) | 9. Tirunelveli (Tirunelveli Dist.) |
| 4. Nelliampathy (Paighat Dist.) | 10. Coorg (Coorg Dist.) |
| 5. Munnar (Idukki Dist.) | 11. Hassan (Hassan Dist.) and |
| 6. Vandiperiyar and Peermade (Idukki Dist.) | 12. Chikmagalur (Chikmagalur Dist.) |

Tea is grown at latitudes ranging from 27°S (Corrientes in Argentina) to 43°N (Georgia, Russian Federation) and from sea level up to an altitude of 2300 meters. Tea soils vary widely from lateritic to volcanic; most of the tea soils are kaolinitic in nature (Ranganathan and Natesan, 1985).

Tea adapts itself well to acidic soils; the soil pH in tea growing areas ranges from 3.3 to 6.0 and in many instances it is below 5.0. To achieve the maximum utilization of applied fertilizers as also to meet the calcium requirements, liming is carried out; it also helps in maintaining an optimum pH between 4.5 and 5.0 (Ranganathan, 1978). Certain varieties can even tolerate pH up to 6.5.

Tea plant prefers a warm humid climate with well distributed rainfall and long sunshine days. Both tropical and temperate regions with an annual precipitation of 1150 to 8000 mm are suitable for tea cultivation. The plant can withstand fluctuations of air temperature between -8° and 35°C and day length of 9.4 to 15.0 hours (Ranganathan and Natesan, 1985). Tea cannot tolerate long durations of water logging and the soils should have proper drainage.

Tea plant belongs to the family Theaceae and all the cultivated plants belong to two distinct species, namely, the small leaved *Camellia sinensis* (L.) O. Kuntze and the large leaved *Camellia assamica*



FIG. 4. A VIEW OF A TEA FIELD
(EXPERIMENTAL FARM - UPASI T.R.I.)



FIG. 5. A VIEW OF A TEA BUSH WITH SHOOTS READY FOR PLUCKING

(Masters) Wight. The "Cambod" type, a subspecies of the latter, is termed *Camellia assamica* spp. *lasiocalyx* (Planchon ex Watt) Wight. Commercial tea populations (Figs. 4 and 5) belong to the above taxa or hybrids thereof or hybrids between them and closely allied species.

The planting material was only seed until four decades ago. Due to immense heterogeneity in the seedling populations, those seedling plants with high yield potential, overall quality and tolerance to pests and diseases were selected and vegetatively propagated. This process of clonal selection for plant improvement is a widely accepted practice, now. Notable among the released clones are 'Sundaram' (UPASI-3), 'Golconda' (UPASI-8), 'Athrey' (UPASI-9), 'Swarna' (UPASI-17) in southern India. Among them, 'Sundaram' a vigorous clone, is a natural triploid; taking a cue from this, attempts are being made to induce polyploidy in some of the clones with certain desirable traits, as triploids and tetraploids are reported to produce more dry matter than diploids (Singh et al., 1987).

Once planted in the field the plant is subjected to several cultural operations like 'training' by centering, pruning (Figs. 6 and 7) at regular intervals with varying severities and 'tipping' of the primary shoots emerging from the pruned frames.



FIG. 7. A PRUNED TEA BUSH



FIG. 6. A PRUNED TEA FIELD



FIG. 21. SPRAYING TEA UNDER PLUCKING WITH AN ORDINARY KNAPSACK SPRAYER

Tender shoots comprising two or three leaves and a bud form the harvest. The crop is plucked at nine to 14- day intervals, depending on the growth and the season. Severe droughts and harsh winters retard the growth, necessitating long plucking intervals. Apart from hand plucking, nowadays the shoots are also harvested by hand-held shears.

The product of commerce consists of black tea of various grades ranging from orange-pekoe to superfine dusts, green tea and semi-fermented Oolong tea.

Under agroclimatic conditions prevailing in southern India, the economic life span of a tea bush may extend over 100 years or more.

During this long life span, the tea bush is prone to many diseases some of which are capable of causing serious crop losses. Tea plants also suffer from nutritional deficiencies and at times are attacked even by phanerogamic parasitic plants.

Among the microorganisms that colonize and infect tea, fungi are the most important and greatly outnumber the other groups. A few bacterial diseases such as Witche's broom, leaf blight, twig canker are reported from Japan and a leaf spot of bacterial origin was reported from Georgia of the Russian Federation. So far, only

one virus disease, namely, "Phloem Necrosis", was described from Sri Lanka (Mulder, 1963) and possibly, in one region in India (Ray Chaudhuri, 1967). Among the parasitic green algae, mention may be made of *Cephaleuros parasiticus* Karst; which causes the red rust disease; it is seen mostly in the tea tracts of north-east India and is rather rare in southern India. Phanerogamic parasites such as *Loranthus* sp. (Sarmah, 1960) and *Cuscuta* sp. on tea are also recorded. Though not pathogenic, certain lichens colonize the trunks of tea bushes during the wet weather.

Agnihotrudu (1964) reported a total of 209 genera comprising 385 species of fungi, from all parts of the tea plant. The fungi included all major groups, namely, the Myxomycetes, Phycomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. A few more species were subsequently added (Rattan and Pawsey 1981, Chandra Mouli and Ravi Kumar, 1988). Among these, 82 genera are parasitic and the remaining are predominantly saprophytic occurring on various parts of the tea bush.

The diseases of tea plant are broadly classified into abiotic and biotic in nature. Abiotic factors that affect the health of tea bush are drought, sunscorch, hail damage, lightning, waterlogging, frost, toxicity caused by excess of inorganic fertilizers, drift of herbicide sprays and both macro and micro nutrient deficiencies.

The diseases caused by microorganisms are grouped into two, namely primary and secondary categories. In primary diseases, the causal organisms are capable of gaining direct entry into healthy tea bushes. The microorganisms involved in secondary diseases are weak parasites, invading the host only after the latter has been debilitated and predisposed. Many of the non-parasitic factors stated above can predispose the plant to invasion by secondary microorganisms.

All parts of tea bush are prone to attack by fungi. In southern India, primary root diseases caused by *Poria hypolateritia* Berk. (red root), *Fomes noxius* Corner (brown root), *Rosellinia arcuata* Petch (black root) are very common. *Armillaria mellea* Vahl., the incitant of root splitting disease, which was prevalent in earlier years is rather rare now. Similarly, attacks by *Xylaria* sp. the causal agent of *Xylaria* root disease are sporadic.

Primary root diseases are a legacy of jungles. The pathogens cited above are harboured by jungle trees on their roots. While clearing the jungles for planting tea, if the roots of the jungle trees harbouring the pathogens are left over, the diseases are transmitted to tea plants by root contact. Once the focus of infection is established, further spread takes place by root contact. In case of the black root disease, the fungus *Rosellinia arcuata* spreads on the soil surface over the organic debris and infects the collar portion of the tea plants. *Armillaria mellea* spreads by producing characteristic rhizomorphs.

Among the secondary maladies, violet root rot (*Sphaerostilbe repens* Berk. & Br.) and Diplodia root disease (*Botryodiplodia theobromae* Pat.) are caused when the tea bushes are predisposed by waterlogging and drought, respectively. Though considered as a primary parasite in north India, the charcoal stump rot pathogen (*Ustilina zonata* Lev.) under conditions in southern India is a weak parasite invading the roots of dead and moribund tea plants injured by lightning (Chandra Mouli and Venkata Ram, 1976).

Several stem diseases have been reported and many of the causal fungi invade either through wounds or when the bushes are debilitated. In southern India, wood-rot (*Hypoxylon serpens* (Pers. ex Fr.) Kickx var. *effusum* (Nitsch.) Miller; *Hypoxylon nummularium* Bull. ex Fr.), collar canker (*Phomopsis theae* Petch), branch canker (*Macrophoma theicola* Petch), and high elevation die-back (*Leptothyrium theae* Petch) are some of the important stem diseases. Thorny stem blight disease (*Tunstallia aculeata* Agni.) which was hitherto a minor problem has become a concern in certain areas.

In north-east India, red rust (*Cephaleuros parasiticus* Karst.), pink disease (*Corticium salmonicolor* Berk. & Br.) and branch canker (*Poria hypobrunnea* Petch) are frequently encountered. Thread blight (*Marasmius pulcher* Berk. & Br.), horse hair blight (*Marasmius equicrinus* Muller & Berk.), stump rot (*Irpex destruens* Petch) die-back (*Nectria cinnabarina* Tode ex Fr.) and velvet blight (*Septobasidium theae* Boed. & Stein.) are also occasionally reported.

Many foliar fungal pathogens have been reported on tea, but only a few of them pose a serious threat. Blister blight (*Exobasidium vexans* Masee) is a major leaf disease problem in southern India, Himachal Pradesh and Darjeeling. In north-east India, black rot (*Corticium theae* Bernard) and red rust (*Cephaleuros parasiticus* Karst.) also pose problems. Apart from these major maladies, certain minor leaf diseases, namely, leaf scab (*Elsinoe theae* Bitancourt & Jenkins), leaf spots (*Hendersonia theicola* Cooke, *Cercospora theae* Petch, *Septoria theae* Car.) reticular blight (*Exobasidium reticulatum* Ito & Sawada), grey blight (*Pestalotia theae* Sawada) and brown blight (*Colletotrichum camelliae* Masee) are also encountered occasionally.

Both *Pestalotia theae* and *Colletotrichum camelliae* are also known to cause die-back of the nursery cuttings (Venkata Ram, 1960a).

1.1. REVIEW OF LITERATURE

Our knowledge on tea diseases is derived from the works of Watt and Mann (1903), Petch (1923), Hainsworth (1952) and Butler (1918). Apart from these general treatises, many regional works are also available for north-east India (Tunstall, 1940; Tunstall and Sarmah, 1947; Sarmah, 1960, Sri Lanka (Gadd, 1949), East Africa (Goodchild, 1952; Hansford, 1943), Mauritius (Ramlogun, 1971) and Peoples' Republic of China (Tzong-Maochen and Shin-Funchen, 1982).

The Exobasidiales is a small order of basidial fungi parasitic on flowering plants mostly belonging to Ericaceae, Empetraceae, Theaceae, Lauraceae and so on (Savile, 1959). Apart from wild plants, the members of the order also attack ornamental plants like *Azalea* L., *Rhododendron* L. and species of *Camellia* L. Though MacNabb and Talbot (1973) recognized five genera, the most commonly encountered one is *Exobasidium*. A less known genus *Kordyana* Racib. is reported as a parasite on the plants belonging to Commelinaceae (Hawksworth et al., 1983).

1.1.1. Taxonomic position

The true taxonomic position of *Exobasidium* within the Basidiomycetes is uncertain. Burt (1915) included the genus in the Thelephoraceae. Many mycologists, today, place it in the family Exobasidiaceae. Several genera have, from time to time, been added (McNabb and Talbot, 1973); probably only *Kordyana*, parasitic on Commelinaceae should be included. The family may be placed in the Homobasidiomycetidae. Talbot (1954) included the genus in Holobasidiomycetes in which the basidiospores germinate by repetition.

Alexopoulos and Mims (1979) classified the genus as follows :

Division	:	Amastigomycota
Subdivision	:	Basidiomycotina

Class	:	Basidiomycetes
Subclass	:	Holobasidiomycetes
Group	:	Hymenomycetes
Order	:	Exobasidiales
Family	:	Exobasidiaceae
Genus	:	<i>Exobasidium</i>

Though the relationship of Exobasidiales with other fungal groups is still obscure, it is believed that there is a relationship between *Exobasidium* and the ascomycete, *Taphrina*. The similarities are striking and the possibility of parallel evolution leading to the similarity in morphology and physiology should not be disregarded (Alexopoulos and Mims, 1979).

1.1.2. Host relationship

The genus *Exobasidium* has a wide host range and each species is predominantly host specific. In north-east India seven species and in southern India five species are reported (Table 1).

The genus *Exobasidium* occurs on the members of Ericaceae, Theaceae, Lauraceae and Symplocaceae. According to Gibbs (1954) these families belong to the Hydrochloric acid/Methanol Positive series which is unique for them. According to Savile (1959), a number of species belonging to the genus *Exobasidium* are in fact



Table 1. Host range and distribution of *Exobasidium* in India

Species	Distribution
<i>Exobasidium assamense</i> Syd. & Butl.	on leaves of <i>Camellia drupifera</i> Dyer non Lour., Khasi Hills
<i>E. butleri</i> Syd.	on leaves of <i>Rhododendron arboreum</i> Sm. Kumaon Hills
<i>E. cinnamomi</i> Petch	on leaves of <i>Cinnamomum tamala</i> Nees. & Eberm., Himalayas
<i>E. indicum</i> Syd. & Butl.	on leaves of <i>Symplocos theaeifolia</i> Buch. Ham ex D. Don., Darjeeling
<i>E. pieridis</i> P. Henn.	on leaves of <i>Pieris ovalifolia</i> D. Don., Ranikhet, Darjeeling, Kalimpong
<i>E. rhododendri</i> Cram.	on leaves of <i>Rhododendron arboreum</i> Sm., India
<i>E. celtidis</i> Ramakr. T.S. & K.	on leaves of <i>Celtis tetrandra</i> Roxb., Ootacamund and Singampatti
<i>E. nilagiricum</i> Ramakr. T.S. & K.	on leaves of <i>Gordonia obtusa</i> Wall., Naduvattam and Coonoor

Species	Distribution
<i>E. triseptatum</i> Ramakr. T.S. & K.	on leaves and stems of <i>Vaccinium</i> <i>leschenaultii</i> Wight, Ootacamund
<i>E. vaccinii</i> (Fuckel) Woron.	on leaves and twigs of <i>Vaccinium</i> <i>neilgherrense</i> Wight Naduvattam, Coonoor Chinnakallar (Anamallais)
	on leaves of <i>Azalea indica</i> L., Ootacamund
<i>E. vexans</i> Massee	on leaves and tender stems of <i>Camellia</i> <i>sinensis</i> , <i>Camellia assamica</i> and their hybrids in Darjeeling, Assam, Himachal Pradesh, Tamil Nadu, Kerala and Karnataka

unrelated to it. They have been, since, segregated and assigned to new genera.

Savile (1959) classified the north American species of *Exobasidium* on the basis of basidiospore morphology and provided a key for their identification.

Agnihotrudu (1964) described six species of *Exobasidium* on various species of *Camellia* : *E. assamense* Sydow H. & P. & Butler, on *Camellia drupifera* Dyer non Lour. *E. camelliae* Shirai in the inflorescence (?) of *C. japonica* L., *E. camelliae* Shirai var *gracilis* Shirai on leaves of *C. sasanqua* Thunb., *E. nudum* (Shirai) Ito & Otani on leaves of *C. japonica* L., *E. reticulatum* Ito & Sawada and *E. vexans* Masee on leaves of *C. sinensis* (L.) O. Kuntze and *C. assamica* (Masters) Wight. and their hybrids.

E. vexans is, by far, the most important of all the species from the economic view point in tea in southern India and forms the subject matter of this thesis.

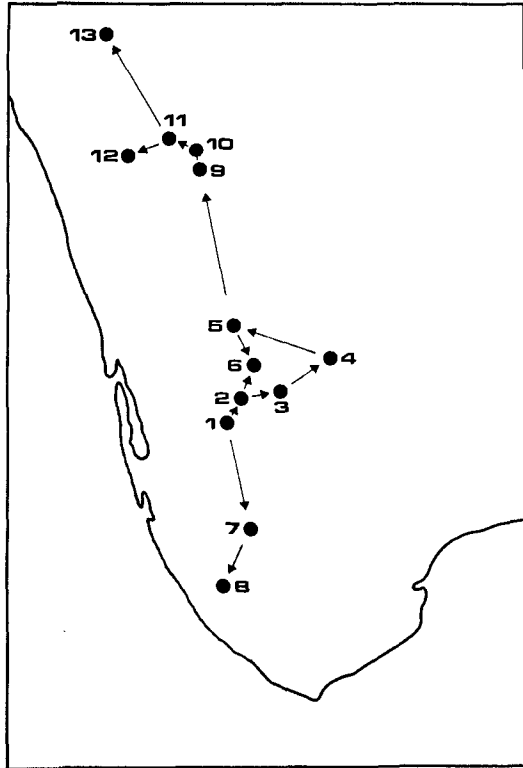
1.1.3. History

Peal (1868) was, perhaps, the first person to mention about the existence of the blister blight disease of tea in Assam. He was under the impression that the disease could be of fungal origin. Earlier, blister blight was believed to be caused by a bug; it was even thought that dew/rain drop when remained on tea leaf acted as a magnifying glass and scorched the leaf when sunlight fell on it and the scorched portion resulted in a blister! Balidon (1877) in his book on tea described blister blight as a serious disease and worse than the then feared mosquito blight.

The disease was next noticed in 1895 in Upper Assam and the causal fungus was identified by Masee (1898) as *Exobasidium vexans*. The disease caused widespread destruction in Upper Assam in 1906 and became the first epiphytotic reported on tea (Mann, 1906). It was confined to Assam until 1908; later it spread to all the tea gardens in Darjeeling where it caused enormous losses (McRae, 1910). The disease was reported in Japan and Formosa between 1912 and 1922 (de Weille, 1959a).

The disease was totally unheard of in southern India until 1946, but in August that year it was first reported in certain estates in Mundakayam area between 9 and 10°N and 77 and 78°E and subsequently, spread rapidly to Peermade of Kerala and Cumbum

Fig. 8. Origin and path of spread of blister blight disease in southern India (Subba Rao, 1946)



- | | |
|------------------|----------------|
| 1. Mundakayam | 8. Ponmudi |
| 2. Peermade | 9. Kotagiri |
| 3. Vandiperiyar | 10. Ootacamund |
| 4. Cumbum Valley | 11. Gudalur |
| 5. Anamallais | 12. Meppadi |
| 6. High Range | 13. Hassan |
| 7. Kalthuritty | |

valley in Tamil Nadu. In the Anamallais the disease made its appearance in September of the same year after covering a distance of approximately 95 km. Following closely the prevailing winds in an exceptionally wet and prolonged north-east monsoon that year the disease further spread to tea growing areas in Kerala (Subba Rao, 1946). In December 1946 and January 1947 the disease spread to Nilgiris and Wynad and in March 1947 it was noticed in Chikmagalur in Karnataka. Thus, within nine months the entire tea growing area in southern India was affected. Later, the disease took a firm hold in Sri Lanka (Tubbs, 1947) and Indonesia (Reitsma and Van Emden, 1950). The manner in which the disease spread in southern India is given in the Fig. 8.

1.1.4. Crop loss

The pathogen, *E. vexans*, infects only tender tea shoots that form the harvestable crop (Fig. 9). Apart from the tender leaves, the fungus is also capable of invading the tender stems. Hence, direct crop losses occur if the bushes are not adequately protected by fungicide sprays. Leaves that are severely affected produce tea of poor quality (Venkata Ram, 1964). When the stem is invaded the entire shoot withers and snaps at the point of infection. The leaves curl up when severely infected (Fig. 10).



FIG. 9. TENDER SHOOTS AFFECTED BY BLISTER BLIGHT



FIG. 10. SEVERELY INFECTED SHOOTS

Tea industry in southern India suffered enormous crop losses during the early years of the incursion of the disease, before control measures could be fully implemented (Subba Rao, 1946). Between 1948 and 1952 the annual loss was estimated to be about 18 million kilograms of tea (Venkata Ram, 1964). Loos (1954) reported a crop loss of 50 per cent over a period of three and a half years when compared to pre-blister blight period in Sri Lanka. Between 1951 and 1952, Indonesia lost approximately ten million kilograms (de Weille, 1959a).

1.1.5. The pathogen

The fungus *E. vexans* is an obligate parasite with no alternate host. Hence, its life cycle has to be completed on tea plant itself. Tea is a perennial plant and the susceptible tissue is present all round the year for completion of the fungal life cycle, concomittant with conditions favourable for infection. Survey has shown that active blisters are present throughout the dry period on tea plants growing in humid, sheltered pockets along water courses. Two races of the pathogen have been identified (Venkataramani, 1956).

Basidiospores of the fungus are dispersed by wind and insects, but infection is most commonly through air-borne spores. On lodging on the susceptible tea leaf surface, the basidiospores germinate and pierce the epidermis. Though the germ tube at times enters

the host through stomata, direct penetration mechanically is more common. The germ tube elongates rapidly and an appressorium is formed, adheres firmly to the leaf surface. A very fine infection thread emerges from underside of the appressorium and penetrates the host tissue (Gadd, 1949).

Reitsma and Van Emden (1949) classified the visible development of fungal life cycle, following penetration of the fungal spore, into seven stages. The occurrence of a translucent spot less than 0.5 mm in diameter, visible three days from fungal penetration is Stage-1; a light spot more than 0.5 mm and less than one mm in diameter is Stage-2; a spot of one to three mm in diameter is Stage-3; a spot that has developed into a well defined lesion of three to six mm in diameter is Stage-4; next when the lower surface of the lesion bulges in a convex shape due to the proliferation of fungal mycelium within the intercellular spaces of spongy parenchyma is Stage-5; the incipient stage of spore formation is Stage-6 and vigorous sporulation is Stage-7.

Sporulation may start ten to 12 days after infection has taken place and spore discharge could continue up to eight days. Loos (1951) calculated that 10,000 spores can lie on one square millimetre area without overlapping. According to Huysmans (1952) one ripe blister discharges two million spores in 24 hours. Studies carried out in southern India indicated that 1.39 million spores occur per one square centimetre (Venkata Ram and Chandra Mouli, 1976a).



FIG. 11. BLISTER LESIONS ON TEA LEAF WITH BASIDIOSPORES

The typical white, powdery or velvety blister blight lesion (Fig. 11) comprises innumerable compact bundles of hyphae constituting the hymenium. On maturity, these hyphae terminate into clavate basidia with generally two, rarely three, or even four sterigmata. The basidiospores which form at the end of the sterigmata are unicellular initially and when they are ripe a septum is formed; at this stage they are ready to be discharged. These two coiled basidiospores, which are still attached to the sterigmatum measure 14 to 17 μ long and 3.5 to 5.6 μ wide (de Welle, 1959a). According to Gadd and Loos (1948) measurements of similar spores lying on the surface of the blister had a length of 13 to 27 μ and 4.3 to 6.5 μ width.

1.1.6. Climatology and Epidemiology

High relative humidity, moderately low temperature and leaf wetness are essential for sporulation, discharge, germination and penetration (infection) of *E. vexans*.

