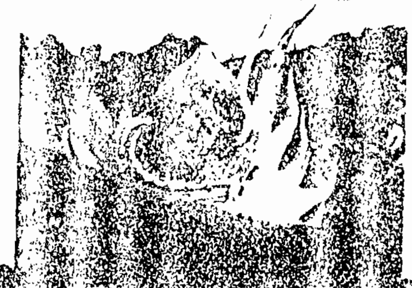
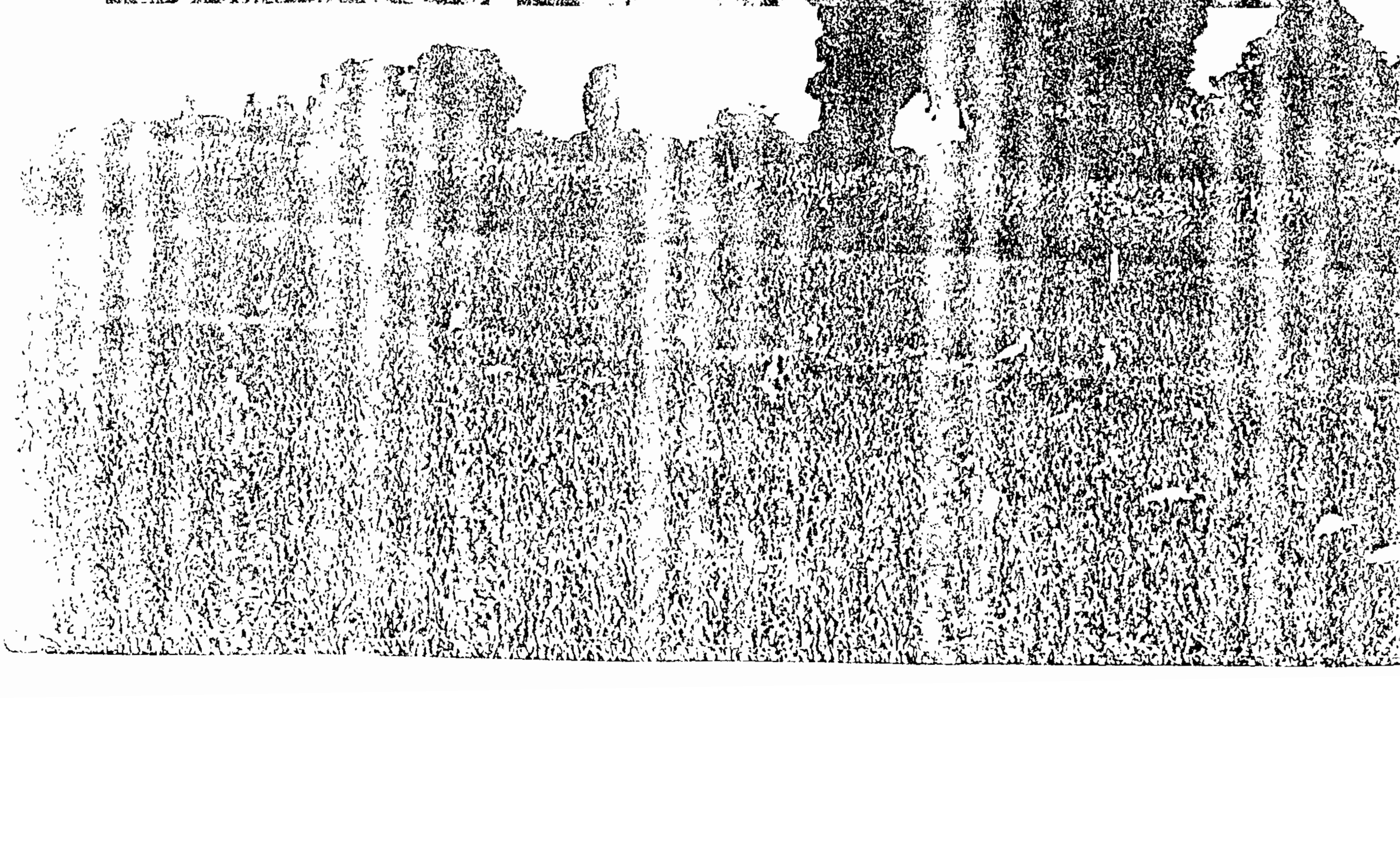
Integrated Pest Management

Principles and Applications

Volume 2: Applications

Amerika Singh
O.P. Sharma • D.K. Garg





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Status and Prospects of Integrated Pest Management Strategies in Selected Crops: Tea

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INTRODUCTION

Tea, *Camellia sinensis* (L.) O. Kuntze is the most popular beverage consumed in almost every part of world. The genus *Camellia* covers a still increasing number of over 260 species. India is the single largest producer of tea with more than 13,000 gardens. Nearly, 30% of the world's tea produced in India comes from Assam, South India, Kangra, and Uttar Pradesh. India exports more than 28% of the world's tea with over 4,80,000 hectares under cultivation. Thus the country ranks fourth in world tea trade with most of it being exported to countries like Russia, UK, Germany, Poland, USA, Afghanistan, Iran, Iraq, Egypt, North Africa, Canada and Japan. The leaves of the plants are alternate, simple and stipulate. The new leaves are full of flavour and ideal for plucking the classic 'two leaves and a bud' in March, the first flush, in April and May the 'second flush' and finally the autumnal flush or the third flush. These leaves on processing produce the world finest tea brands.