A relative humidity (R.H.) of above 80 per cent in the atmosphere is required for spore formation and ejection (de Welle, 1959a; Huysmans, 1952; Laoh and Homburg, 1953; Reitsma and Van Emden, 1950). Shanmuganathan and Arulpragasam (1966) studied the diurnal periodicity of spore ejection and concluded that maximum spore liberation into the atmosphere occurs between midnight and

4.00 am and in this respect, *E. vexans* resembles many typical basidiomycetes showing similar nocturnal pattern of spore discharge. It is quite probable that high spore ejection in the night is due to high R.H. prevailing during that time, fitting in with the findings of de Welle (1959a).

De Welle (1959a) and Huymans (1952) observed that germination of the basidiospores occurred only at R.H. 97 per cent and above. However, Laoh and Homburg (1953) observed germination at 90 per cent R.H. Reitsma and Van Emden (1950) claimed that germination could occur on apparently dry slides if the R.H. was 80 per cent or more. In Sri Lanka, dew was found to be ideal for spore germination (Gadd and Loos, 1948; 1950). De Welle (1959a) laid down the following critical pre-requisites : a relative humidity of above 80 per cent for spore formation and ejection, above 90 per cent for germination but the rapidity increasing sharply above 97 per cent and for germ tube growth an R.H. of above 70 per cent.

Under the most favourable weather conditions, the time needed for germination, formation of the appressorium and penetration into the leaf is relatively short. Tubbs (1947) stated that the entry into the host is accomplished within 24 hours while Loos (1951) recorded this to take place within 16 hours.

An ambient temperature of about 25°C is conducive for the development of the disease. Temperature above 35°C had lethal effect on spore germination (Van der Knaap, 1955). Lesion formation was prevented and the fungus killed in situ when the tea plants were subjected to temperatures of 35°C and above after 48 hours following fungal infection (Venkata Ram, 1965).

Apart from relative humidity and temperature, leaf wetness plays a cardinal role in the incidence of the disease. In critical investigations it was found that no lesions developed when leaf wetness was below ten hours. At 11 hours of leaf wetness, a few lesions occurred and at 13 hours all the inoculated leaves were infected, indicating that 11 hours was the critical period of leaf wetness for blister infection to establish; 13 hours was found to be sufficient for a high level of infection to occur (Venkata Ram, 1979).

Diffused sunlight did not reduce the disease. Direct sunlight was found to be inversely proportional to the disease incidence. The pathogen completes its life cycle in a short span of 11 to 28 days and tea being a perennial tropical plant, abundant susceptible material is available throughout the disease season. This situation warrants fungicide protection at short intervals.

In order to economise, attempts were made to discontinue the protective fungicide treatment based on forecasting, during the period when the disease did not pose a threat. On the basis of the relationship existing between the relative humidity and spore formation, ejection and germination, Huysmans (1952) proposed a system of portending an epidemic whereby fungicide application could be suspended during the periods, when the 3-day average relative humidity remained below 83 per cent. On similar lines Homburg (1953) recommended cessation of fungicide application, when the daily relative humidity averaged less than 80 per cent over a five day period and resumption of treatment when the R.H. exceeded the figure in a period of three days.

The realisation that R.H. and sunshine are inversely related, prompted many investigators to employ sunshine data as a guide to forecast blister blight incidence. Interruption of fungicide was considered safe when average morning sunshine hours remained above the critical limit over a certain period. De Weille (1959a) recommended a three to four day spraying round and suspension of fungicide application when the sunshine valuation rate exceeded 40; on a seven day period, the values computed for sunshine on the 1st, 2nd, 3rd and 7th day and twice the value on the 4th, 5th and 6th day summed up gave the sun valuation rate.

Observing that any system involving indirect calculation was apt to be impractical to the growers, workers in Sri Lanka proposed the fungicide application to be postponed when the sunshine was at a minimum of 16 hours in four days preceding treatment on seven to eight day rounds and 20 hours in five days on nine to ten day rounds (Visser, Shanmuganathan and Mulder, 1959; Mulder and de Silva, 1960; Mulder, 1961). Later investigations in Sri Lanka, on epidemiology of blister blight clearly pointed to the importance of weather conditions in starting an epidemic, since sufficient number of spores occurred in the atmosphere all through the year (Kerr and Shanmuganathan 1966; Shanmuganathan and Arulpragasam, 1966).

However, weather conditions in southern India, during S.W. monsoon do not permit postponement of copper fungicide applications based on sunshine data (Venkata Ram, 1961) and the timing of fungicide application based on the Indonesian (de Welle, 1959a) and Sri Lankan systems (Mulder, 1961; Webster and Park, 1956) gave poor results (Venkata Ram, 1971).

1.1.7. Control

Although blister blight disease first affected tea severely in Assam and Darjeeling, more than 80 years ago, field scale protection against the disease became an economic possibility only in the last 40 years. May be, the epiphytotics were sporadic and suitable chemicals

were unavailable in the earlier years. With the advent of the disease as a regular epiphytotic in southern India, elaborate experiments were initiated to combat the disease.

1.1.7.1. CULTURAL OPERATIONS : Since the pathogen infects only tender leaf, efforts were directed to reduce the severity of the disease by adopting certain cultural practices such as hard plucking and early pruning. Eden (1947) demonstrated that hard plucking (fish leaf plucking) during two or three months in the year reduced blister blight and did no permanent harm to the bush. However, long term hard plucking resulted in progressive diminution of yield. Loos (1953) reported that as the cycle progressed, it became increasingly difficult to build up a new canopy of maintenance foliage on tea bushes rested after hard plucking. Production of new growth turned out to be very irregular, entailing extra protection for delayed growth. Although blister blight became scarce with hard plucking, this operation weakened the bushes considerably and the fields became 'wornout' with the passage of time, resulting in severe drop in yield; such enfeebled bushes became all the more susceptible to mite attack (de Welle, 1959b).

Pruning in hot dry weather was resorted to ensure the come back in a period when the disease presented no danger. Unfortunately pruning in dry weather exposed the bush frames, resulting in severe sun-scald damage, which developed into cankers. This was accentuated

by the removal of shade (Venkata Ram 1974). De Weille (1959b) suggested removal of shade trees in order to achieve maximum blister blight control. He argued that shade is favourable to the disease and that sunlight has a deleterious effect on spore germination. But under conditions in southern India, especially in the south-west monsoon, blister blight remained active whether there was shade or no shade. However, regulation of shade by pollarding the branches wherever necessary was useful to some extent (Venkatarmani, 1973).

1.1.7.2. CHEMICAL CONTROL : Elaborate and well laid out field investigations were initiated to evaluate various fungicides against the disease, in the year following the outbreak of the disease (Anon, 1948). Only a few fungicides were available in the earlier years. Hence, commencement of evaluation was made with copper formulations, chiefly cuprous oxide. The results of these first trials indicated that Perenox, applied at 10-day intervals gave 50 per cent increase in yield (Anon, 1949). Bordeaux mixture, cuprous oxide, copper oxychloride and mercuric compounds were all tried in 1951 (Anon, 1952). Mercuric compounds had to be dropped because of their toxicity (de Jong, 1954).

Evaluation of fungicides against blister blight was being simultaneously carried out by the Tea Research Institute of Sri Lanka, where the superiority of copper formulations, over the then available organic fungicides was initially established (Loos, 1949)



Similar observations were recorded in experiments in southern India (Anon, 1950). Results of evaluation of a further range of organic formulations in Sri Lanka (Loos, 1950; Pfaeltzer, 1951), southern India (de Jong, 1954) and Indonesia (Laoh, 1955; Van Heil and Veenstra, 1950) did not change the situation. Sulphur compounds imparted taint to tea and were not seriously considered. Colloidal copper formulations containing 15 per cent metallic copper were found to be as equally effective as copper oxychloride and cuprous oxide formulations (de Jong, 1954).

In subsequent trials, other formulations of colloidal copper both in southern India (Jayaraman and Venkataramani, 1957; Jayaraman and Venkata Ram, 1959) and elsewhere (Van der Knaap, 1956; Visser et al, 1958) gave good control indicating the possibility of application of these compounds to achieve economic control of the disease. However, the possibility of taint from these oil based formulations limited their application to control blister blight in fields recovering from pruning. Among the other copper formulations, fixed coppers containing 50 per cent metallic copper, either as cuprous oxide or copper oxychloride performed well; the former was superior to the latter (Venkata Ram, 1973; Venkata Ram and Chandra Mouli, 1981).

Many fungicides, both organic and inorganic, were evaluated in the first 15 years and were classified as good, intermediate and poor (Venkata Ram, 1964).

A major breakthrough in blister blight control was achieved with the introduction of nickel chloride, in 1960. Weekly application of nickel chloride reduced the infection from 84 to 24 per cent in the first three weeks and to 13 per cent after five weeks, whereas copper fungicide gave no such striking control (Venkata Ram, 1960b). Furthermore, it was also noticed that continual application of copper alone led to enormous build-up of mite pests in the dry weather (Venkata Ram, 1966b).

Of the various nickel salts tested, nickel chloride was found to be the best (Venkata Ram, 1962). A combination of nickel chloride and copper oxychloride was found to be superior to either of them sprayed alone (Venkata Ram, 1966a). This also greatly reduced the need to apply nickel chloride at higher dosage.

In Sri Lanka (Mulder, 1961) it was reported that nickel chloride either alone or in combination with zineb controlled blister blight satisfactorily. In trials carried out in 1964, de Silva (1965) observed that though nickel chloride offered satisfactory control it was not superior to Perenox. He admitted that both the south-west and north-east monsoons that years were mild with the consequent low levels of disease incidence; the experiments required to be repeated under severe wet weather conditions. Tzong-Maochen and Shin-Funchen (1982) from Peoples' Republic of China stated that nickel sulphate was useful in controlling blister blight. In Indonesia, *Pasaribu and*

Sinaga (1981) reported the usefulness of nickel chloride in checking the disease.

Organic fungicides with systemic action were also evaluated for blister blight control. Carboxin and oxycarboxin the two derivatives of 1, 4-oxathiins, though controlled the disease when tested on potted plants, failed to offer satisfactory control under field conditions (Venkata Ram, 1969). Pyracarbolid (Venkata Ram, 1975; Satyanarayana et al., 1975; Shanmuganathan and Saravanapavan, 1978) and tridemorph (Venkata Ram, 1974b) offered good control even on extended rounds of spraying.

1.2. SCOPE OF THE PRESENT STUDY

This thesis aims at bridging certain gaps in our knowledge on blister blight. Chemical control of the disease has been dealt in detail; the most economic and innovative treatments have been evolved for the benefit of the tea industry. The thesis has been divided into eight chapters.

Chapter 1	Introduction
1.1	Review of literature
1.2	Scope of the present study
Chapter 2	Materials And Methods

- Chapter 3 The Pathogen
- 3.1 The disease cycle
 - 3.2 Crop Loss
 - 3.3 Influence of climatic factors on disease
 - 3.4 Physiology of basidiospore germination of the causal fungus
- Chapter 4 Host Tolerance
- 4.1 Tolerance of vegetatively propagated tea clones (cultivars) to the disease
- Chapter 5 Disease Control : Tea Recovering From Pruning
- 5.1 Evaluation of agricultural antibiotics in combination with copper fungicides
 - 5.2 Evaluation of therapeutic formulations
 - 5.3 Studies on the efficacy of systemic fungicides
- Chapter 6 Disease Control : Tea Under Regular Plucking
- 6.1 Performance of protectant, contact and systemic fungicides
 - 6.2 Antisporulant action of systemic fungicides
 - 6.3 Acaricidal action of systemic fungicides
 - 6.4 Studies on the interaction of dosage and spray interval
 - 6.5 Evaluation of certain formulations of triazoles in disease control

- 6.6 Integrated application of protectant, eradicant and systemic fungicides
- 6.7 Evaluation of Ultra Low Volume spraying equipment
- 6.8 Role of adjuvants

Chapter 7 Disease Control : Evaluation of Alternative Chemicals

- 7.1 Effect of dilute acid sprays on disease incidence and quality

Chapter 8

- 8.1 Discussion
- 8.2 Summary
- 8.3 References

CHAPTER - 2

MATERIALS AND METHODS

MATERIALS AND METHODS

All the laboratory studies on the physiology and pathology of *E. vexans* were undertaken at the Division of Plant Pathology of the UPASI Tea Research Institute, located in the Anamallais, Coimbatore District, Tamil Nadu.

The field investigations were carried out in the Experimental Farm of the Tea Research Institute and disease-prone areas in the High Range and Wynaad, Kerala.

2.1. LABORATORY STUDIES

All the chemicals used for preparing solutions were of Analar grade and the glassware was of either Pyrex or Corning (Borosil) make. Metal distilled water was used for preparing solutions and glass distilled sterilized water for spore germination studies. The glassware was thoroughly cleaned with detergent in copious water after treatment with chromic acid.

2.1.1. Collection of tea shoots from the field

Tea shoots comprising three leaves and a bud having well developed disease lesions at the Stage-6 (Reitsma and Van Emden, 1949) were clipped from seedling tea bushes of large leaved Assam hybrid



FIG. 12. TEA SHOOTS IN PHIALS WITH SUCROSE SOLUTION



FIG. 13. COLLECTION OF BASIDIOSPORES (IN BEAKERS) FROM TEA SHOOTS KEPT IN MOISTENED BELL-JARS

and placed in a clean glass beaker containing a small quantity of distilled water. They were carefully brought to the laboratory.

2.1.2. Preparation of basidiospore inoculum

One per cent sucrose solution was prepared. The solution was poured to the brim in clean phials. The stem-end portion of tea shoots, having leaves with single lesions either on the third or second leaf, was dipped into the sucrose solution through a perforation made in the rubber cap (Fig. 12). A beaker of appropriate size (50 or 100 ml capacity) was chosen and the leaf of the tea shoot was placed on the mouth of the beaker with the convex disease lesion facing downwards into the beaker and given proper support to keep the leaf in position. The shoot was misted with water using an atomizer. The entire set-up was placed in a bell-jar (Fig. 13) which was thoroughly misted inside with water. The shoots were put in the sucrose solution in the evenings and the spores were collected in the beaker on the following mornings.

2.1.3. Inoculation of potted tea plants with *E. vexans*

Potted tea plants of the clone, TES-34 (Fig. 14) were used in all the experiments. This clone is highly susceptible to blister blight disease. Single nodal cuttings from the primary branches of the mother bushes of this clone were drawn and planted in polythene



FIG. 14. POTTED PLANTS OF TES-34 MAINTAINED FOR INOCULATION



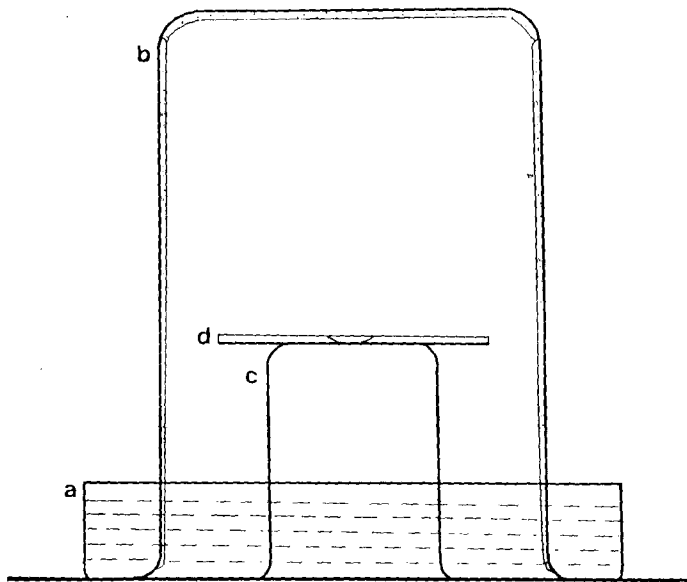
FIG. 15. INOCULATED POTTED PLANTS UNDER MOISTENED BELL-JARS

sleeves containing good soil. The cuttings were raised in the nursery following standard procedure (Sharma, 1976). After 12 months, they were transplanted into earthenware pots with 21 cm diameter at the top and 18 cm height. After the establishment the plants were manured with young tea fertilizer mixture (Ranganathan, 1987). A year after potting, the leader stem of the plants was cut and the primary frame was built up. Two to three years old potted tea plants were used for inoculation. The leaves marked out for inoculation were gently sprayed with an atomizer to form a thin film of water on the leaves.

Freshly harvested basidiospores were picked up from the beaker with a delicate (No. 0) camel hair painting brush and uniformly painted on the upper surface of the leaves. After deposition of the spores, the plants were placed in bell-jars (Fig. 15) which were thoroughly atomized with water in order to provide adequate moisture for the fungal spores to germinate and infect the inoculated leaves. The bell-jars were removed 48 hours later. The plants were routinely misted, during the day, with water for another 78 hours.

The following procedure was employed for studying the anti-sporulant action of systemic fungicides.

Fig. 16. Apparatus for spore germination



- a : Petri dish with water
- b : Beaker lined with blotting paper
- c : Small beaker
- d : Cavity slide

The lower pair of leaves was carefully painted with the appropriate concentration of the fungicide suspension and after a pre-determined time, the upper leaves were inoculated with the pathogen. When the lesions reached the Stage-6, beakers were placed under the leaves with the support of stands and the spores discharged over a period of 24 hours were directly trapped. The lesion area was measured and the spores, suspended in sterilized distilled water, were counted using a haemocytometer and quantified.

2.1.4. Spore germination bio-assay

A large petri dish (21 cm diameter) was filled with sterile water. A 100 ml beaker was placed upside down in the middle of this water filled petri dish. A cavity slide containing the basidiospores of *E. vexans* in appropriate test solution was placed on the beaker. This unit was covered by placing over it a 1000 ml beaker lined all over with a blotting paper (Fig. 16). The blotting paper absorbed the water and maintained a steady level of moisture inside the chamber.

Germination was quantified on per cent basis.

2.2. FIELD STUDIES

In southern India about 95 per cent of the tea area is planted with seedling tea. Hence, all the field experiments were carried out in seedling tea areas, comprising a predominant population of tea bushes of Assam hybrid type.

2.2.1. Meteorological studies

The weather parameters were measured by employing the following standard meteorological equipment.

- a. Sunshine : Campbell-Stokes Sunshine Recorder
Tropical Pattern (England).
- b. Temperature and Humidity : Lawrence and Mayo (India) Limited,
Lynx Thermohygrograph, fitted with
a weekly clock type mechanism.
- c. Rainfall : Lawrence and Mayo (India) Limited,
Non-recording rain gauge.

2.2.2. Randomization of experimental plots

Identical, number of pieces of paper were prepared. They were divided into five number of groups and each group with number

of pieces. Each piece of the same group was labelled with a letter that corresponded to a treatment. The paper bits were uniformly folded and mixed thoroughly. One piece was drawn each time without replacement and mixing well after each draw.

The treatments were assigned to plots based on the letter drawn.

2.2.3. Period of study

In southern India, almost all tea growing areas, excepting the Nilgiris, experience the two monsoon seasons. The south-west monsoon generally sets in in June and tapers off usually by the middle of September. The onset of north-east monsoon is around the middle of October and may extend sometimes up to January.

Field experiments, unless otherwise stated, were initiated in June and continued till the middle of December, covering the south-west and north-east monsoon seasons.

2.2.4. Method of spraying

Three types of spraying equipment were used in the experiments.



FIG. 17. PUMPING OF FUNGICIDE FLUID INTO A PRESSURE
RETAINING KNAPSACK SPRAYER WITH A CHARGE
PUMP

The fungicides were applied in the experimental plots either through knapsack sprayers or air-blast spraying machines (mist blowers). The knapsack sprayers employed were of two types : pressure retaining knapsack sprayers and ordinary knapsack sprayers.

2.2.4.1. PRESSURE RETAINING KNAPSACK SPRAYER : The sprayer worked as a compressed air sprayer and the spray fluid was pumped inside the container by a separate charge pump. The sprayer comprised a cylindrical tank.

Initially, an air pressure of 2.5 kg/cm^2 was developed in the tank with a charge pump. After developing the initial air pressure, the suction hose with strainer was placed in the fungicide fluid. Once the entire fluid was pumped in (Fig. 17), the sprayer was disconnected from the charge pump.

A low volume cone-mist nozzle was fitted to the sprayer. In tea recovering (Fig. 18) from pruning a spray volume of 250 litres per hectare was used. Whereas, in tea under regular plucking (Fig. 19) 175 litres of spray fluid per hectare was employed. A single row of tea bushes on either side was thoroughly covered.

2.2.4.2. LEVER OPERATED KNAPSACK SPRAYER : The ordinary knapsack sprayer consisted of a rectangular body assembly. The pump was operated by a lever. The fungicide fluid filled in the



FIG. 18. SPRAYING PRUNED TEA WITH A PRESSURE RETAINING KNAPSACK SPRAYER

tank was sprayed by operating the lever at frequent intervals. The fungicide spray fluid was discharged at 2.7 kg/cm^2 and the spray volume was the same as mentioned above for pressure retaining knapsack sprayers. The sprayer was fitted either with an NMD nozzle or single duro mist nozzle which delivered a fine mist. One row of tea bushes was sprayed on either side (Figs. 20 and 21).

2.2.4.3. AIR-BLAST SPRAYING MACHINE (MIST BLOWER) : The sprayers were operated by engines fuelled with a combination of petrol and oil. The spray was blown by means of an air current generated by a fan in the machine. The fan delivered 7.82 m^3 of air per minute (5350 RPM) at a velocity of 210.98 km per hour at the nozzle. The spray fluid was blown through nozzle no. 2, which discharged 60 litres of spray fluid per hour.

In tea recovering from pruning a spray volume of 70 litres per hectare was used and two rows of tea bushes on either side were sprayed covering bush frames thoroughly (Fig. 22).

In tea under plucking, only the top hamper was sprayed using 45 litres of spray fluid per hectare. In all, seven rows of tea bushes, five with and two rows against wind direction were sprayed in a single swath (Fig. 23).



FIG. 19. SPRAYING TEA FIELD UNDER PLUCKING WITH A
PRESSURE RETAINING KNAPSACK SPRAYER



FIG. 20. SPRAYING PRUNED TEA WITH AN ORDINARY KNAPSACK SPRAYER



FIG. 22. SPRAYING PRUNED TEA WITH AN AIR BLAST SPRAYER (MIST BLOWER)



FIG. 23. SPRAYING TEA UNDER PLUCKING WITH AN AIR BLAST SPRAYER

2.2.4.4. EVALUATION OF ULTRA-LOW VOLUME MICRON SPRAYER :
Two sprayers, Micron ULVA-8 and Micron-Herbi were evaluated. The principle of these sprayers was based on the controlled droplet application, a method designed to deliver uniform sized droplets for effective control. The spray volume required by these sprayers was very low.

Micron Herbi had an 8.0 cm diameter disc which was flat in the centre and with a 1.2 mm wide flange around the edge angled at 60°, on the outside of which were 360 grooves to the peripheral teeth. The flow rate was regulated by appropriate (No. 4) restrictor. One litre plastic bottle used as a reservoir for the spray fluid was screwed directly into the restrictor. The sprayer was powered by using 12, 1.5 volt, leak-proof battery cells. A specific ULV copper formulation at 4.5 litres per hectare was initially used. Once this formulation exhausted, wettable powder of copper oxychloride suspended in five litres of water was used per hectare. Two rows of tea bushes on either side were sprayed.

With Micron ULVA-8 a spray volume of 11 litres per hectare was used. The diameter of the disc was 5.5 cm, and was cup-shaped to provide droplets of about 100 μ m. The sprayer was operated with 1.5 volt, dry battery cells; two rows of tea bushes were covered on either side. A wettable powder formulation of copper oxychloride was suspended in water and used for evaluation.

2.2.4.5. **HAND ATOMIZER** : For very small plots in the field, a hand atomizer comprising a long spray lance fitted with Bray 000 nozzle which delivered a fine mist was used. The spray volume was adjusted to 175 litres per hectare and a single row of tea bushes was sprayed thoroughly on either side.

2.3. DISEASE ASSESSMENT AND QUANTIFICATION

Different methods were undertaken to quantify the infection level in the experimental blocks.

2.3.1. Disease assessment in tea recovering from pruning

Blister blight infection was assessed in the plots by examining each bush individually for disease incidence. Each bush was given a score in zero to four rating scale on the following severity 0 = no infection; 1 = mild infection; 2 = moderate infection; 3 = severe infection and 4 = very severe infection. The infection data, thus obtained, were pooled and the average infection worked out and analysed statistically.

2.3.2. Disease assessment in tea under plucking

From the harvest of each replicable 100 shoots were picked at random. Each shoot was examined individually for the incidence

of blister blight disease and the infection was quantified on per cent basis. The figures were converted into arc sine angular transformation values and the data analysed statistically.

Assessment of infection was commenced after the third fungicide application and continued thereafter at regular intervals of seven days till the completion of the experiment.

2.3.3. Assessment of infection in clones

Two hundred tea bushes in each clone were marked in a field. These bushes were left as such without any fungicide protection and exposed to natural infection throughout the season. Five hundred shoots were drawn at random from the harvest of each clone and examined individually for blister blight infection at seven day intervals, throughout the tenure of the experiment. The data were quantified as per cent infection.

2.4. PREPARATION OF BLACK TEA SAMPLES FOR ORGANOLEPTIC EVALUATION

Tea leaves harvested from the treatments were processed into black tea by CTC (crush, tear and curl) process in the miniature manufacturing unit. After manufacture, crude fibre from the samples was removed and the cleaned samples were sent to professional

tasters in Cochin for their comments on taint and organoleptic evaluation.

2.5. ESTIMATION OF MITES ON TEA LEAVES

As the fungicides sprayed during the blister blight season were found to influence the build up of mite populations in the ensuing dry season, mite population was assessed in the experimental plots after the fungicide treatments were consod. This was done by collecting ten leaves from each replicate, approximately 15 cm below the plucking table in each plot. Both pink (*Acaphylla theae* Watt) and purple (*Calacarus carinatus* Green) mites were counted under an Olympus binocular dissecting microscope. The number of mites in ten microscopic fields, five each, on either side of mid-rib in each leaf were counted.

2.6. STATISTICAL ANALYSIS

The data obtained in all the experiments were subjected to various statistical procedures to identify the significant treatments.

2.6.1. Analysis of variance

The per cent of infection levels were transformed into arc sine values and the analysis of variance was carried out (Gomez and

Gomez, 1984). The least significant difference (LSD) was worked out at five per cent level.

2.6.2. Chi-square analysis

The dependence of the spray interval and per cent infection and fungicide dosage on each other was estimated by Chi-square test of independence (Sukhatme and Amble, 1985).

2.6.3. Regression Analysis

Regression analysis (Gomez and Gomez, 1984) was adopted to study the relationship of the environmental factors on the disease, per cent infection and crop loss, fungicide spray interval and crop yield. The data were rechecked on Crompton Greaves personal computer.

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CHAPTER - 3

THE PATHOGEN

THE PATHOGEN

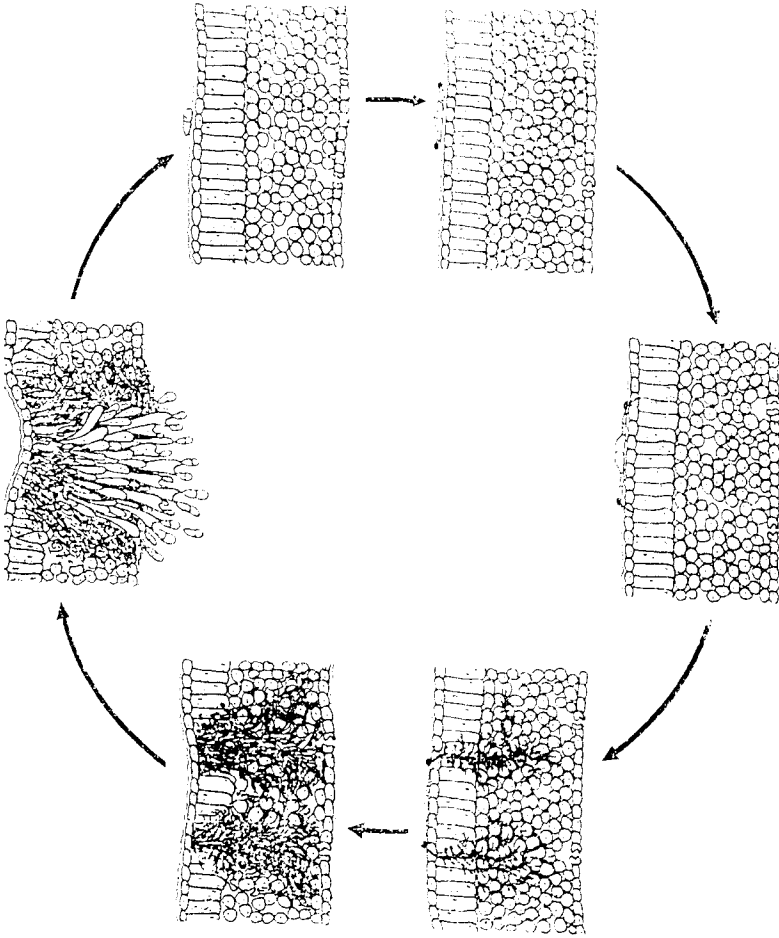
Exobasidium vexans is an obligate pathogen and it can complete its life cycle within a short period, which may range from 11 to 28 days depending on weather conditions.

The life cycle of the fungus, following the deposition of the basidiospore on a susceptible tea leaf under ideal climatic conditions, is shown in Fig. 24.

3.1. THE DISEASE CYCLE

The spores following deposition germinate and the germ tube pierces the epidermis; the germ tube can also enter through stomata but infection by direct penetration is a common phenomenon. The germ tube elongates and the appressoria formed adhere firmly to the surface. Fine infection threads emerge from underside of the appressoria and penetrate the host tissue. The branching of the infection thread (hyphae) begins in the palisade tissue situated under the upper epidermis. After passing through the palisade layer, the branching in the mesophyll tissue is intercellular. The fungus draws its nutrition from the host cells by producing haustoria.

As a consequence of intense parasitism, the invaded cells disintegrate and in course of time become discoloured. The



disintegration of cells and proliferation of the fungal hyphae in the intercellular spaces results in enlargement of the invaded tissue and this enlargement makes the lower surface of the leaf to bulge and form a typical convex 'blister' lesion.

The hyphae on the underside, between the parenchyma cells, form compact bundles which are future basidia. They are directed perpendicularly towards the lower leaf surface. Thus, elevations are formed, containing fertile basidia. The lower epidermis, bulges further and further and ruptures due to pressure exerted by the growth of the pathogen. The exposed tufts of hyphae mature and terminate into clavate basidia. These clavate basidia generally produce two sterigmata which terminate into basidiospores.

The duration of the life cycle can be summarized as follows

- a. from sporulation to germination : 2 hours to 5 days
- b. from germination to infection : 2 to 9 days
- c. from infection to formation of : 3 to 10 days
a translucent spot (Stage-1)
- d. from Stage-1 to Stage-6 : 6 to 9 days

The entire life-cycle, thus, is completed in 11 to 28 days.

3.2. CROP LOSS

Since the pathogen *E. vexans* completes its life cycle in a short span of 11 to 28 days, fungicide protection, with protectant-therapeutant fungicides, at short intervals, is imperative to prevent serious crop loss.

A four year study was carried out to investigate blister blight infection at different spray intervals ranging from three to 13 days. Crop yield at these spray intervals was also recorded. The influence of spray interval on infection and yield was worked out.

3.2.1. Crop loss in the first year

A seedling block, uniformly prone to blister blight was selected for study. The bushes were pruned at 70 cm height during the second fortnight of May. Spray applications were put out with a pressure retaining knapsack sprayer. The spray volume was 250 litres per hectare from pruning till tipping. After tipping, the plots were covered with 175 litres per hectare. Tipping was done in August. Just before tipping the bushes in the plots were examined individually and the impact of treatments on infection is presented in Table 2. The infection, thereafter, was assessed at regular weekly intervals till the experiment was terminated. The details of yield pertain to the three month period, from the end of August to the end of November.

Table 2. Spray interval vs blister blight infection : tea recovering
 from pruning

Treatment : Copper oxychloride + Nickel chloride - 210 g each/ha

Spray interval days		Disease index
3		1.2
5		1.7
7		1.9
9		2.4
11		2.6
13		2.8
Control	Unprotected	3.3
LSD (P = 0.05)		0.4

Fig. 25. Linear regression graphs of blister blight infection on the fungicide spray interval (top) and crop yield on the infection (bottom) in the first year of pruning cycle

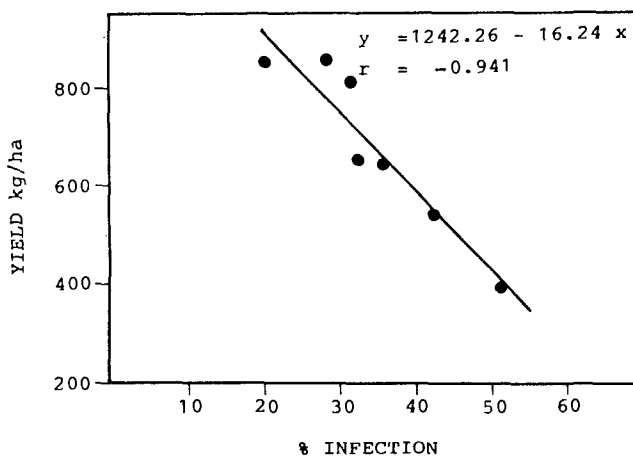
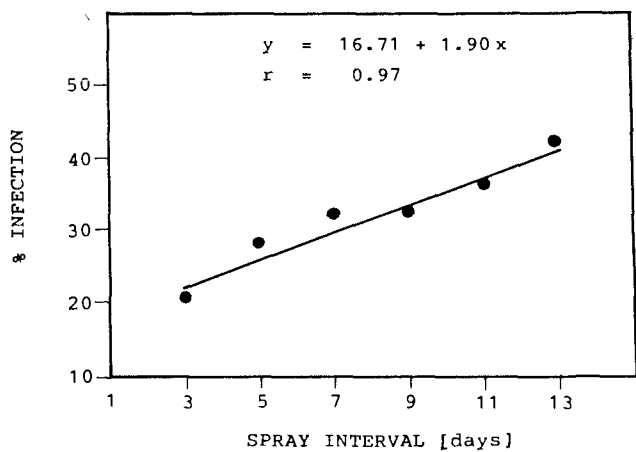
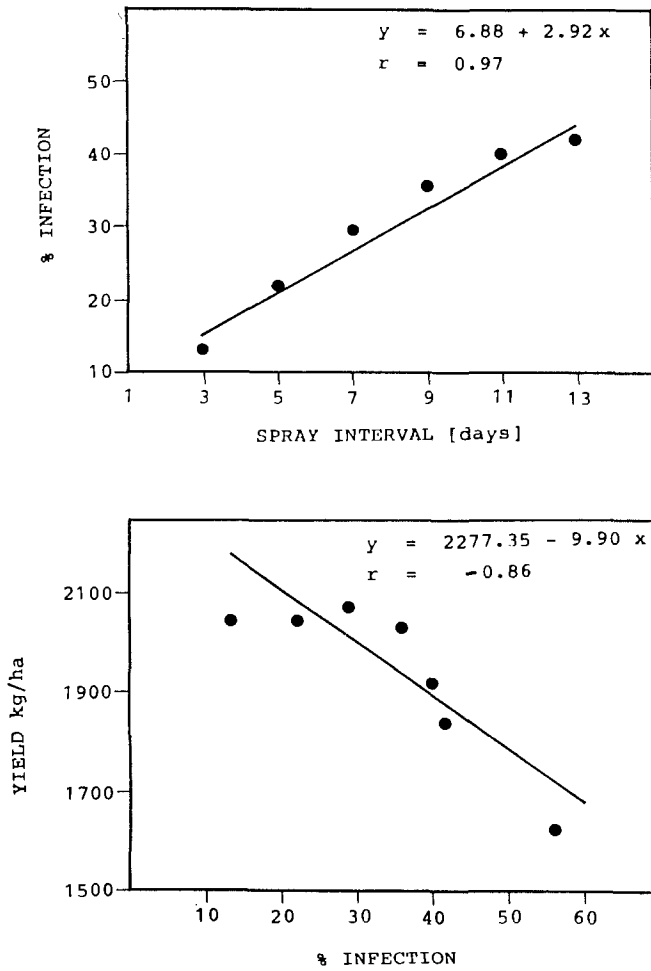


Fig. 26. Linear regression graphs of blister blight infection on the fungicide spray interval (top) and crop yield on the infection (bottom) in the second year

II YEAR



Spray interval had a pronounced effect on the disease incidence. Spraying at three-day intervals, resulted in a very low incidence of the disease (Table 2), which was significantly lower than all the other treatments. There was no significant difference between five- and seven-day, and nine- and eleven-day treatments. Infection became severe as the spray interval was increased. Plots sprayed at three-day interval manifested mild symptoms of nickel phytotoxicity.

A strong positive correlation ($r = 0.970$) existed between the spray interval and disease incidence. Disease incidence increased as the spray interval increased (Fig. 25).

As the infection increased the yield declined sharply. There was a strong negative correlation ($r = -0.941$) between the per cent infection and yield. Drop in the yield was considerable when the infection level exceeded 36 per cent.

3.2.2. Crop loss in the second year

Infection increased when the interval between the sprays was increased and there was a strong positive correlation ($r = 0.978$) between these two variables (Fig. 26).

Spray interval had a pronounced effect on the disease incidence. Spraying at three-day intervals, resulted in a very low incidence of the disease (Table 2), which was significantly lower than all the other treatments. There was no significant difference between five- and seven-day, and nine- and eleven-day treatments. Infection became severe as the spray interval was increased. Plots sprayed at three-day interval manifested mild symptoms of nickel phytotoxicity.

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3.2.2. Crop loss in the second year

Infection increased when the interval between the sprays was increased and there was a strong positive correlation ($r = 0.978$) between these two variables (Fig. 26).

Fig. 27. Linear regression graphs of blister blight infection on the fungicide spray interval (top) and crop yield on the infection (bottom) in the third year

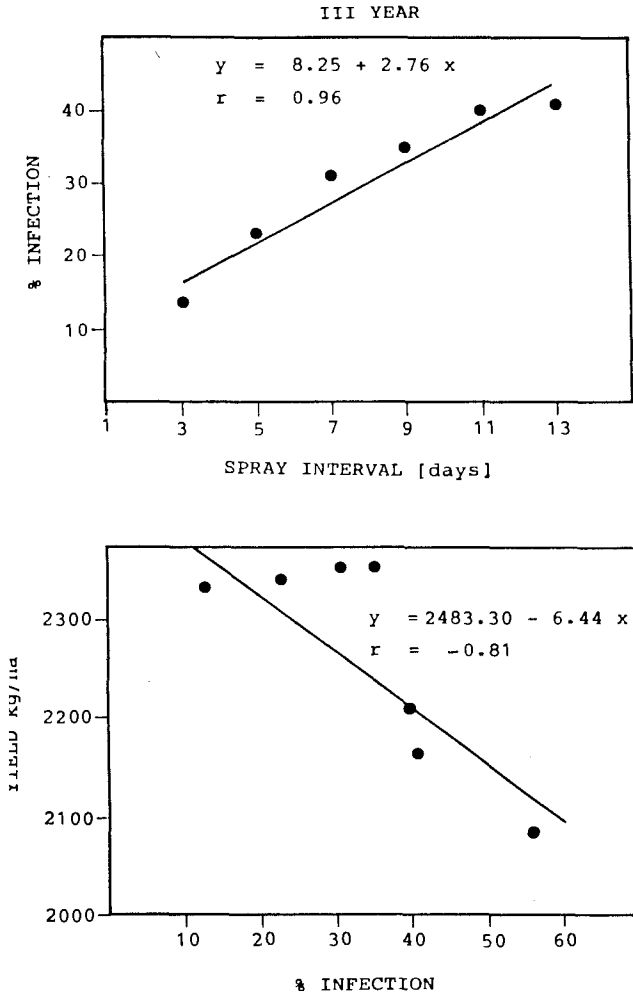
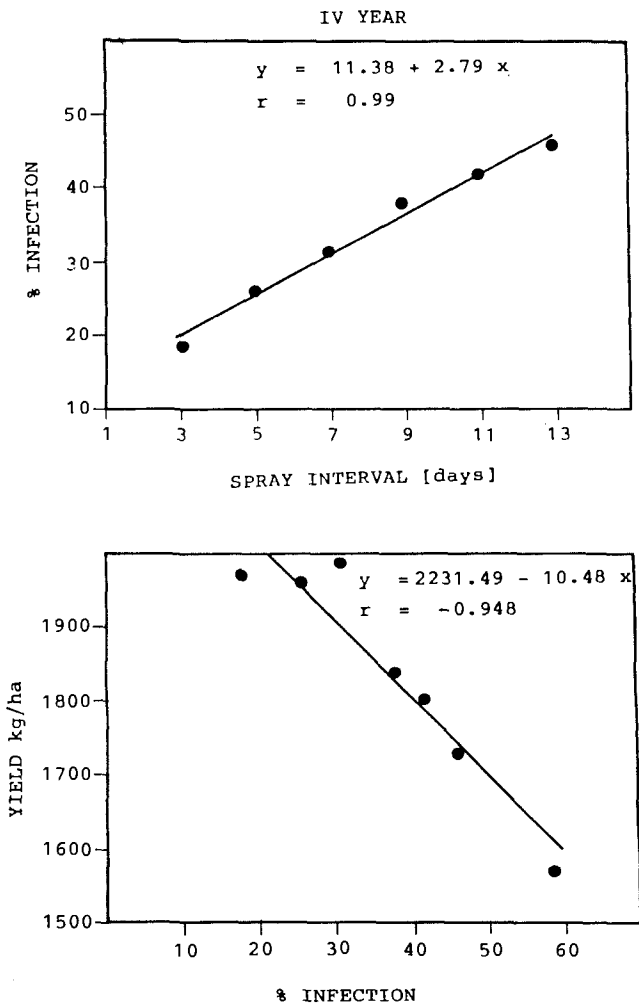


Fig. 28. Linear regression graphs of blister blight infection on the fungicide spray interval (top) and crop yield on the infection (bottom) in the fourth year



A negative correlation ($r = -0.862$) existed between the per cent infection and yield. The drop in yield was considerable beyond 35.5 per cent infection level.

3.2.3. Crop loss in the third year

A strong positive correlation ($r = 0.963$) existed between the spray interval and infection. When the spray interval was extended, disease incidence increased (Fig. 27).

There was a decline in yield with the increase in infection and a negative correlation existed between them ($r = -0.815$). There was sudden drop in yield once the per cent infection crossed 35 per cent.

3.2.4. Crop loss in the fourth year

Almost perfect positive correlation ($r = 0.992$) existed between the spray interval and disease incidence; the latter increasing with the extension of spray interval (Fig. 28).

A strong negative correlation existed between per cent infection and yield ($r = -0.948$), with the yield decreasing with the increase in infection levels. Yield declined sharply once the infection level exceeded 31.4 per cent.

Fig. 29. Linear regression graph of blister blight infection on sunshine period (hours)

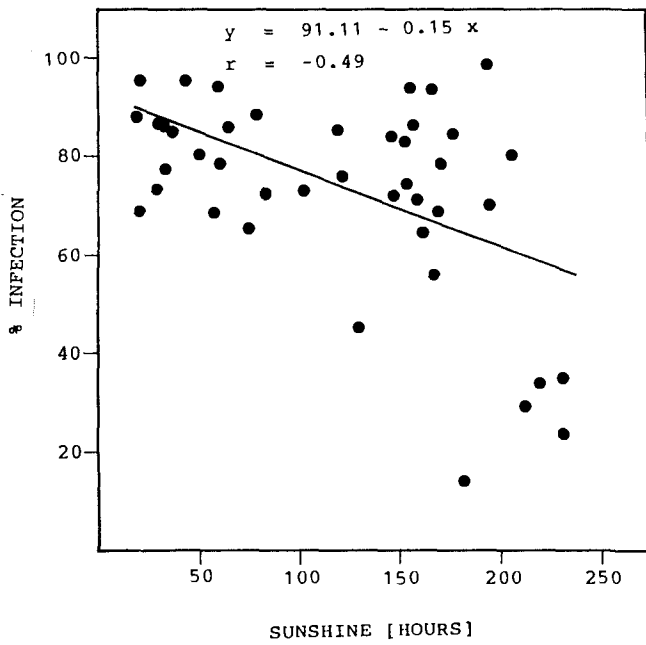
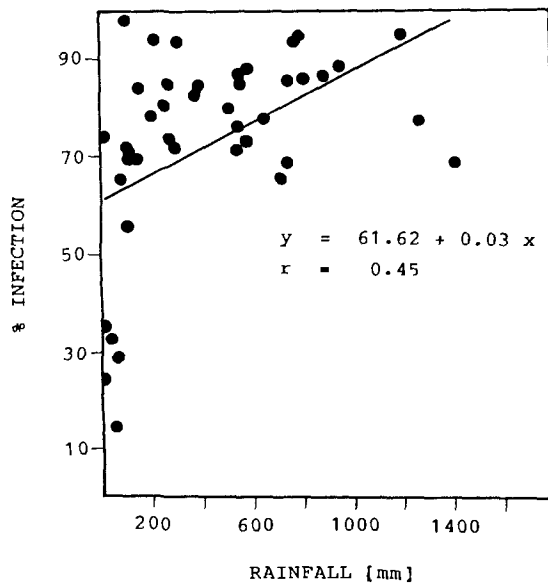


Fig. 30. Linear regression graph of blister blight infection on rainfall (mm)



3.3. INFLUENCE OF CLIMATIC FACTORS ON DISEASE

A study was carried out for six years, during the disease season (June to December), to assess various climatic factors, such as, sunshine, rainfall, temperature and relative humidity on blister blight incidence.