It is an important plantation crop not only in terms of foreign exchange earning, employment and revenue generation but also the world's most popular caffeine containing beverage with anticancer, antioxidant and other medicinal properties. The tea trade in India is one of the largest contributors to the country's economy as it is the world's single largest producer with a production of 870 Mkgs in 1998.

Like other domesticated crops, tea also suffers from the biotic and abiotic stresses. The abiotic stresses need to be controlled to help achieve the target produce without the detrimental effects. Pest problems due to the insects, diseases and weeds affect the crop significantly and need to be substantiated such that target specific approaches could be followed. Tea plant provides a suitable condition for the pest to feed and breed. Over 300 species of pests are known to attack tea plant in India. It was recently estimated that 1034 species of arthropods and 82 species of nematodes infest tea plant. Among the arthropod pests, Lepidoptera is the largest order and contains 32 per cent of the pest species followed by Hemiptera with 27 per cent. The dynamic adaptation of insects has enabled them to attack every part of the tea plant and the maximum number of pests occur on foliage. Each geographic region has its own distinctive pest fauna though many species have been recorded from more than one region. Pest damage in tea often leads to a significant impact on productivity, in both short and long term, the leading to the loss of the capital itself.

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About 8% crop loss was estimated in Asia, while in India a loss of 20 million kg of tea, which accounted to 13% of the production, was assessed in 1961 due to pests. During the last several decades, the control of pests, diseases and weeds in tea fields is predominantly by the use of synthetic chemicals. Though board spectrum pesticides offer powerful incentives in the form of excellent control, increased yield and high economic returns, they have serious drawbacks such as development of resistance to pesticides, outbreak of secondary pests, harmful effects on human health and environment, and presence of undesirable residues in made tea.

INSECT PESTS

Leaf and Shoot Pests

Mites

Various species of phytophagous mites infest tea. Among the leaf feeders, the red spider mite, *Oligonychus coffeae* Nietner, (Eriophyidae) and Purple mite, *Calacarus carinatus* (Green) are widely distributed in India, Bangladesh and Sri Lanka. The pink or orange mite, *Acaphylla theae* (Watt) finds its distribution mainly in China, Bangladesh, Indonesia, Malaysia, Taiwan and Russia. Scarlet mite, *Brevipalpus phoenicis* (Geijskes) is found in India, Africa, China, Bangladesh and Indonesia. The yellow mite, *Polyphagotarsonemus latus* (Banks) sporadically attacks the flush and the young leaves causing damage in isolated patches in northeast and south India. But it is a serious pest in the nursery in east and South Africa, Mauritius and Malwi. Mites remain active through out the year but in the dry weather these cause more damage to the tea crop while during the monsoon their population becomes suppressed.

Both the males and females are sexually mature at the time of emergence. The males emerge from the deutonymphs earlier than the females and wander about in search of quiescent female deutonymphs. Mating follows immediately after female emergence. Small spherical eggs are laid singly on the under surface of the leaves, mostly along the midrib and veins. The female usually lays 4-6 eggs per day. Freshly hatched six legged larvae develops into a protonymph in 1.5-2 days which turns darker in colour and then the deutonymphs which has four pairs of legs. The deutonymphs finally develops into an adult. The total developmental period is directly dependent on the environmental conditions.During warmer climate immediately after rains, the growth of population is maximum. Life cycle during this time usually completed in 8-10 days, however during unfavorable conditions, it may extend even upto 30 days. Generation overlap completely and all stages of the life cycle can be found under foliage cover.

Scarlet Mite (*Brevipalpus phoenicis*)

The scarlet mite, *B. phoenicis* is flat, somewhat elongated oval and scarlet with dorsal black marking and mostly on the affected leaves these appear as very small scarlet dots which move about very slowly and mostly found near the midrib. It inhabits the under surface of the leaf particularly on the petiode and the midrib.

By feeding on the sap the mite cause a general yellowing of the leaves and brownish discoloration along the midrib on first, later extending to the remaining under surface. Affected leaves are finally abscised off from the plant.

Red Spider Mite (*Oligonychus coffeae*)

The red spider mites are elliptical, dark red with black spots on the abdomen and usually attack on the upper surface of the mature leaf. In severe infestation young leaf are also equally attacked and then the mites spread to the under surface of the leaf. All the three stages of the mites viz. larvae, nymphs, adults feed on the depression of the leaf and gradually spreads to the whole leaf surface. The damage is characterized by reddish brown spots, which develop at the point of feeding and as a result of repeated sucking brown patches are formed. With increasing damage the whole upper surface of leaf turns brown and ultimately bronze. The severely affected leaves dry and fall off.