3.3.1. Effect of sunshine on blister blight

There was a mild but highly significant negative correlation ($r = - 0.494$, $F = 12.51^{**}$) between the sunshine hours and disease incidence (Fig. 29). This indicated that increase in sunshine reduced the intensity of the disease. Infection ranged from 70 to 95 per cent when the total monthly sunshine hours were 75 and below. However, disease incidence was also high (55 to 95 per cent) when the monthly sunshine hours were between 150 to 200. Infection declined when the sunshine hours exceeded 200 hours. The data pointed out that the factor of sunshine hours was not the sole criterion in deciding the severity of the disease.

3.3.2. Effect of rainfall on blister blight

There was a mild positive, but highly significant, correlation (Fig. 30) between rainfall and blister infection ($r = 0.459$, $F = 10.30^{**}$). The infection generally increased with the increase in rainfall from

Fig. 31. Linear regression graph of blister blight infection on minimum temperature (°C)

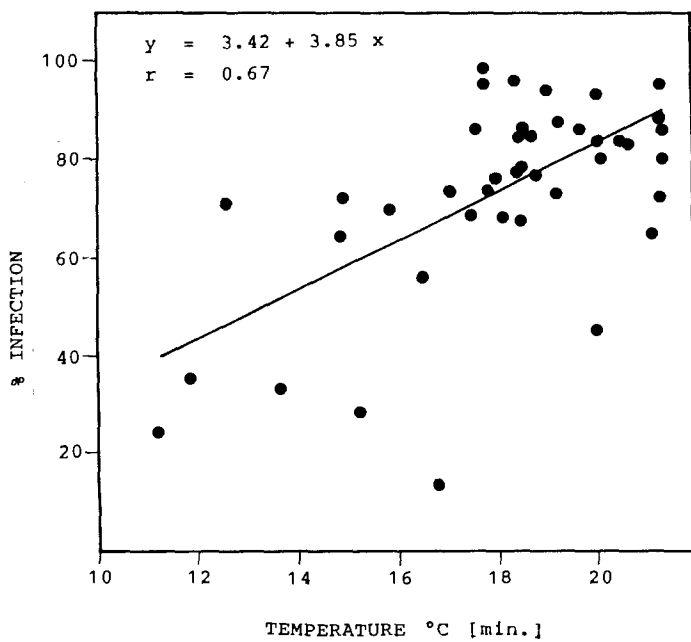
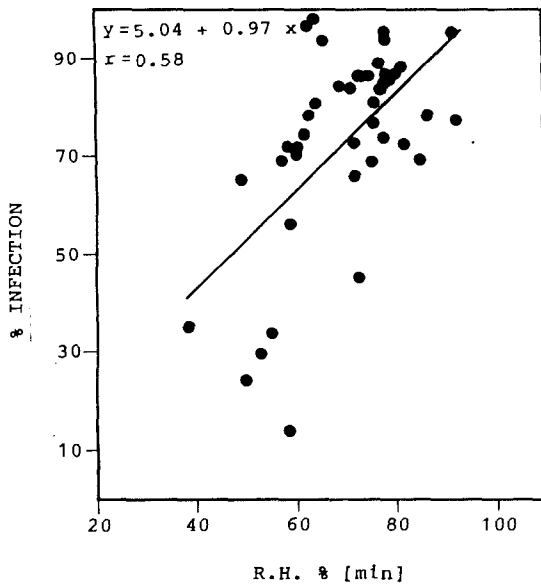


Fig. 32. Linear regression graph of blister blight infection on the minimum relative humidity (R.H.%)



200 to 1000 mm. Infection was between 15 and 35 per cent when the monthly rainfall was below 200 mm. Beyond 1000 mm there was no correlation between severity of infection and rainfall.

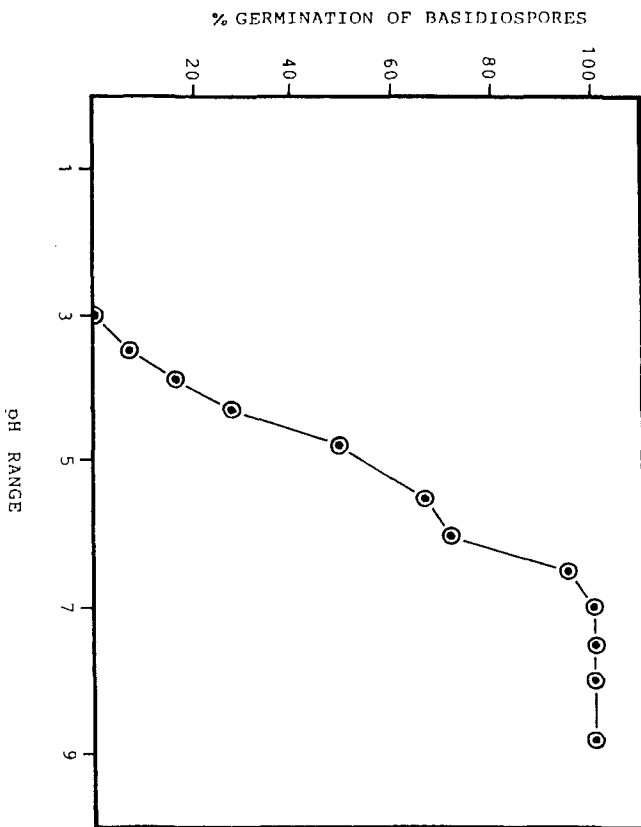
3.3.3. Impact of temperature on blister blight infection

During the monsoon, the mean minimum temperature (mean of six years) was, June : 19.7°C; July : 19.3°C; August : 19.5°C; September: 18.9°C; October : 18.5°C; November : 16.3°C and December : 14.4°C. There was a highly significant ($F = 24.62^{**}$) and positive correlation ($r = 0.67$) between the minimum temperature and disease incidence. Disease levels were high between 17.5°C and 21.0°C (Fig. 31).

3.3.4. Effect of minimum relative humidity (R.H.) on infection

The impact of the mean minimum relative humidity (R.H.) on blister blight incidence was investigated. There was a highly significant ($F = 21.49^{**}$) and positive correlation ($r = 0.58$) between the mean minimum R.H. and infection. Increase in the R.H. resulted in increased disease incidence (Fig. 32). Maximum infection was observed between a mean minimum R.H. of 75 to 85 per cent. The mean maximum R.H. in the period of study ranged between 95 and 100 per cent.

Fig. 33. Effect of pH on the basidiospore germination of *Exobasidium vexans*



3.4. PHYSIOLOGY OF THE BASIDIOSPORE GERMINATION OF THE CAUSAL FUNGUS

The effect of pH on the basidiospore germination was studied. Basidiospores were placed in 0.5% glucose solutions at various pH regimes ranging from 3.0 to 9.0. Nitric acid was used to prepare acidic solutions, while 0.1 N sodium hydroxide for alkaline solutions. Germination was observed 24 hours after treatment.

Spore germination was 100 per cent at pH 7.0, 7.5, 8.0 and 8.8 and declined sharply at lower pH of the solutions (Fig. 33). Germination was markedly reduced at pH 3.5 and was nil at 3.0.

CHAPTER - 4

HOST TOLERANCE

HOST TOLERANCE

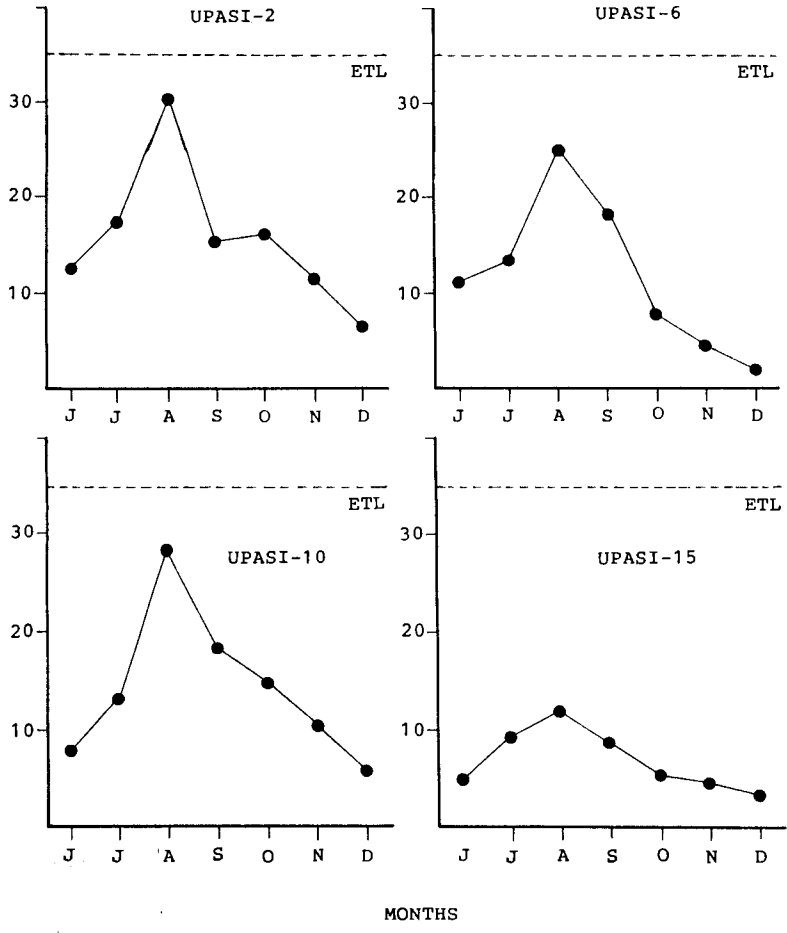
Tea planting in southern India, until mid-fifties was solely by seed material. In a seedling tea field, only about 30 per cent of the bushes were good yielders due to high genetic variation. An attempt was made in the mid-fifties to mark the high yielding tea plants in the field and propagate them vegetatively by internodal stem cuttings. Clonal propagation was, thus, born.

Parameters, such as, yield potential, quality of teas, nursery performance and tolerance to drought are the most important criteria for clonal selection. Tolerance to pests and diseases are important additional criteria of benefit. Hence, attempts were made to evaluate the degree of susceptibility of 12 clones, released by the Tea Research Institute. Four clones, selected by the commercial tea gardens, were also evaluated for their tolerance to blister blight disease.

4.1. HIGHLY TOLERANT CLONES

Four clones were found to be highly tolerant to the disease.

34. Tolerance of clones UPASI-2, -6, -10 and -15 to blister blight disease



4.1.1. Susceptibility of UPASI-2 (D/4/142), 'Jayaram' to blister blight disease

The susceptibility of the clone UPASI-2, exposed to natural infection was studied for five years. The disease incidence in Fig. 34, shows the mean per cent infection recorded in the months of the disease season.

The disease incidence was below the level of economic threshold of 35 per cent in all the months of study. In the month of August disease incidence (30.5%), was at its peak. Based on the infection level this clone was considered to be tolerant to blister blight.

4.1.2. UPASI-6 (B/6/24), 'Brooklands'

Tea bushes of this clone were exposed to natural infection consecutively for five years and the Fig. 34 depicts monthwise average of per cent infection.

Infection in all the months of the disease season was well below the level of economic threshold of 35 per cent. August registered maximum infection (24.0%) followed by September (18.0%) and the lowest infection was recorded in November (4.2%) and December (2.0%).

The clone was considered to be tolerant to the disease.

4.1.3. UPASI-10 (B/6/62), 'Pandian'

Disease incidence, cumulative average of each month of the disease season, from June to December, recorded for five years continuously, is presented in the Fig. 34.

The infection was below the level of economic threshold throughout the period of assessment. However, disease level was high in the months of August (28.2%) and September (18.4%) and least in December (5.6%).

This clone, thus, was also found to be tolerant to the disease.

4.1.4. UPASI-15 (SP/4/5), 'Springfield'

The susceptibility of this clone was studied for three years and the average level of infection, month-wise, is presented in the Fig. 34.

Infection levels were extremely low in all the months of the blister blight season. Infection was slightly higher than others, only in the month of August (11.7%) and the severity declined, gradually thereafter, in the months that followed.

This clone was considered to be highly tolerant to the disease.

4.2. CLONES MODERATELY TOLERANT TO DISEASE

Four clones were found to be moderately tolerant to the disease.

4.2.1. UPASI-1 (B/4/141), 'Evergreen'

The degree of tolerance of the clone was assessed continuously for five years.

Infection exceeded the levels of economic threshold in August (40 per cent) while in other months it was below (Fig. 35). In September the level of infection was slightly higher (31.9%) than in the other months.

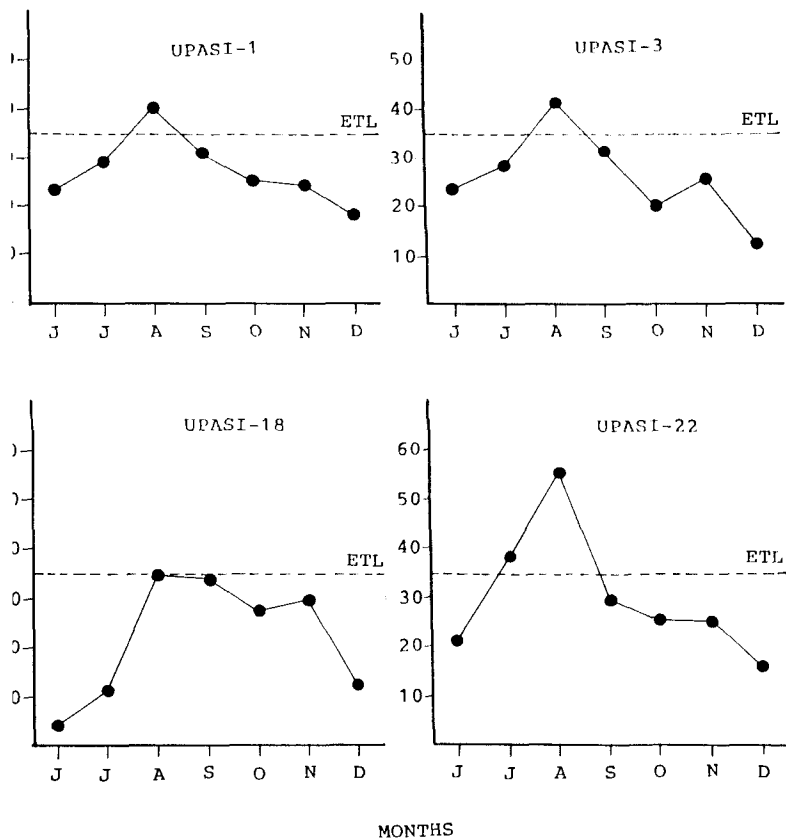
This clone was found to be moderately tolerant to blister blight disease.

4.2.2. UPASI-3 (B/5/63), 'Sundaram'

Disease incidence in UPASI-3 was studied for five years (Fig. 35).

The infection was at the maximum level in August (41.6%) during which it crossed the level of economic threshold. In all

35. Tolerance of clones UPASI-1, -3, -18 and -22 to blister blight diseases



other months, excepting September (31.2%) the disease incidence ranged between 20 and 28 per cent.

The level of infection in this clone was almost similar to UPASI-1 and was found to be moderately tolerant to the disease.

4.2.3. UPASI-18 (B/6/57)

Blister blight infection in UPASI-18 was monitored for four years to assess its tolerance to the disease.

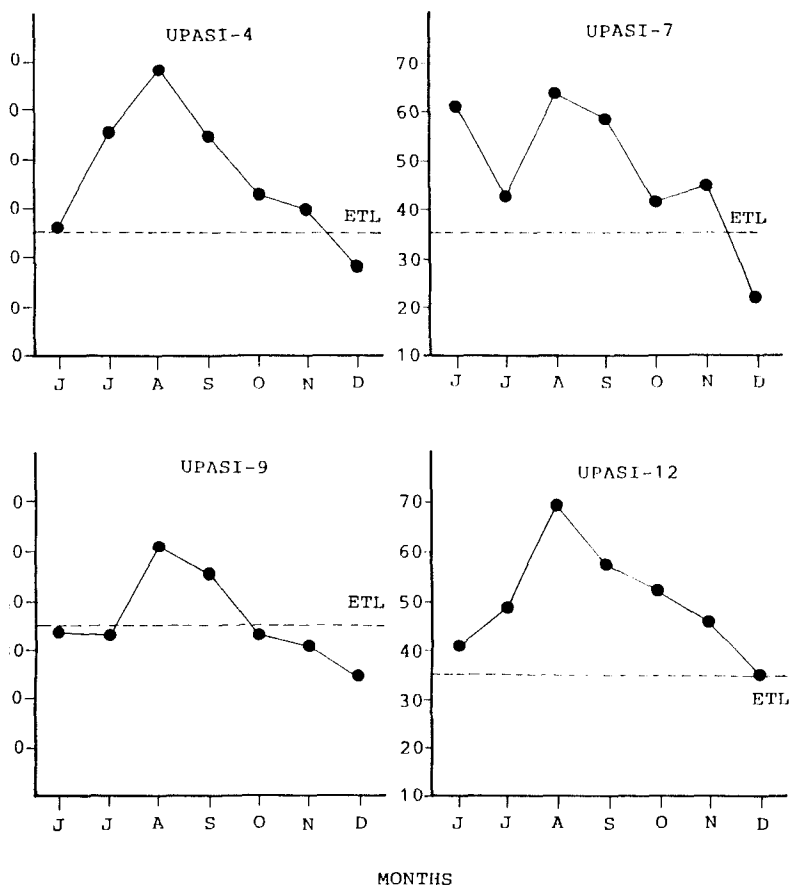
During the months of August and September the infection was high (Fig. 35). However, the per cent infection was slightly less than the level of economic threshold. In other months the disease incidence was much below the critical limit.

This clone was considered to be moderately tolerant to the disease.

4.2.4. UPASI-22 (B/6/29)

A four year study was carried out to assess the tolerance of UPASI-22 to blister blight disease.

36. Tolerance of clones UPASI-4, -7, -9 and -12 to blister blight disease



Infection was not only quite high in the month of August (55.3%), but also exceeded the critical threshold limit in July (38.7%). In other months the infection was below the limit (Fig. 35).

This clone was considered to be fairly tolerant to the disease.

4.3. CLONES LEAST TOLERANT AND SUSCEPTIBLE

Four clones were found to be least tolerant and quite susceptible to blister blight.

4.3.1. UPASI-4 (B/6/10)

In a four year study the susceptibility of UPASI-4 to blister blight disease was investigated. The infection levels are presented in the Fig. 36.

Disease incidence exceeded the level of economic threshold in all the six months of the disease season excepting in December. It was very high in the months of July, August and September, and moderately high in the other months. This clone was considered to be less tolerant and thus susceptible to blister blight.

4.3.2. UPASI-7 (B/6/34)

A five year study was undertaken to investigate the tolerance of UPASI-7 to blister blight infection. The disease incidence by way of per cent infection is shown in Fig. 36.

Disease incidence was above the level of threshold throughout the disease season excepting December. The disease was severe in June (61.8%), August (64.2%) and September (59.2%) and high in other months. Based on the infection levels, the clone was considered to be susceptible and less tolerant to the disease.

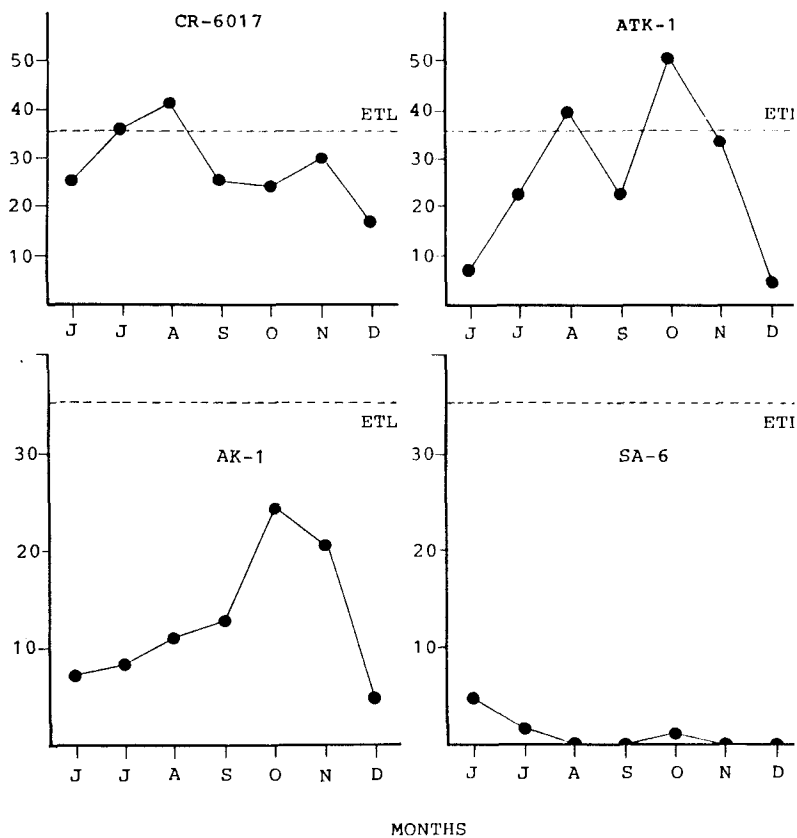
4.3.3. UPASI-9 (B/6/61), 'Athrey'

The level of tolerance of UPASI-9 to blister blight was evaluated in a field investigation carried out for five years. The infection levels shown in Fig. 36, exceeded the level of threshold in August (51.7%) and September (45.9%). In the other months, the infection was marginally below the level of economic threshold. This clone though susceptible appeared to be more tolerant to blister blight than UPASI-4, and -7, described earlier.

4.3.4. UPASI-12 (B/6/129)

The tolerance of UPASI-12 was investigated in a field trial carried out for five years.

Fig. 37. Tolerance of clones CR-6017, ATK-1, AK-1 and SA-6 to blister blight disease



The infection levels were very high in all the months (Fig. 36), of the disease season. The clone was found to be highly susceptible and least tolerant to the disease.

4.4. STUDIES ON THE TOLERANCE OF BLISTER BLIGHT IN SOME CLONES SELECTED BY TEA GARDENS

Four clones were investigated under this category for their tolerance to the disease.