Purple Mite (*Calacarus carinatus*)

The purple mite is extremely small deep red with white dermal buds. It feeds usually on the upper surface of the leaves. The damage is characterized by a copperish discoloration of the leaves, particularly at the margin of the upper surface. While powdery substance consisting of the cast off skins of the mites can be seen on the affected leaves. Severely attacked leaves turn copperish and their margin curved as if affected by severe drought and finally drop off from the plants.

Thrips

Several species of thrips (Thripidae) infest tea and cause heavy by feeding on the buds, tender leaves and older tea under plucking. Pruned tea is usually the worst affected. *Scirtothrips bispinosus* (Bagnal), *Heliothrips haernorrhoidalis* (Bouche) and *Haplothrips tenuipennis* (Bangal), are the three most common species of thrips attacking tea. *Taeniothrips setiventris* (Bangal), is a common thrips and cause considerable damage to tea in Darjeeling hills when new shoots start coming up. *Scirtothrips dorsalis* (hood), is a major pest in northeast India apart from Japan, China and Taiwan. *Scirtothrips aurantii* (Faure), *Scirtothrips kenyesis* (Mound) and Black tea thrips, *H. hearnorrhoidalis* is a serious pest in other parts of world.

Adults and nymphs are yellowish brown to golden brown in colour and slender in shape. The abdomen tapers towards the apex. The wings are either reduced or absent. While feeding the adults and nymphs make rashes on the upper surface of the leaf. Nymphs and adults take shelter and feed inside the folds of unopened and partly opened leaves on the young leaves. While feeding they insert their styles making rashes and suck the sap oozing out of the wounds, which later turn to minute brown spots in scattered patches or in continuous lines at one or both sides of the midrib. Mostly feeding takes place on the upper surface of the leaves. The affected leaf appears roughened and deformed or may even curl up. Continuous feeding of young leaves by adults and nymphs causes lacerations of the plant tissues. Two or more corky lines often called sand papery lines appear on either side of the midrib. Affected leaves become rough, deformed and may curl up. In the extreme cases the leaves and shoots become stunted. Severe damage may also cause leaf tip burn and browning of petiole of all exposed leaves. Most of the damage occurs in April and May (early part of the crop). The thrips remain active throughout the year but during the cold season activity becomes low and during the peak cold month nymphs hibernate and pupate in the soil. Eggs are laid singly in the tissue of the buds and young leaves and the young nymphs emerge through the upper surface. Nymphs are pale yellow. The division of various stages in the life history is not known definitely but the time spent to complete the life cycle appears to be about three weeks in June and July. The developmental period of some species varies from 5-18 days but it is prolonged up to 25 days during cold. Population of thrips gradually declines with the onset of monsoon and prolonged droughts are associated with outbreaks of black tea thrips (*H. heamorrhoidalis*). Generation overlap completely and all stages of the life cycle can be found on the foliage.

Even a few thrips feeding on a bud or young shoot can lower the quality of the shoot. The attached bud will be more brittle (easily breaks into pieces), the processed tea will have a more bitter flavour, the liquor (tea water) will be more yellow and not as green as it should be Heavily damaged leaves become black and drop off, leaving only crown buds (some farmers call this "mangy buds"). A tea bush with many thrips is often stunted and dry.

Tea Mosquito Bug *Helopeltis theivora*, Waterhouse (Miridae)

It is popularly known as 'tea mosquito' and one of the major pests causing extensive damage in northeast and south India, Darjeeling, Bangladesh and Indonesia. This pest is widely distributed in India and has also been recorded in Sri Lanka, Vietnam and Russia. In Africa, *H. schoutedeni* Reuter is a serious pest in east Africa, Malawi and Cameroon. Another species, *H. orophila* Ghesq occurs as a minor pest in Uganda, Burundi and Zaire. *H. bradyi* and *H. cinchona* Mann, infest tea in Malaysia while *H. clavifer* Walker and *H. antonii* Signoret, attack tea in New Guinea and Sri Lanka, respectively.

The adult is a tiny insect with the head black or olive green, thorax pale yellow and black and the abdomen yellowish or greenish black (appears reddish as a result of high anthocynanin content due to sucking). The antennae are long and the horn is strongly recurved to the rear end terminated by relatively large knob. The nymphs and adults of *Helopeltis* are the active sap suckers of buds, young leaves tender stems and shoots. They feed at early morning late evening and night hours. The first instar nymph can make as many as eighty feeding lesions in 24 hours. Infestation of *Helopeltis* may become destructive during the cropping season. On sunny and warm day, it takes shelter in lower layer of bush canopy. The insect injects toxic saliva through their needle like rostrum, which causes necrosis of the tissues and turns brown white first and then black and finally dry up. Adults and nymphs can be seen throughout the year on tea bushes but peak of the incidence is noticed during June-July and August-September. Female lays about 500 white eggs elongated sausageduring March-April 4-10 eggs are laid per day. The eggs are also laid in tissue of tender stem, mid-rib and petiole of leaves. Eggs hatch into wingless nymphs in 5-7 days. In summer it completes its development in about two weeks after passing through five moults. The adult is slender 6-8 mm long, agile and a good flier.