4.4.1. CR-6017

A four year study was carried out to assess the susceptibility of CR-6017 to blister blight. The infection levels are shown in Fig. 37.

The infection level was above the threshold in August (41.5%) and marginally exceeded in July (35.1%). In the other months, the disease incidence was below the level of the threshold. The clone was found to be fairly tolerant to the disease.

4.4.2. AK-1

In a field study, the tolerance of AK-1 to blister blight was investigated for one year. The disease incidence is shown in Fig.37.

Blister blight infection was below the level of economic threshold in all the months of the disease season. The clone was thus found to be quite tolerant to blister blight.

4.4.3. ATK-1

This clone was also assessed for its susceptibility to the disease for one year. The results are presented in Fig. 37.

Disease incidence, crossed the critical threshold limit in two months, August (40.0%) and October (50.5%). In the other months the infection was below the limit. The clone, thus, was found to be moderately tolerant to blister blight.

4.4.4. SA-6

The clone SA-6 was studied for its tolerance to the disease for one year. The disease incidence is presented in Fig. 37.

Infection was very low and far below the level of economic threshold, all through the disease season. The maximum per cent infection noticed in June was only 4.7 and in July and October the infection was below 1.5 per cent. Disease incidence was not noticed in the months of August, September, November and December (0.0%). The clone was found to be highly tolerant to the disease.

CHAPTER - 5

**DISEASE CONTROL IN TEA
RECOVERING FROM PRUNING**

DISEASE CONTROL IN TEA RECOVERING FROM PRUNING

Blister blight control in tea recovering from pruning assumes tremendous importance, since failure to control the disease can delay tipping, thereby, leading to considerable crop loss.

In southern India, normally tea is pruned in the months of April after receipt of good showers (ca five cm of rainfall), August and to a lesser extent in November.

5.1. EVALUATION OF AGRICULTURAL ANTIBIOTICS IN COMBINATION WITH COPPER OXYCHLORIDE

Several formulations of agricultural antibiotics were tested for efficacy in combination with copper oxychloride. The details of the formulations are given in Table 3. They were tested in ppm of the active ingredient.

5.1.1. Evaluation of the Formulation-1

A field experiment was carried out in the Anamallais, to identify the quantity of the antibiotic formulation required to be used in combination with copper oxychloride (henceforth referred as copper). Spray applications were put out with a pressure retaining knapsack sprayer.

Table 3. Details of the Formulations used in the experiments

Formulation Number	Brand Name	Source	Composition
1	Agrimycin 100	Pfizer (India) Ltd., Bombay	A wettable powder containing 15 per cent streptomycin and 1.5% oxytetracycline
2	Paushamycin	Alembic Ltd., Baroda, Gujarat	A wettable powder containing 15 per cent streptomycin and 1.5% oxytetracycline
3	Plantomycin	Arles-Agrovet Industries Ltd., Bombay	A wettable powder containing 9 per cent streptomycin, 1 per cent tetracycline vitamin B-12 and humectant
4	Solamycin	Solar Syndicate Pvt. Ltd., Valsad, Gujarat	A wettable powder formulation with 10 per cent streptomycin, 1 per cent tetracycline, vitamin B-12
5	Streptocycline	Hindustan Antibiotics Ltd., Pimpri, Pune	A wettable powder containing 90 per cent streptomycin and 10 per cent tetracycline as active ingredients
6	Safnik	Woodbriar Estates Ltd., Cochin, Kerala	A liquid formulation containing 20 per cent nickel chloride
7	Fycol 8E	Rallis (India) Limited Bangalore	An oil based copper formulation containing 40 per cent copper, as water dispersible paste

Infection was very severe in unprotected control. Disease incidence was significantly less in all the treatments wherein the antibiotic formulation was used in combination with copper, than the latter used alone. It was interesting to note that at 75, 100, 125 and 150 ppm levels of antibiotics disease incidence remained the same despite reduction in the dosage of copper, from 420 to 280g per hectare (Table 4).

5.1.2. Comparison of the Formulation-2 with other antibiotic formulations

This experiment was undertaken in a tea estate in Wynaad (Kerala) during the south-west monsoon period. Spray applications were put out with an air-blast spraying machine.

Formulation-1 at 100 ppm was significantly superior to all other treatments. Formulation-2 registered the lowest disease incidence at 100 ppm, which was significantly less than the same applied at other dosage. Surprisingly, at higher concentrations of 125 and 150 ppm, disease incidence was more than at 100 ppm. Similar observation was made with Formulation-1, wherein the disease incidence at 100 ppm was less than 150 ppm. The Formulation-3 provided significantly superior control at 150 ppm to 100 ppm. All the formulations, excepting Formulation-2 at 50 and 75 ppm, were significantly superior to copper used alone at high dosage (Table 5).

Table 4. Evaluation of antibiotic Formulation-1

Treatment	Rate/ha	Average disease index
Copper oxychloride + Formulation-1	420g + 50ppm	1.5
Copper oxychloride + Formulation-1	420g + 75ppm	1.5
Copper oxychloride + Formulation-1	420g + 100ppm	1.5
Copper oxychloride + Formulation-1	420g + 125ppm	1.4
Copper oxychloride + Formulation-1	420g + 150ppm	1.4
Copper oxychloride + Formulation-1	280g + 50ppm	1.6
Copper oxychloride + Formulation-1	280g + 75ppm	1.5
Copper oxychloride + Formulation-1	280g + 100ppm	1.5
Copper oxychloride + Formulation-1	280g + 125ppm	1.4
Copper oxychloride + Formulation-1	280g + 150ppm	1.4
Copper oxychloride	420g	1.7
Control	Unprotected	3.2
LSD (P = 0.05)		0.03

Table 5. Evaluation of antibiotic Formulations-1, -2 and -3

Treatment	Rate/ha	Average disease index
Copper oxychloride + Formulation-2	350g + 50ppm	1.56
Copper oxychloride + Formulation-2	350g + 75ppm	1.39
Copper oxychloride + Formulation-2	350g + 100ppm	0.78
Copper oxychloride + Formulation-2	350g + 125ppm	0.97
Copper oxychloride + Formulation-2	350g + 150ppm	0.92
Copper oxychloride + Formulation-3	350g + 100ppm	0.95
Copper oxychloride + Formulation-3	350g + 150ppm	0.85
Copper oxychloride + Formulation-1	350g + 100ppm	0.64
Copper oxychloride + Formulation-1	350g + 150ppm	0.72
Copper oxychloride	420g	1.33
LSD (P = 0.05)		0.07

5.1.3. Evaluation of the Formulation-2

Formulation-2 was tested in combination with copper against blister blight disease on an estate in the High Range (Idukki Dist., Kerala) during the south-west monsoon season. Spray applications were imposed with a pressure type knapsack sprayer.

At a concentration of 100 ppm, the Formulation-2 has provided superior performance and the disease incidence was significantly lower than all other treatments. In this experiment also disease incidence was more at 125 and 150 ppm than at 100 ppm. However, these three rates were significantly superior to copper used alone at a higher rate (Table 6).

5.1.4. Comparative evaluation of Formulation-4 and -5

Two new formulations, i.e., '4' and '5' were evaluated for efficacy in a field experiment in the Anamallais during the peak disease season of the south-west monsoon. Test formulations were put out with an air-blast spraying machine.

The Formulation-5 at both 75 and 100 ppm with 350g of copper per hectare was found to be significantly superior to copper fungicide used alone at a higher rate of 420g per hectare. The difference in disease level between the Formulation-4 with copper fungicide

Table 6. Evaluation of antibiotic Formulation-2

Treatment	Rate/ha	Average disease index
Copper oxychloride + Formulation-2	350g + 50ppm	0.87
Copper oxychloride + Formulation-2	350g + 75ppm	0.89
Copper oxychloride + Formulation-2	350g + 100ppm	0.63
Copper oxychloride + Formulation-2	350g + 125ppm	0.75
Copper oxychloride + Formulation-2	350g + 150ppm	0.73
Copper oxychloride	420g	0.87
LSD (P = 0.05)		0.05

and copper alone was not significant, though the former was superior. The Formulation-2, as in previous experiments provided significantly superior control to copper alone (Table 7).

5.2. EVALUATION OF THERAPEUTIC INORGANIC FUNGICIDE FORMULATIONS

Applications of nickel chloride salt in combination with copper to control blister blight in tea recovering from pruning was feared to result in phytotoxicity due to the toxicity of nickel chloride. A liquid formulation (Formulation-6) containing 20 per cent of nickel chloride and certain safeners was tested for efficacy in a field trial.

5.2.1. Formulation-6 - Comparison of dosage

A field investigation was undertaken to see whether the rate of usage of the Formulation-6 could be reduced and study its efficacy either singly or in combination with copper fungicide. The trial was put out in the Anamallais during the south-west monsoon. Sprays were imposed at three-day intervals with a pressure retaining knapsack sprayer. A combination of copper oxychloride and Formulation-3 was employed for comparison.

There was no significant difference between the two rates of Formulation-6 used in combination with copper and the infection

Table 7. Evaluation of antibiotic Formulations-2, -4 and -5

Treatment	Rate/ha	Average disease index
Copper oxychloride + Formulation-4	350g + 75ppm	1.65
Copper oxychloride + Formulation-4	350g + 100ppm	1.59
Copper oxychloride + Formulation-2	350g + 75ppm	1.84
Copper oxychloride + Formulation-2	350g + 100ppm	1.56
Copper oxychloride + Formulation-5	350g + 75ppm	1.54
Copper oxychloride + Formulation-5	350g + 100ppm	1.48
Copper oxychloride	420g	2.04
LSD (P = 0.05)		0.46

was less when the formulation used alone. High incidence of blister blight resulted when copper fungicide was used alone. Addition of the spray adjuvant, Triton AE resulted in better disease control than when the fungicide was used without this. When Triton AE was added to the fungicide mixture containing copper oxychloride and Formulation-3, disease incidence was marginally more than the combination without this adjuvant (Table 8).

5.2.2. Evaluation of Formulation-6

In order to economise on the spraying cost the efficacy of Formulation-6 was assessed both singly and as a tank mix with copper fungicide by extending the spray interval to five days, during the south-west monsoon season. Fungicide treatments were applied with a pressure retaining knapsack sprayer and the efficacy was compared with Formulation-3.

Infection was high in all the treatments with no significant difference between them, pointing to the fact that spray interval with the formulation cannot be extended (Table 9).

5.3. ASSESSMENT OF OIL BASED COPPER FORMULATION

The possibility of controlling blister blight by employing oil based copper fungicide formulation (Formulation-7) was studied in a field

Table 8. Evaluation of the Formulation-6

Treatment	Rate/ha	Average disease index
Copper oxychloride + Formulation-6	350g + 350ml	1.4
Copper oxychloride + Formulation-6 + Triton AE	350g + 350ml + 125ml	1.3
Copper oxychloride + Formulation-6	350g + 700ml	1.4
Copper oxychloride + Formulation-6 + Triton AE	350g + 700ml + 125ml	1.2
Formulation-6	350ml	1.7
Formulation-6 + Triton AE	350ml + 125ml	1.5
Formulation-6	700ml	1.4
Formulation-6 + Triton AE	700ml + 125ml	1.3
Copper oxychloride + Formulation-3	350g + 100ppm	1.3
Copper oxychloride + Formulation-3 + Triton AE	350g + 100ppm + 125ml	1.4
Copper oxychloride	350g	1.7
Copper oxychloride + Triton AE	350g + 125ml	1.4
LSD (P = 0.05)		0.3

Table 9. Evaluation of the Formulation-6

Treatment	Rate/ha	Average disease index
Copper oxychloride + Formulation-6	350g + 700ml	2.0
Copper oxychloride + Formulation-6 + Triton AE	350g + 700ml + 125ml	1.7
Formulation-6	700ml	2.1
Formulation-6 + Triton AE	700ml + 125ml	2.0
Copper oxychloride + Formulation-3	350g + 100ppm	2.1
Copper oxychloride + Formulation-3 + Triton AE	350g + 100ppm + 125ml	1.8
Copper oxychloride	350g	2.2
Copper oxychloride + Triton AE	350g + 125ml	1.9
LSD (P = 0.05)		0.6

experiment. Spray applications were given with an air-blast spraying machine. The efficacy of the formulation was compared with a combination of copper fungicide and the Formulation-6. The effect of extending the spray interval was also investigated.

The oil based copper formulation was inferior to the treatment employed for comparison. Incidence of the disease also increased with extension of the spray interval (Table 10).

5.4. STUDIES ON THE EFFICACY OF ORGANIC FUNGICIDES

Some of the organic fungicides which were found to be effective against blister blight in tea under regular plucking were tested in tea recovering from pruning for their efficacy against blister blight disease.

5.4.1. Evaluation of chlorothalonil

Chlorothalonil was evaluated at two rates and at two spray intervals. The treatments were put out with an air-blast spraying machine. Comparison was made with copper fungicide used in combination with the Formulation-6.

There was no significant difference between the rates of chlorothalonil used, between the intervals tested, and also with

Table 10. Evaluation of oil based copper formulation

Treatment	Rate/ha	Spray Interval days	Average disease Index
Formulation-7	130g	3	1.3
Formulation-7	130g	5	1.5
Formulation-7	260g	3	1.1
Formulation-7	260g	5	1.5
Formulation-7	520g	5	1.2
Copper oxychloride + Formulation-6 + Triton AE	350g + 350ml + 35ml	3	0.9
Copper oxychloride + Formulation-3	350g + 70g	3	1.1
LSD (P = 0.05)			0.3

the treatment employed for comparison. Infection was high in plots where the fungicide was used at extended interval of five days. All the treatments, excepting those at five day spray intervals, were found to be equally effective (Table 11).

5.4.2. Evaluation of captafol

Captafol at three dosage rates was applied at two spray intervals and the efficacy was compared with copper fungicide and the Formulation-3 combination. Fungicide treatments were imposed with an air-blast spraying machine.

All the three rates of captafol failed to control blight, when their application was extended to ten days and the infection levels were significantly inferior to the standard fungicide treatment used for comparison. At five day intervals captafol was comparable with the standard and there was no significant difference between the treatments (Table 12).

5.4.3. Evaluation of tridemorph

Tridemorph, a morpholene based systemic fungicide, was tested for efficacy. Two rates applied at two spray intervals were compared, with the standard copper fungicide and the Formulation-6 combination. A binder was incorporated with tridemorph sprays. Additionally,

Table 11. Evaluation of chlorothalonil As Daconil 2787 75% WP

Treatment	Rate/ha	Spray interval days	Average disease index
Chlorothalonil	200g	3	1.6
Chlorothalonil	200g	5	1.6
Chlorothalonil	300g	3	1.6
Chlorothalonil	300g	5	1.8
Chlorothalonil + Copper oxychloride	100g + 200g	3	1.4
Copper oxychloride	400g	3	1.4
Copper oxychloride + Formulation-6	350g + 350ml	3	1.5
LSD (P = 0.05)			0.3

* As Daconil 2787 75% WP

Table 12. Evaluation of captafol As Foltaf 80% WP

Treatment	Rate/ha	Spray interval days	Average disease Index
Captafol	250g	5	1.3
Captafol	300g	5	1.2
Captafol	350g	5	1.2
Captafol	250g	10	2.2
Captafol	300g	10	2.4
Captafol	350g	10	1.9
Copper oxychloride + Formulation-3	350g + 67g	3	1.2
LSD (P = 0.05)			0.6

* As Foltaf 80% WP

Table 13. Evaluation of tridemorph As Calixin 80% EC

Treatment	Rate/ha	Spray interval days	Average disease Index
Tridemorph + binder	90ml + 500ml	5	0.07
Tridemorph + binder	180ml + 500ml	5	0.04
Tridemorph + binder	180ml + 500ml	10	0.08
Tridemorph + Formulation-6 + Triton AE	90ml + 350ml + 35ml	5	0.09
Tridemorph + Formulation-6 + Triton AE	180ml + 350ml + 35ml	10	0.07
Copper oxychloride + Formulation-6 + Triton AE	350g + 350ml + 35ml	3	0.19
LSD (P = 0.05)			0.08

* As Calixin 80% EC

the combination of tridemorph with Formulation-6 was also screened for efficacy. Spray applications were put out with an air-blast spraying machine.

The overall infection levels were less and all the treatments were significantly superior to the standard treatment (Table 13).

CHAPTER - 6

**DISEASE CONTROL IN TEA
UNDER PLUCKING**

DISEASE CONTROL IN TEA UNDER PLUCKING

Chemical protection by means of fungicide application is by far the most efficient method to achieve disease control, not only rapidly but also economically. While application of protectant-therapeutant fungicides has to be precisely timed, systemic fungicides have a long residual action and permit their application on extended rounds.

6.1. PERFORMANCE OF INORGANIC PROTECTANT FUNGICIDES

The inorganic protectant fungicide formulations evaluated were essentially based on copper. They were tried as ammoniacal copper polymer formulation, cuprous oxide, ready to use bordeaux mixtures. Additionally, some of the copper oxychloride formulations were evaluated. The results of effective compounds are presented and discussed.

6.1.1. Ammoniacal copper polymer formulation

A fungicide formulation containing 15 per cent metallic copper as ammoniacal copper polymer received under the brand name Cobox L, was evaluated for two years.

6.1.1.1. In the first year Cobox L. was tried in combination with nickel chloride. Spray treatments were put out with a pressure retaining knapsack sprayer.

The level of blister blight infection (Table 14) could be brought down by increasing the dosage of Cobox L. The rate of nickel chloride was kept constant at 210g per hectare irrespective of the quantity of Cobox L tested. Cobox L at the highest dose (750ml) with nickel chloride provided disease control which was marginally superior to the standard, copper + nickel treatment. The difference, however, was statistically insignificant. Among the other treatments, Cobox L at 500ml also offered good control. The increase in infection levels with the addition of Triton A.E. as a spray adjuvant, is inexplicable.

6.1.1.2. In the following year Cobox L was tested alone, in order to assess its efficacy. The treatments were imposed with a pressure retaining knapsack sprayer.

Disease control (Table 15) was poor when the product was used alone; thus, it looks that it can be used only in combination with nickel chloride and not singly.

Table 14. Evaluation of ammoniacal copper polymer (Cobox L) with nickel chloride

Treatment	Rate/ha	Blister blight incidence %
Cobox L + Nickel chloride	250ml + 210g	36.6
Cobox L + Nickel chloride + Triton AE	250ml + 210g + 87.5ml	37.4
Cobox L + Nickel chloride	500ml + 210g	32.9
Cobox L + Nickel chloride + Triton AE	500ml + 210g + 87.5ml	34.3
Cobox L + Nickel chloride	750ml + 210g	30.6
Cobox L + Nickel chloride + Triton AE	750ml + 210g + 87.5ml	33.7
Copper oxychloride + Nickel chloride + Triton AE	210g + 210g + 87.5ml	33.4
Control	Unprotected	68.1
LSD (P = 0.05)		4.6

Table 15. Evaluation of ammoniacal copper polymer (Cobox L)

Treatment	Rate/ha	Spray Interval days	Blister blight incidence %
Cobox L	280ml	7	45.4
Cobox L	420ml	7	43.2
Cobox L	560ml	7	38.5
Cobox L / Nickel chloride*	280ml/280g	7	41.4
Cobox L / Nickel chloride*	420ml/280g	7	39.4
Copper oxychloride + Nickel chloride + Triton AE	210g + 210g + 87.5ml	5/7	31.2
Control	Unprotected	-	62.0
LSD (P = 0.05)			2.9

* Treatments were alternated with each other

6.1.2. Evaluation of cuprous oxide formulations

In many field experiments in earlier years, cuprous oxide was found to offer good control of blister blight; in some instances, this product was found to be even superior to copper oxychloride. However, due to various problems encountered in manufacture and storage, this product subsequently became unavailable. Recently, cuprous oxide has been evaluated again, as it appeared to be available in the market.

6.1.2.1. In the first investigation, plain cuprous oxide, which was not a fungicide formulation, was tested singly and in combination with nickel chloride. Fungicide sprays were put out with an air-blast sprayer (mist blower).

Disease incidence (Table 16) exceeded the economic threshold of 35 per cent, when copper oxychloride, nickel chloride and cuprous oxide were used alone. There was no significant difference between cuprous oxide and copper oxychloride when used in combination with nickel chloride.

6.1.2.2. A wettable powder formulation of cuprous oxide containing 50 per cent as metallic copper was received for evaluation. Fungicide treatments were imposed with a pressure retaining knapsack sprayer.

Table 16. Cuprous oxide against blister blight disease

Treatment	Rate/ha	Spray interval days	Blister blight incidence %
Cuprous oxide + Triton AE	400g + 30ml	7	42.0
Cuprous oxide + Nickel chloride + Triton AE	200g + 100g + 30ml	7	36.6
Cuprous oxide + Nickel chloride + Triton AE	200g + 200g + 30ml	7	32.1
Nickel chloride + Triton AE	280g + 30ml	7	39.3
Copper oxychloride + Triton AE	400g + 30ml	7	38.5
Copper oxychloride + Nickel chloride + Triton AE	200g + 200g + 30ml	5/7	31.5
Control	Unprotected	-	58.8
LSD (P = 0.05)			3.9

Cuprous oxide (Table 17) at 210g in combination with 210 of nickel chloride per hectare was significantly superior to copper oxychloride plus nickel chloride at the same rate. In the other treatments, though not significantly different, cuprous oxide was superior to copper oxychloride.

6.1.2.3. COMPARATIVE EFFICACY OF CUPROUS OXIDE AND COPPER OXYCHLORIDE : A study was carried out in which the efficacy of cuprous oxide was compared at equal rates with copper oxychloride. Cuprous oxide was tested alone and in combination with nickel chloride and compared with copper oxychloride used similarly. The fungicide treatments were applied with a pressure retaining knapsack sprayer. The treatment intervals were put out at five-day intervals during the south-west and at seven-days in the north-east monsoon seasons. A non-ionic wetting agent (0.05%) was added to all the treatments to improve the tenacity. The results in Table 18 represent the per cent infection, average of 23 weekly assessments carried out between July and December.

Cuprous oxide at 210g in combination with 210g of nickel chloride per hectare was significantly superior to copper oxychloride at the same rate. Both cuprous oxide and copper oxychloride were ineffective when used alone. Amongst the other treatments, cuprous oxide was superior to copper oxychloride, but not significantly so.

Table 17. Cuprous oxide against blister blight disease

Treatment	Rate/ha	Blister blight incidence %
Cuprous oxide + Triton AE	420g + 87.5ml	37.5
Cuprous oxide + Nickel chloride + Triton AE	210g + 105g + 87.5ml	34.9
Cuprous oxide + Nickel chloride + Triton AE	210g + 210g + 87.5ml	31.2
Copper oxychloride + Triton AE	420g + 87.5ml	37.8
Copper oxychloride + Nickel chloride + Triton AE	210g + 105g + 87.5ml	36.3
Copper oxychloride + Nickel chloride + Triton AE	210g + 210g + 87.5ml	33.6
LSD (P = 0.05)		2.0

Table 18. Comparative efficacy of cuprous oxide and copper oxychloride

Treatment	Rate/ha	Blister blight incidence %
Cuprous oxide	420g	37.5
Cuprous oxide + Nickel chloride	210g + 105g	34.9
Cuprous oxide + Nickel chloride	210g + 210g	31.2
Copper oxychloride	420g	37.8
Copper oxychloride + Nickel chloride	210g + 105g	36.3
Copper oxychloride + Nickel chloride	210g + 210g	33.6
LSD (P = 0.05)		2.0

6.1.3. Efficacy of ready to use (instant) Bordeaux mixture formulations

Three formulations, each differing in metallic copper content, of ready to use (instant) Bordeaux mixture were evaluated. The test formulations were applied with a mist blower.

None of the Bordeaux mixture formulations (Table 19) provided adequate control of the disease. Possibly, the copper quantity in these products at the rates tested might not have been sufficient.

6.1.4. Comparison of various copper oxychloride formulations

The efficacy of three copper oxychloride formulations was investigated in a field experiment during the north-east monsoon season. Fungicide formulations were applied with a pressure retaining knapsack sprayer.

All the three copper formulations, when tested in combination with nickel chloride, were comparable (Table 20) and the differences between them were not significant.

6.1.5. Performance of organic fungicides with protectant/therapeutant action

Of the many organic fungicides and their formulations evaluated, only a few offered satisfactory control. The efficacy of two chemical

Table 19. Evaluation of Instant Bordeaux mixtures

Treatment	Rate/ha	Spray Interval days	Bliister blight incidence %
Bordeaux TCM (22% Cu)	240g	7	46.9
Bordeaux TCM (22% Cu)	480g	7	46.0
Bordeaux Imp. (22.5% Cu)	460g	7	45.5
HOECHST Bordeaux (25% Cu)	210g	7	45.8
HOECHST Bordeaux (25% Cu)	420g	7	42.2
Copper oxychloride + Nickel chloride + Triton AE	210g + 210g + 30ml	5/7	30.1
Control	Unprotected		64.8
LSD (P = 0.05)			5.8

Table 20. Blister blight control with different brands of copper oxychloride

Treatment	Rate/ha	Blister blight incidence %
Cuprasol + Nickel chloride	210g each	20.6
Fytolan + Nickel chloride	210g each	15.3
Blitox + Nickel chloride	210g each	16.0
Control	Unprotected	48.1
LSD (P = 0.05)		8.9

formulations, chlorothalonil (Daconil 2787 75% WP and Safeguard 75% WP) and dithianon (Delan 75% WP) are discussed here.

6.1.5.1. EVALUATION OF CHLOROTHALONIL AND DITHIANON : The efficacy of chlorothalonil and dithianon was investigated during the north-east monsoon season. Spray applications were imposed with a pressure retaining knapsack sprayer. Blister blight incidence was less than the level of economic threshold (35 per cent) under both chlorothalonil and the standard, copper + nickel treated plots, in all the months from September to December (Table 21); in the latter treatment, infection was low in August also. There was no significant difference between chlorothalonil and the standard treatments in October, November and December, wherein the former (chlorothalonil) offered superior control to the standard in October and December and exceeded only marginally in November. The performance of dithianon was satisfactory only in October, November and December during which the infection levels were below the economic threshold. There was no significant difference between dithianon and the standard in October and December.

6.1.5.2. As the performance of chlorothalonil was encouraging it was further evaluated in large blocks. The size of the block was one hectare and the treatments were imposed with a mist blower. Comparison was made with the standard copper + nickel treatment imposed in the adjoining block of one hectare.

Table 21. Evaluation of chlorothalonil* and dithianon**

Treatment	Rate/ha	% Blister blight incidence				
		August	September	October	November	December
Chlorothalonil	560g	44.1	33.0	12.4	18.4	14.2
Dithianon	750g	42.4	46.9	20.2	29.6	20.5
Copper oxychloride + Nickel chloride	210g + 210g	29.4	22.6	17.9	15.2	14.9
Control	Unprotected	58.5	54.1	43.1	48.9	49.6
LSD (P = 0.05)		7.0	7.4	7.6	10.2	7.5

* As Daconil 2787 75% WP

** As Delan 75% WP

In all the assessments blister blight incidence was less in the chlorothalonil treated plots, than the standard combination (Table 22).

6.1.5.3. In one of the field investigations, a recently developed formulation of chlorothalonil (Safeguard 75 WP) was evaluated against blister blight disease. Spray applications were put out with a mist blower.

During the south-west monsoon the disease incidence was significantly higher under all the chlorothalonil treatments compared to that under the standard treatment. However, during the north-east monsoon, the product at 500 and 600g, sprayed at 7-day intervals, provided significantly superior disease control. At 7-day intervals, combination of chlorothalonil at 300g and copper oxychloride at 210g per hectare offered better control than the former sprayed alone at 400g. When the spray interval was extended to 14 days, chlorothalonil failed to control the disease satisfactorily (Table 23).

6.2. ANTISPORULANT ACTION OF SYSTEMIC FUNGICIDES

The antispore action of tridemorph and pyracarbolid was investigated on potted tea plants in the laboratory.

Table 22. Evaluation of chlorothalonil* in large blocks

Treatment	Rate/ha	% Blister blight incidence		
		October	November	December
Chlorothalonil	560g	16.6	11.4	9.7
Copper oxychloride + Nickel chloride	210g + 210g	29.4	35.0	18.3

* As Daconil 2787 75% WP

Table 23. Evaluation of chlorothalonil**

Treatment and rate per hectare*	Spray interval days	% Blister blight incidence		
		S.W. Monsoon	N.E. Monsoon	Overall
Chlorothalonil 300g + Copper oxychloride 210g	7	49.3	27.9	42.0
Chlorothalonil 400g	7	54.1	31.8	46.2
Chlorothalonil 500g	7	49.9	24.1	41.3
Chlorothalonil 600g	7	43.7	23.3	37.0
Chlorothalonil 300g + Copper oxychloride 210g	14	56.9	39.7	50.5
Chlorothalonil 400g	14	57.6	40.7	51.4
Chlorothalonil 500g	14	55.9	34.8	48.3
Chlorothalonil 600g	14	52.8	36.2	46.8
Copper oxychloride 210g + Nickel chloride 210g***	5/7	34.1	29.5	32.5
Control	Unprotected	65.9	54.1	61.4
LSD (P = 0.05)		6.0	5.3	4.2

* All the treatments were incorporated with Triton AE at 30ml/ha

** As Safeguard 75% WP

*** Standard fungicide treatment employed for comparison

6.2.1. Antisporulant action of tridemorph

The quantitative assessment of antisporulant action of the systemic fungicide tridemorph was undertaken by applying the fungicide onto the potted plants of the clone TES-34. In one batch the lower leaves on the shoot were treated with 0.1 per cent tridemorph and the upper two leaves were dusted with freshly harvested basidiospores of *E. vexans*. Treatment with the fungicide was done (a) five days prior to inoculation (b) at the time of inoculation and (c) at the Stage-4 of lesion development of the pathogen. In another, the systemic fungicide was applied on artificially induced blister lesions (a) when they had just appeared (b) at the Stage-3 and (c) the Stage-4 of the lesion development. The results are presented in Tables 24 and 25.

When the fungicide was treated five days prior to inoculation with the pathogen, the lesions developed, though were greatly reduced in size, still produced some spores. No spores were produced when the fungicide treatment was carried out simultaneously at the time of inoculation and at the Stage-4 of the lesion development. The lesions turned waxy (Figs. 38 and 39) and aborted (Table 24).

It was observed (Table 25) that when the fungicide was applied directly on the incipient lesions, they failed to sporulate and aborted. The same treatment at the Stage-3 of the blister lesion



FIG. 38. ANTISPORULENT ACTION OF TRIDEMORPH



FIG. 39. BLISTER LESIONS ABORTED FOLLOWING TREATMENT WITH TRIDEMORPH

Table 24. Application of tridemorph* on the lower leaves and inoculation of the first and second leaves on the same shoot with blister spores

Treatment tridemorph at	Sporulation of lesions 10 days after inoculation	No. of spores per cm ² in 24 hours
5 days prior to inoculation	Yes	17,095
At the time of inoculation	None	-
At Stage-4 of lesion development	None	-
Control - Untreated	Yes	1,390,692

* As Calixin 80% EC

Table 25. Treatment of artificially induced blister lesions with tridemorph*

Treatment tridemorph at	Sporeulation 72 hours after treatment	No. of spores per cm ² in 24 hours
Stage-1	None	0
Stage-3	Yes	270
Stage-4	Yes	2,828
Control - Untreated	Yes	13,90,692

* As Calixin 80% EC

gave similar results, although a few spores were ejected from the fungicide painted lesion. Treatment at the Stage-4 considerably inhibited sporulation, the total number counted in a 24-hour period being a mere 2828 compared to 1,390,692 under the untreated control.

6.2.2. Antisporulant action of pyracarbolid

The antisporulant action of pyracarbolid was investigated. Potted plants of the susceptible clone were inoculated with the pathogen and the lesions which developed following inoculation were treated at various stages of their development, with 0.1 per cent concentrations of the product containing 15 per cent pyracarbolid

It was observed that the treated lesions at all the three stages of development failed to produce any spores. The lesions turned waxy and aborted subsequently (Table 26).

6.3. SYSTEMIC FUNGICIDES AND MITE PESTS

In casual observations it was noticed that the plots treated with systemic fungicides to control blister blight during the disease season appeared to have a low incidence of mite pests in the dry weather that ensued. A critical study was undertaken to quantify the occurrence of mite pests in the plots treated with systemic fungicides.

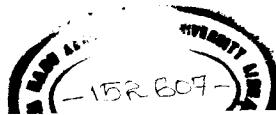


Table 26. Treatment of artificially induced blister lesions with pyracarbolid*

Treatment pyracarbolid on	Sporulation 72 hours after treatment	No. of spores per cm^2 in 24 hours period
Small lesions just discernible	None	0
Lesions easily detected	None	0
Well developed lesions	None	0
Control - Untreated	Yes	15,30,815

* As Sicarol 15% EC

6.3.1. Mites in plots treated with pyracarbolid

Incidence of pink and purple mites, two ubiquitous mite pests was studied in the dry weather, for two years in plots treated with pyracarbolid for controlling blister blight. The mite population was compared with that obtained in copper oxychloride treated plots.

In the first year (Table 27), both pink and purple mites were considerably low in plots which were sprayed with pyracarbolid, compared to copper oxychloride where the build up was enormous. In the second year, both the types of mites, were less in pyracarbolid plots, than copper oxychloride.

6.3.2. Mites in plots treated with tridemorph

Mite population was quantified for four years, in the dry season in plots, where tridemorph was sprayed earlier to control blister blight disease. Here again, the mite build up was compared with that in copper oxychloride treated plots.

In the first year, mites were twice more in copper oxychloride treated plots than those sprayed with tridemorph (Table 28). In the second and third years of study, enormous mite build up was recorded under copper treatment which was about six and four times

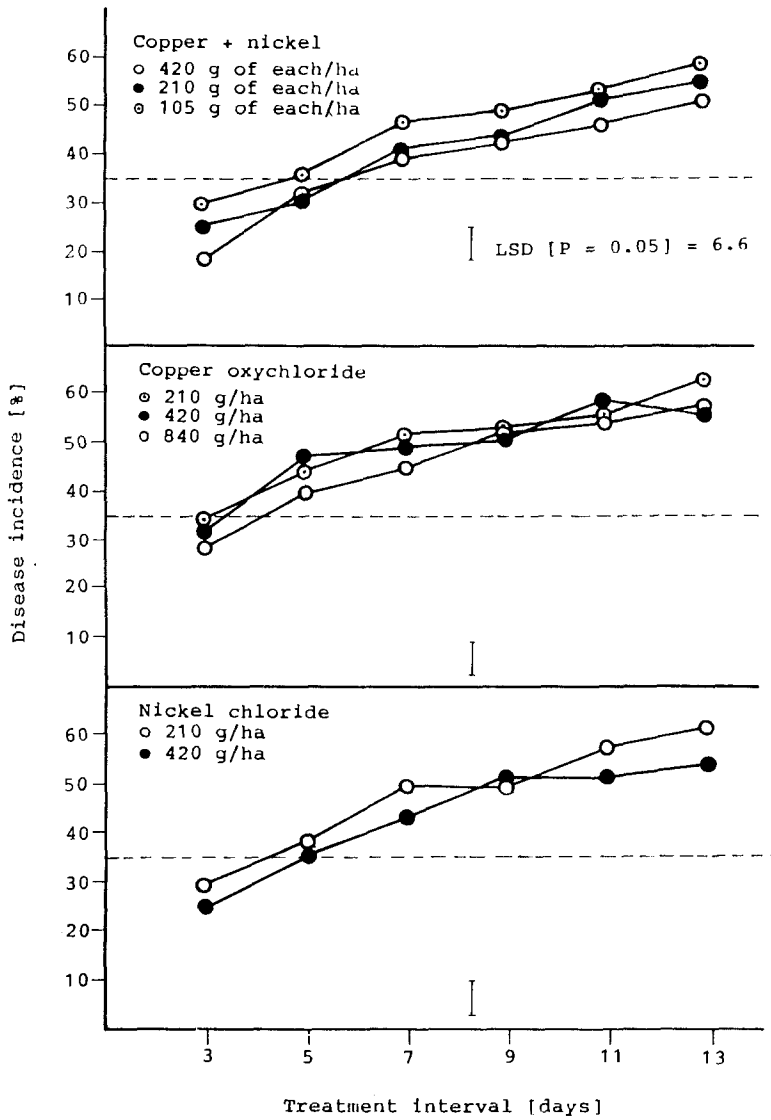
Table 27. Effect of pyracarbolid on mite build up

Year	No. of observations	Copper oxychloride			Pyracarbolid		
		Mean No. of Mites/10 leaves		Total	Mean No. of Mites/10 leaves		Total
		Pink	Purple		Pink	Purple	
I	8	354	66	420	81	9	90
II	7	412	43	455	369	19	388

Table 28. Effect of tridemorph on mite build up

Year	No. of observations	Copper oxychloride				Tridemorph		
		Mean No. of Mites/10 leaves		Total	Mean No. of Mites/10 leaves		Total	
		Pink	Purple		Pink	Purple		
I	4	326	36	362	145	9	154	
II	3	119	2	121	17	1	18	
III	3	415	15	430	82	12	94	
IV	2	153	12	165	36	10	46	

10. 10. Disease blight incidence during the south-west monsoon period in different treatments



more than that of tridemorph. In the fourth year of the study, also, the mites were thrice more under copper oxychloride treatment than tridemorph.

It was interesting to see that in all the years of observation in pyracarbolid, tridemorph and copper oxychloride treated plots, the number of pink mites greatly outnumbered the purple mites.

6.4. STUDIES ON THE INTERACTION OF DOSAGE AND SPRAY INTERVAL

Copper oxychloride at three dosage rates, nickel chloride at two rates and a combination of two at three rates were tested at six different treatment intervals from June to November. The fungicide treatments were imposed with a pressure retaining knapsack sprayer.

During the very wet monsoon period none of the treatments gave effective control at seven-day or longer treatment intervals (Fig. 40), inasmuch as the percentage disease incidence (average of seven assessments) exceeded the critical limit of 35 per cent. Only under the higher rates of copper oxychloride and nickel chloride in combination was disease incidence on 11-day spraying rounds below 50 per cent, whereas, in all other 11-day treatments it was above 50 per cent, which is considered to be exceedingly high, likely to lead to heavy crop loss. Again, only the copper oxychloride and nickel chloride combination treatments at the three usage rates,

and nickel chloride alone at 420 g per ha, gave adequate protection on five day treatment rounds, the three levels of copper fungicide and the lower dose of nickel chloride being ineffective. In all the eight treatments under test, blister incidence was below the critical level of 35 per cent when the spraying interval was three days; infection was significantly higher at five day intervals of spray application in all the treatments, where copper and nickel were used alone.

The interaction of spraying interval and dosage was highly significant in all the treatments (Table 29). At 210g and 420g per ha of copper, only at the three-day interval was disease incidence lower than the critical level of 35 per cent in six out of the seven samplings. At longer spraying intervals, disease incidence was higher either in six or in all of the seven observations. At the highest copper rate, infection was always below the critical level at the three-day treatment interval and in three out of the seven observations at the five-day interval. With longer intervals the disease was above the economic threshold either throughout, or in six out of the seven observations. The results were very similar with nickel chloride at both rates of application. In contrast with the combination of copper and nickel at 210 and 420g each per hectare, disease incidence was always below the critical level at the three day spraying interval and at the five day spraying interval at the higher rate; this was also the case six times out of seven

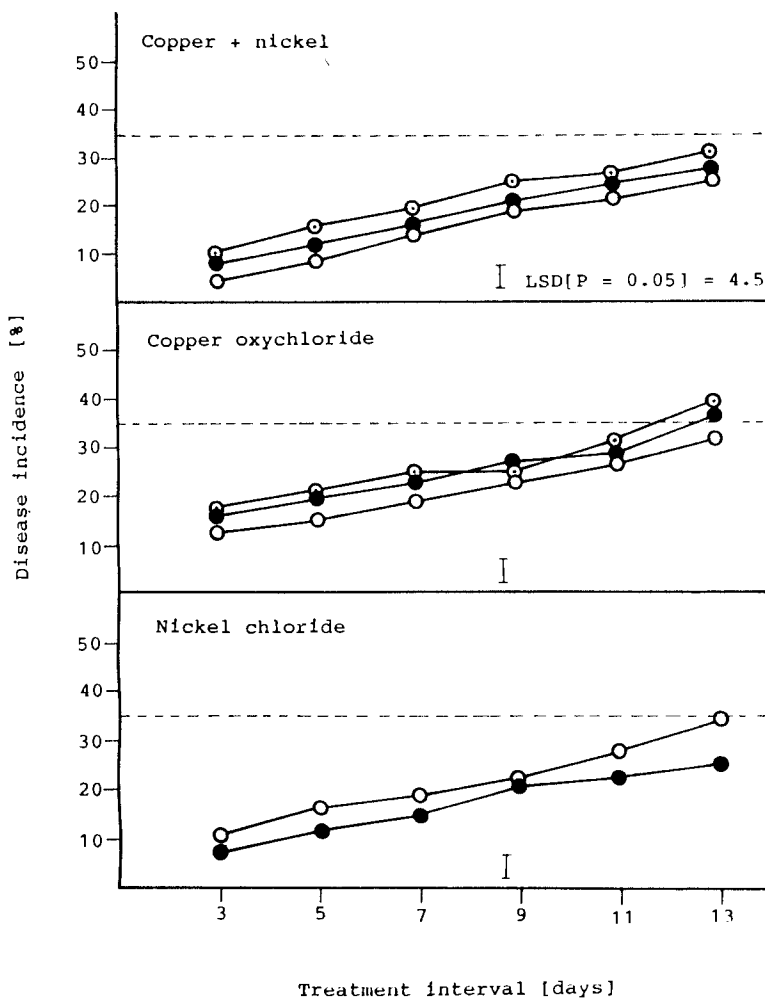
Table 29. Interaction of dosage, spray interval and fungicide action in the S.W. monsoon period (June-September)

Spray interval days	Copper oxychloride g/ha			Copper oxychloride + Nickel chloride g each/ha			Nickel chloride g/ha		
	210	420	840	105	210	420	210	420	420
3	1	1	0	1	0	0	0	0	0
5	6	7	4	4	1	0	3	3	3
7	7	7	6	6	5	4	7	7	7
9	6	7	7	7	7	7	6	7	7
11	6	7	7	6	6	6	7	7	7
13	7	7	6	7	6	6	7	7	7
χ^2 significance level	0.001	0.001	0.001	0.01	0.001	0.001	0.001	0.001	0.001

The figures represent the number of assessments, out of a total of seven, in which disease incidence exceeded

35 per cent

Fig. 41. Blister blight incidence during the post south-west monsoon period in different treatments



at 210g of each compound. The lower dosage, 105g each compound, was satisfactory at the three-day treatment interval only.

During the post S.W.monsoon period, at all the levels of fungicide use, nickel chloride by itself or in combination with copper oxychloride, gave excellent disease control : even at the longest treatment interval of 13 days, blister infection (average of six assessments) was below the economic threshold (Fig. 41). However, the higher rate of nickel chloride was significantly superior to the lower rate, at 11- and 13-day spray intervals. In the case of copper oxychloride, the average of six assessments of disease incidence was above the critical threshold at the 210g per ha rate 13-day intervals, but all other copper treatments were satisfactory. Comparison of the data on disease incidence recorded at equal rates of fungicides used shows that nickel chloride was always superior to copper oxychloride. Similarly, the combination of copper-nickel was superior to copper oxychloride alone.

At 210g per ha of nickel chloride in the post monsoon period the dependence of the treatment interval was significant, but at 420g per ha the spraying interval was not significant (Table 30). Similarly, at the two higher levels of copper-nickel combination the dependence of the blister blight infection on the treatment intervals, with reference to the threshold disease level, was not significant, but at the lower rate of 105g of each, the interaction

Table 30. Interaction of dosage, spray interval and fungicide action in the post S.W. monsoon period
(October - November)

Spray interval days	Copper oxychloride g/ha			Copper oxychloride + Nickel chloride g each/ha			Nickel chloride g/ha		
	210	420	840	105	210	420	210	210	420
3	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0	0
11	3	0	0	0	0	0	0	1	0
13	4	4	3	2	0	0	0	3	0
χ^2 significance level	0.02	0.001	0.01	0.1	NS	NS	NS	0.05	NS

The figures represent the number of assessments, out of a total of six, in which the disease incidence exceeded 35 per cent

was significant. On the other hand, at all the three copper oxychloride rates blister blight incidence, with reference to the critical threshold value was significantly dependent on the treatment interval. At 210g per ha only, up to a spraying interval of seven days, the disease was below the critical level of 35 per cent throughout, while at the nine-day interval, infection was above the critical threshold on one occasion, and at 11- and 13-day intervals, it was higher on three and four occasions, respectively. At 420 and 840g per hectare blister blight incidence was over 35 per cent at 13-day interval only.

6.5. STUDIES ON CERTAIN FORMULATIONS OF TRIAZOLES IN DISEASE CONTROL

Triazoles are a modern group of organic fungicides. They are systemic and inhibit the synthesis of ergosterol in fungal metabolism. Ergosterols are essential for fungal growth and reproduction.