Aphids [*Toxoptera auranti* (Boyer de Fonscolombe)]

The black citrus aphid is found wherever tea is grown throughout the tropics and subtropics. It is present in South America, Africa, India, Eastern Asia and Australia, as well as the Mediterranean region, Central America and Southern U.S.A. In Hawaii, it is present on all major islands except Lanai. If timely managed, aphids seldom cause economic damage. They cause symptoms like curled and deformed leaves that can be confused with mites and mosquito bugs also.

Aphids are oval, shiny black, brownish-black or reddish in color, either with or without wings, measuring 1/25 to 1/12 inch in body length and having short black-and-white banded antennae. Winged individuals tend to have darker abdomens and are slightly thinner. Eggs are not produced by this species. Females give birth to living young which go through four nymphal stages to reach adulthood. The first stage is approximately 1/36 inch in length and the last about 1/17 inch. They are wingless and brownish in color. Population density and leaf age affect the incidence of winged individuals. Reproduction is parthenogenic or non sexual. Females start reproducing soon after becoming adults. They produce 5 to 7 live young per day, up to a total of about 50 young per female. Newly born nymphs are found aggregated together.

Aphids feed by sucking sap from their hosts, causing plants to become deformed, the leaves curled, shriveled and in some cases, galls are formed on the leaves. This pest congregates on the tender young shoots, flower buds and the underside of young leaves. They are not known to feed on the older and tougher plant tissues. It is often more a serious pest in nurseries. Sweet and watery honeydew produced is fed on by bees, wasps, ants and other insects. The honeydew serves as a medium on which a sooty fungus decreases vigor and causes disfigurement of the host. Aphids also serve as a vector for many plant diseases, which cause substantially greater losses than caused by direct feeding injury. This is often the most important feature of an aphid infestation, which must be taken under consideration.

Aphid development is temperature dependent and completes its life cycle (nymph to adult) in about 6 days at 25° C. In cooler temperature (below 15° C), a generation may take as long as 20 days. Higher temperatures also reduce development rate, at 30° C population of this aphid will sharply decline. Generations are almost continuous throughout the year in Hawaii.

Adult winged females with wings travel for kilometres on the wind, then land on tea bushes. They do not lay eggs, but instead give birth to 8-20 wingless nymphs in a life span of 10-12 days even without fertilization. The young nymphs are brownish and undergo 4 moults to become adults in 5-8 days. Nymphs shed their skins several times as they grow into adults that do not have wings. Breeding occurs almost throughout the year and both winged and wingless forms are present. Winged adults are largely produced after tea has finished its flush of new growth.

Damage is from the loss of sap and sometimes from the heavy growth of sooty mold that reduces photosynthesis. Larger tea bushes can tolerate moderate numbers of aphids without yield loss. Young bushes are more susceptible.

Nettle Caterpillars and Saddleback Caterpillars

Aphendala recta, Cania bilinea, Chalcocelis albiguttatus, Cheromettia (= *Belippa*) *laleana, Darna* sp., *Narosa conspersa, Parasa lepida, Scopelodes* sp., *Setora nitens* or *Thosea* sp *Camprises nettle caterpillas.* Several of these species may be present at the same time. The caterpillars chew holes in mature leaves, but usually don't cause enough damage to reduce yields. The caterpillars are usually found on the undersides of mature leaves. They have thick, fleshy bodies of green colour.

Some species have stripes or saddles of white or brown colour on their backs. Unlike most caterpillars, their bodies do not appear to be divided into separate segments. Also their legs are very tiny (some have sucker disks underneath their bodies). Most of the species have groups of branched spines around the outside of their body. When mature, the caterpillars are about 1-1.5 cm long. Egg laying occurs on the mature leaves. Caterpillars start feeding on the undersides of mature leaves. Large mature caterpillars drop off the bush and pupate (from cocoons) on the ground. Cocoons look like large seeds and are spherical, about 5-15 mm in diameter, and consist of a hard papery shell covered dead with a thin layer of silk. Cocoons are found buried in the soil (within the top 2 cm), or among dead leaves, or in crevices among stones. Adults (small brown moths) emerge from the cocoons.

Coccids

Coccids are sucking pests, which attack the foliage, stems and roots of the tea bushes. Their increasing trends have been found throughout Northeast India and Darjeeling. Over 30 species of scale insects and mealy bugs have been recorded from tea out of which 12 are serious pests infesting leaves and tender stems. In south India, two coccids viz., *Saissetia coffeae* Walker, *Coccus viridis* Green are commonly found in tea plantations. Other species reported from South Indian tea are *Aspidiotus destructor, Chrysomphalus dictyospermii* Morgan and *Ceroplastes foridensis.* In South India, very recently *Nipaecoccus viridis,* the shoot mealy bug, has started appearing in many estates in Anamallais. Most of these coccoids also occur either throughout the year or occasionally in Doors Assam and Kangra valley. The mulberry scale, *Pseudaulacaspis pentagona* has been serious pest and it occurred in 40% of tea areas in Japan. The coccid and scale infested shoots become unproductive leading to drying of leaf and defoliation. When attack lasts for long, the irregular swelling is noticed on the branches due to growth of callus inside. Infestation by *N. viridis* on tea is localized and honey dew excreted by the insect favors the development of sooty mould on tea leaves. This affects normal photosynthetic activity.