Triazoles belong to 14 α Demethylation inhibitors (DMI), blocking cytochrome oxidase P-450, the enzyme which hydroxylates the 14 α -methyl group. Many of the triazoles are systemic in action and are effective at very low dosage rates. They control, practically almost all classes of fungal pathogens except Peronosporales. A number of fungicides based on triazoles have been evaluated, the important amongst which are discussed.

6.5.1. Evaluation of bitertanol

A 25 per cent wettable powder (WP) formulation of bitertanol, a triazole compound, was critically screened against blister blight disease.

6.5.1.1. BITERTANOL : EFFECT OF DOSAGE AND SPRAY INTERVAL
ON INFECTION : In a field experiment carried out during the north-east monsoon, bitertanol (WP) was tried at different rates at two intervals, in order to identify the right treatment. The treatments were put out with an air-blast spraying machine. The data in Table 31 show blister blight infection as an average of ten weekly assessments.

Bitertanol offered good control of the disease. At 300 and 400g per hectare, at seven-day intervals, the infection was significantly less than the standard treatment. When the interval was extended to 14 days, the infection levels were below the critical threshold. At 200g per hectare, at seven-day intervals, the disease incidence was less than the standard but the difference was not significant. The disease level marginally exceeded the economic threshold when the interval was extended to 14 days with 200g of bitertanol per hectare.

Table 31. Bittertanol* (WP) : Effect of dosage and spray interval on infection

Treatment	Rate/ha	Spray interval days	Bilster blight incidence %
Bittertanol	200g	7	22.8
Bittertanol	200g	14	37.0
Bittertanol	300g	7	19.6
Bittertanol	300g	14	31.2
Bittertanol	400g	7	16.1
Bittertanol	400g	14	31.5
Copper oxychloride + Nickel chloride	210g + 210g	7	24.9
Control	Unprotected	-	55.1
LSD (P = 0.05)			4.4

* As Baycor 25% WP

6.5.1.2. COMPARATIVE EFFICACY OF BITERTANOL : The efficacy of bitertanol (WP) at different rates was compared in a field investigation carried out throughout the disease seasons covered by both south-west and north-east monsoons. The treatments were imposed with an air-blast spraying machine. The data in Table No. 32 represent, infection level as an average of 21, weekly assessments carried out from June to December.

Blister blight infection was significantly lower in plots sprayed with bitertanol at 200g per hectare than at 100g. However, when bitertanol at the lower dosage was combined either with copper or nickel, infection level was comparable to 200g but the difference was not significant.

6.5.1.3. EVALUATION OF BITERTANOL WITH PROTECTANTS AND THERAPEUTANTS : Bitertanol (WP) was tested both singly and in combination with inorganic fungicides, namely, copper oxychloride and nickel chloride, in a field experiment during north-east monsoon. The treatments were applied with an air-blast mist spraying machine. The results are presented in Table 33 which show the disease incidence as an average of five, weekly assessments, between October and November.

Infection level with bitertanol (200g) marginally exceeded the standard treatment, but the difference between them was

Table 32. Efficacy of bitertanol* (WP)

Treatment	Rate/ha	Spray interval days	Blister blight incidence %
Bitertanol	100g	7	33.6
Bitertanol	200g	7	27.8
Bitertanol + Copper oxychloride	100g + 210g	7	30.0
Bitertanol + Nickel chloride	100g + 210g	7	26.0
Copper oxychloride + Nickel chloride	210g + 210g	7	28.8
Control	Unprotected	-	55.0
LSD (P = 0.05)			3.5

* As Baycor 25% WP

Table 33. Evaluation of bitertanol* (WP) with protectants and therapeutants

Treatment	Rate/ha	Spray Interval days	Bilater blight incidence %
Bitertanol	200g	7	27.0
Bitertanol + Copper oxychloride	200g + 210g	7	23.4
Bitertanol + Nickel chloride	200g + 210g	7	25.2
Copper oxychloride + Nickel chloride	210g + 210g	7	24.0
Control	Unprotected	-	52.7
LSD (P = 0.05)			4.6

* As Baycor 25% WP

insignificant. Combination of bitertanol with copper oxychloride and nickel chloride resulted in superior control, than bitertanol used alone.

6.5.1.4. EVALUATION OF AN EMULSIFIABLE FORMULATION OF BITERTANOL : An emulsifiable formulation (EC) of bitertanol containing 30 per cent of the active ingredient was evaluated, during both south-west and north-east monsoons. The formulation was sprayed with an air-blast spraying machine. Bitertanol was also evaluated by alternating it with copper oxychloride treatment. The data presented in Table 34 represent an average of 21, weekly assessments, undertaken between July and December.

Disease incidence in the plots treated with bitertanol in combination with copper was comparable to the standard treatment; the degree of infection under both was below the economic threshold. The combination was superior to bitertanol used alone even at the highest rate. This indicates the possibility of reduction in the dosage of bitertanol when combined with copper oxychloride, for an effective disease control. Bitertanol at 170ml per hectare provided good blister blight control.

6.5.2.1. STUDIES ON THE EFFICACY OF CYPROCONAZOLE : The performance of a new emulsifiable formulation containing five per

Table 34. Evaluation of an emulsifiable formulation of bitertanol*

Treatment	Rate/ha	Spray interval days	Blister blight incidence %
Bitertanol/CuOCl ₂ /CuOCl ₂ + NiCl ₂ **	85ml/420g/210g + 210g	7	37.3
Bitertanol/CuOCl ₂ /CuOCl ₂ + NiCl ₂	170ml/420g/210g + 210g	7	33.5
Bitertanol/CuOCl ₂ /CuOCl ₂ + NiCl ₂	340ml/420g/210g + 210g	7	30.7
Bitertanol + CuOCl ₂ /CuOCl ₂ /CuOCl ₂ + NiCl ₂ ***	45ml + 210g/420g/210g + 210g	7	36.1
Bitertanol + CuOCl ₂ /CuOCl ₂ /CuOCl ₂ + NiCl ₂	85ml + 210g/420g/210g + 210g	7	33.7
Bitertanol + CuOCl ₂ /CuOCl ₂ /CuOCl ₂ + NiCl ₂	170ml + 210g/420g/210g + 210g	7	30.1
CuOCl ₂ + NiCl ₂	210g + 210g	5/7	29.5
LSD (P = 0.05)			2.2

* As Baycor 30% EC

CuOCl₂ = Copper oxychloride ; NiCl₂ = Nickel chloride

** Bitertanol was alternated with Copper oxychloride + Nickel chloride from June to October; the plots were sprayed with Copper oxychloride + Nickel chloride thereafter till December

*** Bitertanol + Copper oxychloride was also alternated similarly as above

cent cyproconazole (Atemi 50 SL) was evaluated in a field investigation. The treatments were put out with an air-blast spraying machine. The data in Table 35 represent an average of 18, weekly assessments.

Cyproconazole at 400ml per hectare, at seven-day intervals, was significantly superior to all other treatments; this was followed by the same at 200ml, which also offered excellent disease control at seven-day intervals.

There was no significant difference between cyproconazole at 200ml and its combination, at equal rate, with chlorothalonil (75WP) sprayed at seven-day intervals. The disease incidence exceeded the economic threshold level of 35 per cent when cyproconazole was sprayed at extended interval of 14 days.

6.5.2.2. DOSAGE PERFORMANCE OF CYPROCONAZOLE : The dosage performance of cyproconazole was assessed in a field investigation in the following year. The emulsifiable test formulation was sprayed with an air-blast spraying machine. The infection data in Table 36 represent the average of 15, weekly assessments.

Blister blight incidence was significantly lower in plots treated with 400ml of cyproconazole, at seven-day intervals than the standard treatment. The disease incidence exceeded the economic threshold

Table 35. Evaluation of cyproconazole*

Treatment	Rate/ha	Spray interval days	Bilster blight incidence %
Cyproconazole	200ml	7	29.9
Cyproconazole	400ml	7	23.1
Cyproconazole	400ml	14	37.7
Cyproconazole	600ml	14	38.3
Cyproconazole + Chlorothalonil	200ml + 200g	7/14	31.2
Copper oxychloride + Nickel chloride	210g + 210g	5/7	33.7
Control	Unprotected	-	57.8
LSD (P = 0.05)			2.9

* AS Atami 50 SL (SAN 619 F)

Table 36. Dosage performance of cyproconazole*

Treatment	Rate/ha	Spray interval days	Blister blight incidence %
Cyproconazole	200ml	7	38.4
Cyproconazole	400ml	7	27.4
Cyproconazole	400ml	14	39.5
Cyproconazole	600ml	14	35.6
Cyproconazole + Chlorothalonil	100ml + 400g	7/14	36.2
Copper oxychloride + Nickel chloride	210g + 210g	5/7	34.1
Control	Unprotected	-	59.6
LSD (P = 0.05)			3.3

* As Atemi 50 SL (SAN 619 F)

marginally when the test fungicide was sprayed at 14-day intervals at 600ml per hectare, but the difference between this and the standard treatment was not significant. Application of cyproconazole in combination with chlorothalonil, at seven-day intervals in the south-west and 14-day interval during the north-east monsoon resulted in disease control superior to the former used alone, at double the rate.

6.5.3.1. EVALUATION OF HEXACONAZOLE : A new triazole compound, hexaconazole (Anvil 5 SC), was tested for efficacy at four different rates, as also in combination with copper and nickel fungicides at the lowest rate. Fungicides were applied with a pressure retaining knapsack sprayer. The investigation was carried out during north-east monsoon, from October to December. The data in Table 37 represent the average of six, weekly assessments. Hexaconazole, at the lowest dosage (35ml) was ineffective by itself. Disease incidence was low at the higher rates, but the differences between them and the standard treatment were not significant. The disease control was good when hexaconazole at the lowest rate (35ml) was combined with copper oxychloride.

6.5.3.2. STUDIES ON THE EFFICACY OF A NEW FORMULATION OF HEXACONAZOLE : A field trial was carried out to assess the efficacy of a new formulation of hexaconazole (Contaf 5% EC) during south-west and north-east monsoons. The treatments

Table 37. Evaluation of hexaconazole*

Treatment	Rate/ha	Blister blight incidence %
Hexaconazole	35.0ml	36.4
Hexaconazole	87.5ml	32.4
Hexaconazole	175.0ml	28.5
Hexaconazole	210.0ml	24.5
Hexaconazole + Copper oxychloride	35 ml + 210g	26.8
Hexaconazole + Nickel chloride	35 ml + 210g	31.3
Copper oxychloride + Nickel chloride	210g + 210g	24.0
Control	Unprotected	52.7
LSD (P = 0.05)		4.6

* As Anvil 5 SC

were applied with an air-blast spraying machine. The fungicide was tested at four rates applied at seven-day intervals during south-west and at 14 days in north-east monsoon seasons. The data presented in Table 38 represent the average of 18, weekly assessments.

The lowest rate of disease incidence was recorded in plots sprayed with hexaconazole, at the highest rate of 400ml per hectare and the infection level was significantly lower than the standard treatment. At 200ml per hectare, the infection was marginally less than the standard but the difference was not significant. Control at the lowest dosage (50ml) of hexaconazole was not satisfactory.

6.6. INTEGRATED APPLICATION OF PROTECTANT, THERAPEUTANT AND SYSTEMIC FUNGICIDES

At some of the systemic fungicides, namely tridemorph and pyracarbolid exhibited powerful antispore action and also suppressed the mite populations in dry weather, attempts were made to develop spray schedules wherein the systemic, protectant and therapeutic fungicides were sprayed in an integrated schedule. As pyracarbolid became unavailable, tridemorph was used in the studies. Of the many experiments, only the results of the important ones are presented.

Table 38. Evaluation of a new formulation of hexaconazole*

Treatment	Rate/ha	Spray interval days	Blister blight incidence %
Hexaconazole	50ml	7/14	43.2
Hexaconazole	100ml	7/14	36.6
Hexaconazole	200ml	7/14	31.7
Hexaconazole	400ml	7/14	27.2
Hexaconazole + Copper oxychloride	50ml + 210g	7/14	39.6
Copper oxychloride + Nickel chloride	210g + 210g	5/7	32.5
Control	Unprotected	-	57.8
LSD (P = 0.05)			2.3

* As Contaf 5% EC

6.6.1. Comparison of Integrated schedule with conventional spraying

Two large scale field investigations were carried out in two estates in the Anamallais to assess the performance of the integrated spray schedule wherein the systemic fungicide tridemorph (180ml per hectare) was used in the beginning (three rounds) from the middle of May to the middle of June, then switching over to the protectant copper oxychloride-nickel chloride (210g each per hectare) till the middle of September. From the last week of September the treatment was reverted to tridemorph but at extended intervals (three to four rounds) till the end of the disease season. An acrylic binder at 500g per hectare was incorporated into tridemorph treatments. The infection level was compared with that under continuous copper + nickel combination throughout the seasons. Fungicides applications were made with an air-blast spraying machine. Each block was ten hectares; 1000 shoots picked at random from the harvest of each block at every assessment, were examined individually and assessed. The per cent infection at each assessment is presented individually in Tables 39 and 40.

Blister blight infection was lower in all the assessments in the block under the integrated schedule than the conventional treatment in one estate (Table 39). In the other estate, on two out of eight occasions, blister blight incidence was more in block under integrated schedule (Table 40).

Table 39. Evaluation of Integrated Schedule (Estate-1)

Treatment	Assessment (% blister blight incidence)							
	1	2	3	4	5	6	7	8
Integrated Schedule*	41	33	18	16	8	6	36	14
Copper oxychloride + Nickel chloride	52	44	32	32	14	16	52	32

* Two applications of tridemorph in mid May and early June at fortnightly interval; copper oxychloride + nickel chloride at weekly interval from mid June to mid October; three applications of tridemorph at fortnightly interval from end October to early December

Table 40. Evaluation of Integrated Schedule (Estate-2)

Treatment	Assessment (% blister blight incidence)							
	1	2	3	4	5	6	7	8
Integrated Schedule*	17	15	16	16	14	23	20	18
Copper oxychloride + Nickel chloride	24	17	33	6	16	25	17	20

* Described in the previous Table

6.7. EVALUATION OF ULTRA LOW VOLUME SPRAYING EQUIPMENT

A field experiment was carried out to evaluate efficacy, and economy in the use of two micron sprayers namely, Micron ULVA-8 and Micron Herbi. The ULV copper fungicide formulation was supplied with the equipment. Comparison was made with a pressure retaining knapsack sprayer, covering a single row of bushes on each side. Apart from the ULV copper formulation, wettable copper oxychloride was used with all these sprayers for studying the efficacy. Leaf samples were drawn from a transect marked at the centre of each plot.

As the ULV copper formulation contained 0.3158 per cent metallic copper, the quantity of copper put out per hectare with it was 14.21g. Blister control achieved was poor (Table 41). Disease control using 50 per cent wettable copper at 420g per hectare obtained with Micron ULVA-8 was superior to that obtained with Micron Herbi, but both were inferior to that achieved with knapsack spraying equipment.

6.8. ROLE OF SPRAY ADJUVANTS IN ENHANCING DISEASE CONTROL.

In a field experiment the efficacy of two non-ionic wetting agents was compared. They were incorporated at 0.05 per cent concentration into copper oxychloride - nickel chloride fungicide mixture and

Table 41. Evaluation of Ultra Low Volume (ULV) spraying equipment

Treatment	Spray Equipment	Rate/ha	Spray Volume litres/ha	Blister blight incidence %
ULV Copper Formulation	Micron Herbi	4.51	4.5	42.0
Copper oxychloride	Micron Herbi	420g	5.0	40.7
Copper oxychloride	Micron ULVA-8	420g	11.0	35.0
Copper oxychloride	Knapsack	420g	175.0	26.3

Table 42. Spray adjuvants

Treatment	Rate/ha	% Blister blight incidence	
		S. W. Monsoon	N. E. Monsoon
Copper oxychloride + Nickel chloride + Triton AE	210g + 210g + 87.5ml	29.7	25.6
Copper oxychloride + Nickel chloride + Sud FGN	210g + 210g + 87.5ml	33.3	26.8
Copper oxychloride + Nickel chloride	210g + 210g	39.4	30.9
Control	Unprotected	58.8	53.8
LSD (P = 0.05)		5.3	4.3

sprayed with a pressure retaining knapsack sprayer. The data in Table 42 show, separately, the average per cent infection of ten assessments during south-west monsoon and five in north-east monsoon.

Addition of spray adjuvants improved the performance of fungicides. Blister blight incidence was significantly lower in plots where Triton AE was used as a spray adjuvant during both south-west and north-east monsoon seasons, when compared to the treatment in which no wetting agent was incorporated. However, there was no significant difference between the efficacy of Triton AE and Snid-PGN.

CHAPTER - 7

**DISEASE CONTROL : EVALUATION OF
ALTERNATIVE CHEMICALS**

DISEASE CONTROL : EVALUATION OF ALTERNATIVE CHEMICALS

While studying the physiology of the basidiospore germination, it was observed that the basidiospores of the blister blight fungus germinated readily at the neutral and alkaline pH and their germination was greatly inhibited at the acidic pH. This property was utilised and experiments were conducted to see whether the disease could be controlled, just by spraying dilute acid water sprays having a low pH.

7.1. EFFECT OF DILUTE SOLUTIONS OF NITRIC, SULPHURIC AND PHOSPHORIC ACIDS ON BLISTER BLIGHT INFECTION

A field trial was carried out to study the effect of dilute solutions of nitric, sulphuric and phosphoric acids against blister blight disease. Appropriate quantities of these acids were diluted in tap water and individual solutions were prepared maintaining a uniform pH of 1.3. Acid water solutions were prepared afresh, each time before spraying. They were sprayed with a hand atomiser in a non-replicated clonal block (TES-34), highly susceptible to blister blight disease.

Apart from assessment of disease, the harvested leaf in each treatment was also manufactured in a mini-CTC unit and sent to professional tasters in Cochin for organoleptic evaluation. The black

tea samples were also analysed for thearubigins (TR), theaflavins (TF) and high polymerised substances (HPS) by the Tea Technology Division of the Tea Research Institute. The data in Table 43 represent the infection level as an average of ten weekly assessments and valuation for each treatment as an average of five assessments.

Daily nitric acid sprays offered very good disease control. In all other treatments, with acid sprays at different spray intervals, the infection was above the level of economic threshold of 35 per cent. The teas valued by the tasters, under the nitric acid treatment, were superior in quality to other treatments.

The biochemical parameters were not affected by any of the treatments (Table 44). The levels of colouring constituents such as, TF, TR and HPS and total colour values of teas made from the treated leaves registered an improvement over untreated control.

As nitric acid performed better than sulphuric and phosphoric acids, this was selected for further evaluation.

7.2. ROLE OF ACID WATER IN ARRESTING INFECTION BY *E. VEXANS*

Potted plants of the susceptible clone TES-34 were used in the study. In the first series, the leaves were inoculated with the spores of *E. vexans*; the leaves were treated with dilute nitric

Table 43. Effect of dilute solutions of different acids on blister blight infection and quality

Treatment	Quantity ml per litre	Spray interval days	Average infection %	Valuation made tea Rs/Kg
Nitric acid	3.0	1	20.6	15.58
Nitric acid	3.0	2	39.2	15.43
Nitric acid	3.0	3	51.2	15.34
Sulphuric acid	1.5	1	37.6	15.43
Sulphuric acid	1.5	2	51.6	15.39
Sulphuric acid	1.5	3	69.8	15.09
Phosphoric acid	6.0	1	57.2	15.32
Phosphoric acid	6.0	2	66.4	15.06
Phosphoric acid	6.0	3	73.6	14.95
Control	Untreated		84.4	15.23

Table 44. Acid sprays and chemical quality parameters

Treatment	Spray Interval days	TF %	TR %	HPS %	Total* Liquour Colour
Nitric acid	1	1.00	8.38	9.65	5.99
Nitric acid	2	0.96	8.39	9.73	5.96
Nitric acid	3	0.88	8.46	9.48	5.66
Sulphuric acid	1	0.86	8.18	9.85	5.75
Sulphuric acid	2	0.84	8.15	10.57	6.12
Sulphuric acid	3	0.91	8.19	10.11	5.90
Phosphoric acid	1	0.86	7.75	9.94	5.78
Phosphoric acid	2	0.86	7.77	10.51	6.03
Phosphoric acid	3	0.84	7.51	9.93	5.64
Control	Untreated	0.85	7.37	9.42	5.34

* O D at 460nm of two per cent tea brew

Each value is the average of five determinations

acid water with a pH of 2.0 following inoculation at 24, 48 and 72 hours.

In the second series, leaves were first treated with acid water and at 24, 48 and 72 hours following the treatments, were inoculated with *E. vexans*. Five plants were maintained in each treatment.

Blister blight infection was low when the leaves were treated with acid water 24 and 48 hours after inoculation (Table 45). Acid water treatment after 72 hours following inoculation had no effect and the infection was high.

Similarly, infection was low when the leaves were first treated with acid water and inoculated 24 hours later with *E. vexans* (Table 46). Disease incidence was high at 48 and 72 hours treatments intervals.

7.3. STUDIES ON THE BLISTER BLIGHT CONTROL WITH DILUTE NITRIC ACID WATER SPRAYS

A field experiment was performed to explore the possibility of obtaining adequate control of blister blight disease, with dilute acid water sprays by preventing spore germination.

Table 45. Effect of acid water on infection of the shoots inoculated with

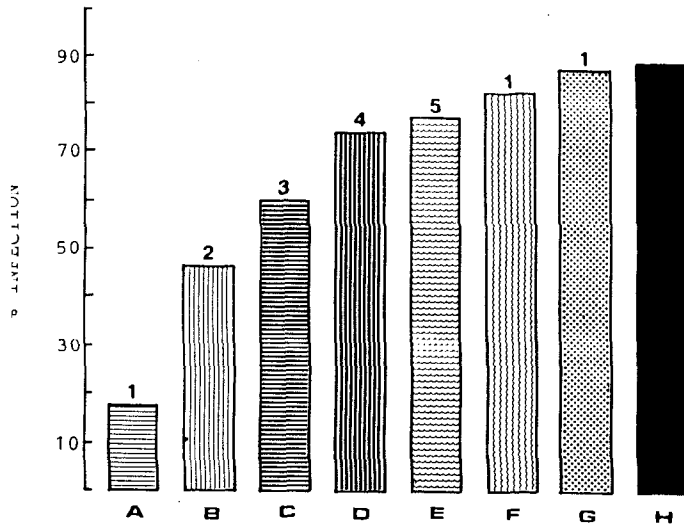
E. vexans

Interval between inoculation and acid water treatment hours	Leaves inoculated No.	Leaves infected No.	Blister blight incidence %
24	28	3	10.7
48	19	4	21.1
72	25	20	80.0
Control	17	17	100.0

Table 46. Effect of inoculation on the blister infection of shoots treated with acid water

Interval between acid water treatment and inoculation hours	Leaves inoculated No.	Leaves infected No.	Blister blight incidence %
24	22	5	22.7
48	26	19	73.1
72	18	14	77.8
Control	17	14	82.4

Fig. 42. Bar chart showing blister blight infection in dilute acid sprays (A-E), alkali sprays (F and G) and unprotected control (H). Number shown on the top of each bar represents the spray interval in days



Aqueous solutions of nitric acid were prepared by adding 3 ml of concentrated acid in one litre of water (pH 1.3). Similarly, alkaline solutions were prepared with 0.1N sodium hydroxide to give pH of 8.0 and 9.0. These acid and alkali solutions were sprayed on tea plants, in small non-replicated plots, with a hand atomizer employing a spray volume of 175 litres per hectare. Acid sprays were done at one, two, three, five and seven days, whereas, dilute alkali sprays were applied daily. The teas manufactured from each treatment were sent to professional tasters for organoleptic evaluation.