Reproduction in coccids takes place sexually or parthenogenetically. Some scale insects give birth to young ones directly, *i.e.*, without any egg stage in between. However, in certain stages, eggs are laid in advance stages of development. Within few minutes of egg laying, larvae hatch out from these eggs. Young larvae crawl on the leaf surface or stems for a couple of hours plant tissues with hair like mouth parts and starts sucking the sap. Duration of the life cycle varies in different scale insects in different months of the year. Total life cycle of the scale during May-June varies from 30-35 days. As the nymphs settle, they start secreting a silken substance to cover the body. The life cycle is similar to other scale insects. However, when the nymphs settle they secrete a wooly mass of silken threads, which covers the colony in a puff protecting it from the enemies and the environment.

Hard or Armored Scales: (*Aonidiella* sp., *Aspidiotus destructor, Chrysomphalus aonidum, Hemiberlesia* sp., *Pseudaonidia duplex* or *Pseudaulacaspis pentagona*).

At first glance, scale insects seem to be dead. They are glued onto the undersides of leaves (especially along the mid-vein) or onto green shoots, and do not move. Most scales are protected under waxy shield that may be soft or quite hard. Shields may be round or elongated (shaped like an oyster shell) and are about 2-6 mm long. The actual body of the scale insect is found underneath the shield. It looks something like an aphid, but with very short legs and antennae. The insect uses its sharp tube-like mouthparts to pierce the leaf or shoot and suck the sap. Like aphids, scale insects excrete a sugary liquid that causes sooty mold to grow on the leaves. Ants often protect scales because they like to drink the sugary liquid. The presence of sooty mold or ants are good indicators for the presence of scales in the crop. Damage is from the loss of sap and sometimes from the heavy growth of sooty mold that reduces photosynthesis. Large tea bushes can tolerate numbers of scales without yield loss. Young bushes are more susceptible.

Female adults lay eggs under their shields. Active nymphs, 'crawlers' hatch from the eggs and walk to other shoots on the bush, or are carried by the wind to other bushes. Sometimes ants carry crawlers to new bushes. Once nymph finds a good place to feed, it secretes a waxy liquid that hardens over their bodies to form the shield. As they grow larger, they secrete more wax, and their shield also gets larger. Eventually, they mature into adults. Adult males are shaped like tiny mosquitoes, and fly to search for females for mating. But adult females remain under their shields for their entire life. Adult females do not move to new bushes to lay eggs, instead, it is only young crawlers that infest new bushes. Scales take about 4-6 weeks to complete a generation (from eggs to adults).

Red Slug Caterpillar (*Eterusia magnifica*)

Adult moths are brilliantly colored, newly hatched larvae are dirty white with two brownish sub dorsal strips running almost parallel, full grown larvae measure 25 mm long brownish red to brick red in colour. When disturbed the larvae exude nontoxic thick clear fluid from its pores, pupae pale yellow cocoon pinkish yellow. Usually the caterpillar attacks the leaves but in severe outbreak, the bark is also eaten away resulting in die-back of the branches. Caterpillars is the damaging stage and the pest first eats out holes and bites off the edges, then devours the whole of the leaf leaving nothing but stalk. In case of epidemic whole bush is defoliated. Caterpillars prefers mature leaves and rarely attack young leaves. If the mature leaves are not sufficient it attacks bark of young shoots. It causes serious damage to young shoots. The pest remains active throughout plucking season but m- the warmer period. There are about 4-5 gen-

Black or Sungma Caterpillar (*Lymantria albulunata* Mre.)

Other caterpillars are the Darjeeling black hairy caterpillar, *Euproctis latifascia* Walker, *E. virescens* Butler, *E. singala* Moore.

The Darjeeling black hairy caterpillar is observed in many gardens of Darjeeling hills with limited damage caused by them. It was also reported to cause damage in estates of north bank in Assam. It attacks old leaves of young and mature tea. They make small perforations on the leaves and occasionally whole leaf is eaten up. The hairy caterpillars remain concealed underneath the stones, fallen bamboos and lath frames or clods of earth during the day and the damage is caused during night. Many times the young plants in the nursery are defoliated which results in death of the plant. The body color of the full-grown caterpillar is blackish brown. Folding caterpillar such as flushworm (Tortricidae) *Cydia leucostoma* Meyrick, a main tortricid pest in India, Indonesia and Bangladesh. In south India, flush worm is abundantly seen in the mid elevation tea areas of Anamallais and Vandiperiyar during July to December. It has become a serious pest of young tea in Darjeeling hills.

Damage is mostly from the loss of older leaves, which reduces photosynthesis. However, tea can tolerate a moderate loss of leaves without reducing yield. In addition, some buds cannot be plucked because they are ruined by leaf nests.

The Red Stem Borer (*Zeuzera coffeae*)

Often damage young plants in India. It causes considerable damage in some parts of Assam apart from Sri Lanka, Malaysia, Taiwan, Indonesia. Another species *Z. leuconotum* causes damage in Japan. The larva tunnels through the branches and reach the main stem. They even sometimes reach upto root of the plant, which results its in death. The red borer is generally pest of new tea clearings and appears in patches. The adult lay eggs in strings and the emergent reddish brown settles on the stems and bore tunnels.

The adult moth is white with numerous small black spots on the fore wings and marginal black dots on the hind wings. The full grown larvae are pinkish light brown in colour with a brown head and small black spots on the segments. The larvae bore in to the tea stem mostly of one or two year old wood. The leaves of affected branch wither and the branch eventually dies. The damage is more serious in the case of nursery seedlings and young plants, since the main stem is affected. Considerable damage is often done to seed trees, where older stems are also occasionally affected.

In the plains there are two broods in a year. The peak of emergence of moth is in April-May and again in August-September. At higher elevations there is only one generation. The greater part of the year is rather passed in larval stage. The eggs are deposited in strings on the bark of the stem or branches. The larvae hatch out within 10 days and while suspended on silken threads are carried by the wind. On finding a suitable host, they bore into a leaf scar or at the junction of a petiole. It tunnels downwards eating away the woody tissues. At various intervals during this course of tunnelling, circular holes are cut out through which excreta in the form of pinkish pellets is ejected and piled up on the ground underneath. Pupation takes place in the cavities and adult moth emerges after three to four weeks leaving the empty pupal skin protruding through the hole.

Other Borers

In upper Assam and also in China, the oecophorid stem borer, *Casmara patrona* Meyrick occasionally damage tea stem to extensive cankers. Wood of the stem and callus tissue is used by the larva as food. The entrance hole of the tunnel is covered by frassy mat of chewed wood and silk. The cerambycid, *Haplothrix griseatus* Gah., bores the stem of mature tea. As the larva grows it tunnels through the branches and the affected branches become unproductive and they dieback. The scolytid shot-hole borer *Euwallacea (Xyleborus) fornicatusichoff*, found to damage tea in India, Indonesia and Taiwan. This is a well-known pest of tea in the middle and low elevation areas of southern India and occasional pest in north-east India. It is a major pest in Sri Lanka.

Females of this beetle are black in colour and capable of flying, enter tea stem by boring a hole through the bark and construct galleries within the branches in which eggs are laid. These beetles have symbiotic association with certain groups of fungi. In Sri Lanka, the shot-hole borer was found associated with *Macrosporium ambrosium* and in south India it is *Fusarium bugnicourtii* Brayford. The larvae of the beetle on the mycelia of the fungus growing on the walls of the gallery, pupation takes place within the gallery and the newly emerged adults mate within the gallery. The new branches formed after pruning are more susceptible to this borer attack. Population reaches peaks in April-May, July, October and September in south India.

Tea tussock moth or lappet (*Euproctis pseudoconspersa*, Smooth cluster caterpillars, *Andraca bipunctata*)

These caterpillars have tufts of long hairs are found in groups on tea branches. They chew holes in leaves, but seldom cause enough damage to reduce yields. However, the hairy caterpillars stop farmers from plucking, because their hairs release a poison that irritates farmer's hands. A typical moth-caterpillar life cycle. Masses of round yellow eggs are laid on the undersides of leaves. Dark-brown pupae are found at the bases of large branches. Adult is a small yellow north.

Termites

Termites cause considerable damage usually in dry period to young and mature tea including cutting in the beds and shade trees in North-east India. Cachar and Darrang district of Assam are the most affected areas. They remain active during cold weather. However, these are not serious pests in south India and considered as secondary pests but pose a serious threat to tea in North-east India, Sri Lanka and Bangladesh. Termites sometimes girdle branches and attack frame of mature plants. In Africa, *Macrotermes natalensi, Eudoacanthotermes militaris* etc., often sever or ring bark young plant suited wilting and in severe cases dies. Killing of bushes is Mauritius due to building of galleries inside the main stem, branches and roots by *Coptotermes havilandi* was observed. *Microtermes sp., M. kistanicus, Microcerotermes sp.*, are live wood eating termites in north-east India and Bangladesh while *Odontotermes assamensis, O. feae* and *Neotermes buxensis* are scavenging termites damaging tea in north-east India.

A heavy infestation of termites that attack live wood can reduce yields by 10-15%. Termites that attack live wood can kill even large mature tea bushes. They can also harm shade trees. Even termites that eat only dead wood make the wood moist and dirty, and therefore more susceptible to fungus diseases.