In the Fig. 42, the average disease incidence over the duration of the experiment, in the seven treatments and the control is presented. Only with acid spray, sprayed daily, the infection level was well below the critical threshold limit of 35 per cent; in all other acid spray treatments at intervals of two, three, five and seven days, disease incidence was above the critical limit. In alkali spray treatment at both pH 8.0 and 9.0 the disease incidence was very high and was on par with untreated control.

Highest valuation was received from teas sprayed with acid water daily. The valuation was on par at two- and three-day intervals, while it fell gradually at five- and seven-day spray intervals. Teas sprayed with dilute alkaline water, were low in quality, and valued, almost, on par with control (Table 47).

Table 47. Effect of acid and alkali treatments on the quality of manufactured tea

Treatment	pH	Spray interval days	Valuation made tea Rs/Kg
Acid water	1.3	1	14.60
Acid water	1.3	2	14.20
Acid water	1.3	3	14.20
Acid water	1.3	5	14.10
Acid water	1.3	7	13.65
Alkali water	8.0	1	13.50
Alkali water	9.0	1	13.85
Control	Untreated	-	13.50

Table 48. Effect of acid sprays on quality during non-disease season

Treatment	Concentration %	Taster's Report (Marks awarded)							Valuation Rs/Kg
		Leaf	Infusion	Colour	Strength	Quality	Total		
Nitric acid	0.1	6.7	7.6	6.6	6.9	7.3	35.1	29.62	
Phosphoric acid	0.2	7.2	6.6	5.8	6.0	5.4	31.0	29.20	
Control	Untreated	7.0	6.6	5.4	5.6	4.8	29.4	28.75	

7.4. EFFECT OF ACID WATER SPRAYS ON QUALITY DURING NON-DISEASE SEASON

Daily sprays of acid water not only controlled blister blight, but also improved the overall quality of teas. However, one point needed clarification - whether the quality improved because of low blister blight infection, since severely diseased leaves are known to produce low quality teas. Hence, an experiment was carried out during the non-disease season between March and May, when the plots were totally free of blister blight disease. The investigation was taken up in clonal tea (TES-34). One day before every plucking, the plots were sprayed with hand operated 'Akela' sprayer at 175 litres per hectare. The plots were plucked on the following day and the black tea samples were manufactured. They were sent to professional tasters in Cochin for organoleptic evaluation. The data in Table 48 represent an average of ten assessments.

Tea manufactured from leaf sprayed with water containing nitric acid registered an average increase of 87 paise per kilogram over untreated. The increase was 45 paise in phosphoric acid treatment. Nitric acid water treatment was superior to all others and improved the infusion, colour, strength and quality of teas. The results, thus, were very interesting.

CHAPTER - 8

DISCUSSION

DISCUSSION

Of all the diseases that affect tea in southern India, blister blight caused by *Exobasidium vexans*, is the most important and warrants intensive control measures on extensive scale. Though reported from north-east India as early as 1868, this disease made its appearance all of a sudden, in southern India in 1946 (Subba Rao, 1946); later it had spread to Sri Lanka (Tubbs, 1947) and Indonesia (Reitsma and van Emden, 1950). This disease was reported to occur in Japan in 1922 (de Welle, 1959a) and in Taiwan in 1938 (Liau, 1966).

8.1.1. The Pathogen

The weather conditions of the south-west monsoon are highly conducive and the fungus completes its life cycle in a relatively short period of 11 days. The life cycle may extend up to 28 days during the fluctuating climatic conditions of the north-east monsoon. Blister blight appears with the onset of the south-west monsoon, generally in June, in southern India. The disease is severe from June to the middle of September. Once the south-west monsoon starts tapering off, the severity of the disease decreases; again it increases from mid October to early December. Almost all the tea growing areas in southern India experience severe pressure from disease in November. Tea tracts in the Anamallais (Colmbatore), and High Wavys (Madurai)

in Tamil Nadu, Central Travancore, High Range, Malabar Wynaad and Nelliampathys in Kerala and Chikmagalur and Hassan in Karnataka suffer from severe onslaught of the infection as they are in the south-west monsoon belt. Areas, namely, the Nilgiris and Nilgiri - Wynaad which are predominantly in the north-east monsoon zone, are affected by the disease from October to January and the disease incidence, excepting in November, is not severe.

3.1.2. Epidemiology

Climatic conditions, namely, temperature, relative humidity and rainfall are believed to play a cardinal role in influencing the severity of the disease. Disease incidence was found to increase under wet and cloudy weather (Visser, et al., 1961). In the present investigation carried out for six years in southern India, the sunshine hours, though highly significant, expressed only a mild negative correlation with the disease incidence (Fig. 29). This could be due to an important additional factor, viz., the leaf wetness, which played a decisive role in the severity of the disease.

Venkata Ram (1979) found that an optimum period of 11 hours of leaf wetness was needed for infection. He observed that at 13 hours, maximum infection occurred; this is a conclusive proof that 16 hours is not required for entry to be accomplished under the most favourable conditions as claimed by Loos (1951). This finding

is extremely relevant as it explains why blister blight epiphytotic occur in southern India even when the number of sunshine hours occurring are adverse to the outbreak of the disease (Venkata Ram, 1971). Thus the forewarning systems suggested by Homburg (1953), Van der Knaap (1955), de Welle (1959a) and Mulder (1961) offered little success under south Indian conditions. Later studies in Sri Lanka (Kerr and de Silva, 1969) also confirmed the importance of leaf wetness. The effect of sunshine after the infection is established in the 11 to 14 hours period can be the temperature effect. Venkata Ram (1979) reported that it would take 15 to 17 hours at 30°C of leaf temperature for the infection to be inhibited in situ. However, the maximum temperature during the S.W. monsoon in southern India rarely crosses 23°C and the differences between the maximum and minimum temperature do not vary much. In the present study a highly significant and positive correlation was established between temperature and infection (Fig. 31) when the former was in the range of 17.5°C and 21°C.

Though wet weather increased severity (Visser et al., 1961) rainfall was not considered to have a direct relation to blister blight epiphytotic (de Welle, 1959a). The results of the experiment presented here were significant but exhibited mild positive correlation (Fig. 30).

The maximum relative humidity (R.H.) in southern India during the S.W. monsoon was found to range from 95 to 100 per cent which was highly conducive for disease development. In a study on the impact of minimum R.H. on infection, a significant and positive correlation was noticed between the two variables (Fig. 32). Maximum infection was noticed when the minimum R.H. was between 75 and 85 per cent. Studies in Indonesia revealed that at an average R.H. of 83 per cent for a period of 20 to 24 days, maximum infection resulted (Huysmans, 1952).

8.1.3. Damage and Crop loss

Crop loss occurred when the infection level crossed 35 per cent. Similar observation was made by Webster and Park (1956). De Silva et al. (1972) reported that the effect of the disease was most marked in the early part of the pruning cycle and diminished towards the end of the cycle. This may be due to the low level of infection occurring in their unshaded experimental plots. In the present investigation a strong negative correlation was recorded between the spray interval and infection and crop yield, in all the years of the pruning cycle; this could be attributed to uniformly high levels of infection in the experimental blocks (Figs. 25, 26, 27 and 28). Based on the studies, it was concluded that a level of 35 per cent of leaf infection can be considered as the economic threshold limit.

8.1.4. Host tolerance

Certain clones were observed to possess high tolerance to blister blight disease (Figs. 34 and 37). They were also hardy, high yielding and produced quality teas. Presently, replanting, replacement planting, no-tillage replanting and single and block infilling of tea fields are being done with high yielding, hardy and quality clones. Disease tolerance of these clones is highly desirable as it reduces the overall cost of disease control.

In a study on disease control in clonal tea in Sri Lanka, de Silva et al. (1974) found that crop loss caused by blister blight in the clone TRI 2024 was negligible in all the years of pruning cycle. They felt that high yielding clones, even if susceptible, would grow more rapidly compared to average seedling tea. Any losses suffered by clonal tea, due to disease in individual harvests, may be made up quickly resulting in no significant differences in crops over long periods; this is regardless of whether the disease was controlled or not, thus, achieving savings on disease control in clonal tea (de Silva et al., 1974).

Since the pathogen has a short life cycle, several generations are completed in a single season. Tea being a perennial plant, there is every possibility that a highly tolerant clone, may, over a period of time become susceptible to the disease (Venkata Ram, 1961) due

to the development of biological races of the pathogen. Venkataramani (1950) suspected the presence of physiological strains of the pathogen in southern India.

8.1.5. Disease control in tea recovering from pruning

Incorporation of low concentrations of agricultural antibiotics to copper fungicide sprays improved the performance of the latter in controlling blister blight in tea recovering from pruning (Table 4). Similar results were obtained in Darjeeling (Barua *et al.*, 1978). However, Arulpragasam *et al.* (1982) did not observe any synergistic effect when the Formulation-3 (Plantomycin) was used in combination with copper fungicide.

The exact mode of synergism between the antibiotics and copper against the blister blight pathogen is not well understood. Streptomycin has been reported to damage the cell membrane as shown by the leakage of metabolites (Anand and Davis, 1960). This would increase the penetration of copper into the fungal spore resulting in decreased infection. Streptomycin is also known to inhibit protein synthesis (Hahn *et al.*, 1962). In the studies carried out in the Peoples' Republic of China, polyoxin at 100 ppm was also found to be effective in controlling the disease (Tzong-Maochen and Shin - Funchen, 1982).

A liquid formulation containing 20 per cent nickel chloride effectively controlled blister blight when used in combination with copper oxychloride (Table 8). Addition of a non-ionic wetting agent improved disease control further. The overall treatment cost with this combination was low and the tea industry widely applied this finding, as it was not only effective but also economical.

As the treatment with protectant-eradicant fungicides had to be repeated at short intervals, attempts were made to control the disease in tea recovering from pruning using organic fungicides at extended intervals. Both chlorothalonil and captafol were disappointing when the spray interval was extended to five days. However, tridemorph provided good control in a short term trial; the study will be continued for further confirmation.

8.1.6. Disease control in tea under plucking

Many fungicides of protectant, eradicant and systemic nature - both organic and inorganic - were evaluated in tea under plucking to identify the most effective ones. Earlier work on the efficacy of the fungicides was reviewed by Venkata Ram (1964) and Chandra Mouli (1979b). In the present study it has been found that cuprous oxide had an edge over copper oxychloride in controlling blister blight, at the same dosage (Table 18). There was no significant difference among the three copper oxychloride formulations tested.

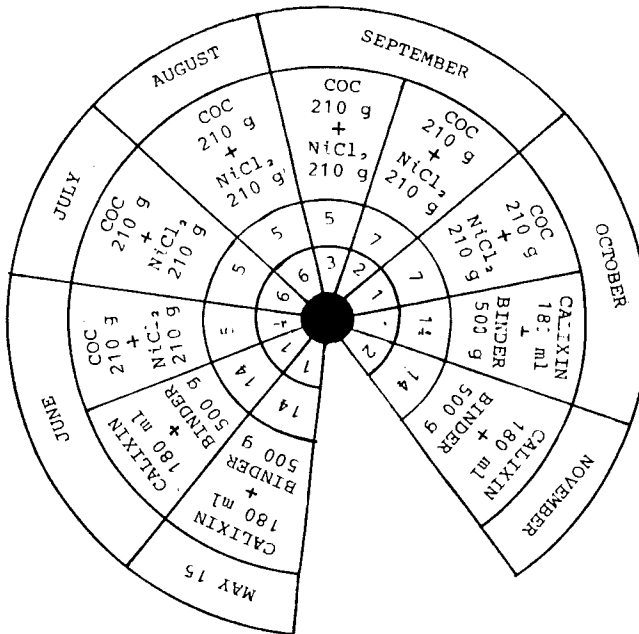
Similar results were obtained under conditions in Himachal Pradesh (Gulati and Satyanarayana, 1989). Bordeaux mixture did not offer satisfactory control, probably, due to the low copper content of the formulations (Table 19). Ammoniacal copper formulation was effective only in combination with nickel chloride (Table 14).

Many organic fungicides with protectant-therapeutant action were evaluated. Chlorothalonil provided better control than dithianon (Table 21). Chlorothalonil was more effective than the conventional copper-nickel treatment (Table 22). Shanmuganathan and Saravanapavan (1974) observed that chlorothalonil was more effective than cuprous oxide, but significantly less persistent than the latter due to poor tenacity. This could be overcome by addition of a suitable wetting agent during the high monsoon period.

Systemic fungicides such as tridemorph and pyracarbolid with long residual activity permitted their application on extended rounds; thus, they provided considerable advantage over the protectant-eradicator, copper-nickel fungicides which had to be applied at short intervals. These fungicides were powerful antisporegents and the treated blister lesions produced a very low number of basidiospores (Tables 24, 25 and 26). Both pyracarbolid and tridemorph suppressed the mite pests in the following dry weather (Table 27 and 28). Tridemorph was reported earlier also to possess acaricidal action on tea mites (Chandrasekaran, 1980). Pyracarbolid



Fig. 43. Integrated spraying schedule



provided good control of the disease (Venkata Ram, 1975; Satyanarayana et al., 1975; Shanmuganathan and Saravanapavan, 1978) but the product became unavailable to the growers for commercial use.

An integrated spray schedule based on critical field experimentation under various agroclimatic zones of southern India, has been evolved to combat blister blight economically. In this schedule the systemic fungicide, tridemorph, is recommended in the beginning of the disease season followed by the protectant-therapeutant, copper-nickel combination, during the south-west monsoon and finally, reverting to systemic tridemorph during the north-east monsoon, till the end of the disease season. As a consequence, only 27 spraying rounds are needed as against 34 rounds of conventional copper + nickel treatments (Fig. 43). Thus, there will be a saving of seven rounds of fungicide application effecting a reduction of Rs.409.66 per hectare per season at the present input costs. Furthermore, fields sprayed with integrated schedule registered a substantial crop increase ranging from eight to ten per cent over the conventional treatment (Chandra Mouli, 1979a), making the schedule more lucrative.

There was a rapid degradation of Calixin in the samples which were processed at one, seven and 15 days after spraying. The residue levels sharply declined from 1.89 ppm at one day after spraying

to 0.11 ppm at 15 days after spraying, which was well within safe human consumption limits (Venkata Ram and Chandra Mouli, 1976 b).

The exact mode of action of morpholenes, to which tridemorph belongs is not well understood. Although the inhibition of sterol biosynthesis seems to be established, uncertainties about the precise site of inhibition still exist. The most recent report suggest that tridemorph inhibits at two different sites to different degrees (Koller and Scheinpflug, 1987). As morpholenes are not cross-resistant to sterol demethylation inhibitors (Butter *et al.*, 1984), reports that suggest the possibility of cross-resistance in the field are questionable (Hippe and Koller, 1986). Development of resistance to morpholenes has not been reported so far.

Introduction of organic fungicides based on triazoles opened new vistas in blister blight control. These fungicides with a low active ingredient, were effect even at low dosage rates. Bitertanol provided good control of the disease in the present study confirming the earlier reports (Arulpragasam *et al.*, 1987; Sudirman, 1987).

The overall treatment cost with bitertanol was more than the conventional copper + nickel fungicide sprays, due to the high cost of the former. However, the overall economics tilted in favour of bitertanol as the treatment with this resulted in an increase of the crop by 14.3 per cent over the conventional treatment (Chandra

Mouli, unpublished data). The dosage of bitertanol could be reduced from 200g to 100g per hectare when used as a tank mix with copper oxychloride (Table 32).

Of the other triazoles, hexaconazole and cyproconazole also offered good disease control (Tables 35, 36, 37 and 38). Good disease control has been obtained in Sri Lanka with hexaconazole and propiconazole and suitable recommendations have been made to the tea industry, there (Anonymous, 1988).

Though copper fungicide formulations contain inert ingredients such as fillers and surfactants, addition of non-ionic wetting agent to the copper + nickel sprays significantly improved the performance of the fungicide mixture during the monsoon season, by improving the tenacity (Table 42).

8.1.7. Effect of alternative chemicals

As the germination of the basidiospore of the blister blight pathogen was inhibited at the acidic pH range (Fig. 33), effort was made to control the disease by precluding spore germination on the tea leaf surface. This was attempted by foliar application of dilute nitric acid water (0.3%) at daily, two-, three-, five- and seven-day spray intervals. Dramatic disease control was achieved by daily application of nitric acid water. The treatments were not

phytotoxic and the quality of the tone has also improved. The teas from acid water treatment were valued at a price higher than untreated one (Table 47). Cloughly and Ellis (1980) recorded an increase in the content of theaflavins and reduction in the levels of thearubigins by adjusting the pH of the fermenting tea leaf to a pH of 4.5 to 4.8 by sprays of 0.2 M of orthophosphoric acid. In an investigation on the effect of acid sprays, an improvement in total liquor colour constituents in made tea over untreated control was recorded (Table 44).

Tea industry would considerably benefit by adopting certain important findings presented and discussed in this thesis.

SUMMARY

SUMMARY

Blister blight disease is a serious leaf disease problem in tea cultivation in southern India.

The pathogen *Exobasidium vexans*, the causative fungus of this disease completes its life cycle in a short period of 11-28 days. Both the south-west and north-east monsoon seasons, provide conducive climatic conditions for the pathogen to develop rapidly and cause epiphytotic.

Sunshine and infection were negatively correlated and increased sunshine lowered the infection. The minimum temperature during disease season, comprising both the S.W. and N.E. monsoon seasons, in southern India, in a six year study, was found to range from 14.4 to 19.7°C. Disease intensity increased as the minimum temperature increased showing a positive correlation. The minimum relative humidity (R.H.) also had a positive correlation with the infection. Monthly rainfall exhibited a positive correlation with disease incidence upto 1000mm. There was no direct relationship between the rainfall and infection when the former was more than 1000mm and above.

Crop loss occurred as the infection increased. There was a strong negative correlation existed between per cent infection

and crop yield in all the four years of the pruning cycle. When the infection level crossed 35 per cent crop yield suddenly dropped, indicating this mark as the critical threshold limit.

Twelve clones released by the UPASI Tea Research Institute and four by the commercial tea gardens were studied for their tolerance to blister blight. Among the highly tolerant clones UPASI-15 had the highest level of tolerance, followed by UPASI-6, -10 and -2 in the decreasing order of tolerance. Of the moderately tolerant clones UPASI-18 had the lowest level of infection and this was followed by UPASI-3, -1 and -22. Four clones were found to be susceptible. Of them, UPASI-9 had less infection than UPASI-4, -7 and -12.

SA-6 had the least infection among the four clones released by the commercial tea gardens. AK-1 was also found to be highly tolerant.

Addition of low concentrations of agricultural antibiotics to copper fungicide spray fluid resulted in superior blister blight control to the latter used alone in tea recovering from pruning. All these antibiotic formulations were mixtures of streptomycin either with tetracycline or oxytetracycline. They were effective at 100ppm concentration in combination with copper fungicide. The dosage of copper fungicide could be reduced by combining it with antibiotics.

A liquid formulation, with low nickel chloride content, when used in combination with copper fungicide, controlled blister blight better than copper alone in tea recovering from pruning. The combination treatment was also economical.

Tea recovering from pruning warranted protective fungicide treatment at short spray intervals of three days. Disease control was unsatisfactory, when spray interval was extended beyond three days.

Extensive studies were undertaken in tea under plucking, to identify the most effective fungicide treatment which was also economical. Ammoniacal copper polymer formulations had to be used only in combination with nickel chloride as they were ineffective when used alone. Cuprous oxide performed better than copper oxychloride at the same usage rate. The three brands of copper oxychloride were found to be equally effective. Of the organic protectant/therapeutant fungicides, chlorothalonil was better than dithianon.

Systemic fungicides, such as, tridemorph and pyracarbolid exhibited powerful antispore action and the blister lesions treated with these fungicides aborted with a very low production of basidiospores. Application of these fungicides in blister blight season also reduced the mite population in the non-disease dry season that ensued.

An integrated spraying schedule was designed, in which the systemic tridemorph was applied at the beginning of the season to harness its antispore activity, then switching over to the protectant/therapeutant copper-nickel combination at close intervals during the heavy monsoon season and reverting to tridemorph during the last part of the disease season to achieve the added benefit of mite reduction in the dry season.

This schedule was more effective and economical than the conventional copper-nickel treatment and the tea industry in southern India adapted it to its advantage.

Critical studies on the interaction of fungicide dosage and spray interval, clearly indicated, that shorter spray intervals of five days were required during the monsoon season to combat blister blight effectively with copper and nickel fungicides. A combination of copper oxychloride and nickel chloride was superior to either of the fungicides, used alone. The ideal dosage of copper oxychloride and nickel chloride was 210 grams each per hectare. Addition of non-ionic adjuvants at 0.05 per cent concentration, to copper-nickel fungicide spray fluid, during the monsoon, provided superior disease control to the fungicide without these adjuvants. Tea industry adopted this finding immediately to achieve better control of the disease.

Performance of triazoles in controlling blister blight was extremely good. These fungicides, namely, bitertanol, cyproconazole and hexaconazole had low active ingredient and were effective at low dosage. Combination of lower quantities of triazoles with copper sulphate provided better disease control than the former used one at higher rates. The residue levels of bitertanol, in tea, have been worked out and some of the tea estates in southern India have already started using this product for blister blight control.

Dramatic disease control was achieved by spraying very dilute sulphuric acid water. However, daily sprays with acid water were necessary to keep the infection levels below the economic threshold levels. Surprisingly, acid water treatment improved liquor characters and overall quality of teas and were valued at a higher rate.

The findings presented in this thesis, have led to better understanding of the blister blight disease, evolve more effective control methods and help the tea industry in managing the disease effectively and economically.

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