Nematodes or Eelworms

There are 40 species belonging to 20 genera of parasitic nematodes which are associated with tea in different tea growing countries. But most of them have no positive evidence of pathogenicity. However, infestation of root-knot nematoes *Meloidogyne incognita* Kofoid & White, *M. hapla* Chitwood and *M. javanica* Treub, are very destructive to young plants in the nursery as well as fields in north-east and south India. *M. javanica* is commonly associated with tea in India, Sri Lanka, China, Indonesia, East and Central Africa and Queensland of Australia. *M. brevicauda* Loos, parasitises the roots of mature tea in isolated pockets of south India. *Pratylenchus curvitatus* Van der Linde, is reported from the feeder roots of tea in north-India, Japan and Sri Lanka. *Helicotylenchus dihystera* Cobb and *H. erythrina* Zimm., are predominant in Sri Lanka and Japan respectively. The invasion of roots by eelworms stimulates the root tissue to abnormal growth with the result that galls or root knots are produced which virtually blocked and transport of water, solutes are impaired. Therefore, nutrient imbalance is created, photosynthetic rate is reduced and symptom of nutrient deficiency is expressed causing a general decline in the vigour of the plant which ultimately becomes more susceptible to various kinds of stresses. Premature flowering and fruiting some times noticed in case of severely infested plants. The resultant symptoms in the aerial parts are stunted growth, pallor of the leaves and later wilting. Tea plantation infested with nematodes are characterised by patches of unthrifty teas having weak frames. In the nursery, plants and seedlings are equally affected by root knot nematodes but clonal plants can withstand nematode attack comparatively better than seedlings since they possess greater amount of roots.

White Grubs

Holotrichia sp., normally causes damage to young plant tea plant around the collar region which is debarked in the from of a ring or in patches. In such cases the mulch materials during late February or early March should be kept in between rows of tea plants instead of keeping them around the collar, so that the adult cockchafer do not lay eggs near the collar region in the mulch. The early instar grubs feed on the tender roots of grasses and on dry decomposed leaves. The later instars, feed on the young tea plants in the collar region. Cockchafer beetles emerge between March and June in north-eastern region of India. They mostly affect plants in new clearings. But damage is not uncommon to three to four year old plants. In Sri Lanka, adult *H. dislarilis* Arrow, lay eggs in April-May and the grubs emerge from June onwards. The pupation takes place in December-January and the life cycle completed in about a year. In the plains of north east India, the duration of life cycle of *H. impressa* Burm. is about a year but the life cycle lasts for two years at an altitude above 1600 m. This insect is abundantly found through the tea growing area.

INTEGRATED PEST MANAGEMENT STRATEGIE

The pest management strategy is based the careful consideration of all available pest control techniques and subsequent integration of appropriate measure that discourage the development of pest populations beyond economic threshold and keep pesticides and other intervention of pest populations that are economically justified and reduce or minimize risks to human health and the environment. The pest control strategy have played significant role in the sustainable management of tea cultivation for improving trend in production and productively at economic level. Tea, being a perennial crop grown over vast acres of land as a monoculture crop, invites several pests over a wide spectrum which can be grouped into two main categories e.g. seasonal pests and perennial pests. Seasonal pests (e.g. aphids, mites, caterpillars and jassids) occur at a specific time not causing much substantial damage to the plant as a whole but also at times seriously affect the crop yield and quality. However the perennial pests can be found round the year. These pests can further be subdivided into two sub-categories:

1. The pest which attack the plants affecting the overall health over a prolonged period (e.g. Nematodes, grubs, tea mosquitoes, bugs, scale insects and mealy bugs), ultimately rendering the bush unproductive.
2. The pest which equally destroys the bushes over a shorter period of time e.g. termites.

The various practices and strategies might be adopted for pest control in tea which can be described under the following headings.

Cultural Method

This involves the manipulation of cultural practices to the disadvantage of plant pests and for the encouragement of beneficial predators and parasites. The micro-climate that predators and parasites live in needs to be monitored and adjusted to suit their particular needs. In tea, routine cultural operations such as mulching, plucking, pruning, manuring, regulations of shade and drainage which increase the vigor of the bush plays predominant role in suppression of pests. Cultural control aimed against one pest may well improve conditions for another.

Frequent plucking greatly reduces the population of caterpillars (Flushworm and leaf rollers), thrips and aphids. Leaf folding caterpillars during plucking can be manually removed. Thrips feed mostly on buds and the youngest leaves, plucking can greatly reduce the number of thrips. Frequent ("fine") plucking reduces thrips more than plucking only once a month. Frequent plucking ("fine plucking") removes aphids and is often the only control necessary. Eliminating host plants is difficult because this aphid species also feeds on citrus, cocoa, coffee, mango, remnutan, soursop and many other trees. Pruning will control the stem bores like shot-hole bore weed serves as alternative hosts for many tea pests. Removal of weeds will destroy the alternate hosts of many insects and fungus. Effective weed control assumes great significance in the management of tea mosquitoes. This may involve appropriate climatical changes, the provision of mulches for pupating insects or the growing of plants with shallow nectaries as many adult predators and parasites are small an need smal flowers to feed on the nectar which supplements their diet.

Cultural control, though providing control inferior to that of pesticides, is a valuable restrain on the average pest density and therefore, is valuable in reducing the challenge that insecticides may be called upon to meet in the future.

Physical Method

This is an oldest method in which manual collection of pests are done and destroyed. Population of foliage feeding caterpillars such as looper, bunch caterpillar, faggotworms, flushworm, leaf roller and tea tortix can be reduced to great extent by manual removal of larvae and pupae. The tea mosquito bugs lay number of eggs on broken ends of plucked shoots. Intensive manual removal of stalks during plucking will help to reduce the incidence of tea mosquito bug. Soil used in nursery may be heated to 60-62° C for killing infective juvenile. Soil solarisation during summer is also found quite effective in reducing the *Meloudogyne javanica* population. Removing infected stumps followed by soil treatment may reduce termite and nematode population to great extent. Some insects which are attracted by light are trapped in the night by keeping lanterns in the field with tubs of water nearby. Some trapping devices are also designed by entomologists to trap some pest which are nocturnal in habit.

Biological Method

Biological control coupled with all types of eco-friendly control involving the use of living organisms are more effective. In addition to the use of predators, parasites and disease causing pathogens, one can include sterilization, genetic manipulations, use of pheromones and use of resistant varieties of clones under biological control measures. The main attraction of biological control is that it obviates the necessity of using chemical poisons, and in its most successful cases gives long term (permanent) control from one introduction.

Numerous biocontrol agents are active in tea fields exerting a natural regulation of several pests. A considerable number of natural enemies of pests of tea have been identified and some of them have proved capable under ideal conditions of keeping the pest populations below economic threshold levels. The minor status of several pests bush as aphids, scale insects, flushworm, leaf rollers and tea tortix is due to the action of these natural enemies. The strategy of using biological agents to control insect pests entails identification and intervals. Phytophagous mites infesting tea are mainly preyed upon by several predatory mites, mostly belonging to Phytoseidae, Stigmaeidae and Tydeidae. *Amblyseius herbicolus* and *Euseius ovalis* are two common Phytoseiids feeding on the eriophyids, *Acaphylla these* and *Calacaru carinatus*. The stigmaeid, *Aegistamus flescneri* is an important predator of eggs and nymphs of *Oligonychus coffeae* in the north east India. Mite belonging to Pronematus Parapronematus and Tydeius are also active in tea fields. *A. herbicolu* is the most common predator of mite pests, *Acalypha theae*. Coccinelids (*Crytogonous bimaculatus, Jauravia quadrinotata, J. soror, J. opaca, Minochilus sexmacultus* and *Stethorus gilcifrins*) are the second largest group of predators of phytophagous mites in tea fields. The most commonly occurring natural enemies of thrips in tea fields are *Aeolothrips intermedius* and *Mymarothrips garuda*. Most commonly occurring larval parasite for flushworm is *Apateles aristaeus*. The eulophid is playing a significant role in the suppression of leaf population. *Apanteles fabiar* and *A. [illegible]probnanae* parasitize the looper caterpillar, *Buzura suppressaria*. Tachnid, *Cylondromya sp.*, is the chief larval parasitoid of *Andraca bipunctata*, the bunch caterpillar in many tea fields.

Several microbes are pathogenic to tea pests. Formulations of the bacterial insecticides, *Bacillus thuringiensis* have been effectively used for control of looper caterpillars, cutworms, flushworms and lepidopterus pests. Certain commercial formulations of entomopathogenic fungi, *Verticillium, lecanii* and *Hirsutelia thomposonii* are effective against pink purple and red spider mites.

Sterile male techniques may also be an effective biological control measure. In this technique male insects are sterilized by X-rays or R-rays. Control of pests by this technique is termed autocide. Sterlization can also be affected by exposure to various chemicals and this practice is called chemo-sterilization. The rational behind this method is that male sterilization in effective is species whose female mate only once in life time and are unable to distinguish or discriminate against sterilized males. In genetical manipulation method, electromagnetic radiations induce dominant lethal mutations in the germ cells of the insects. These mutations in insect sperm are lethal to its descendant, the zygote fails to develop to maturity. These mutations arise as a result of chromosome breakages in the treated cells.

Pheromones have been used in pest control programme in two ways. Firstly they can be used in pest population surveys or population monitoring and secondly for direct behavioural modification control. Generally, however, a technique called mating disruption is more effective. Synthetic pheromone is released from numerous sources placed throught the crop to be protected; the males are then unable to locate the females and the number of mating and offspring is reduced. If the synthetic attractant is exceptionally seducing and the population level is very low, some control can be achieved with pheromone traps or with a technique caled "attract and kill". Pheromone trap of *Spodoptera litura* infesting tea are commercially available and can be used for controlling the population of the moth. The pheromones of tea leaf roller has been filed tested. The female sex attractants of flushworm have also been identified recently.

As an efficient and effective control measure, biological control may be used in conjunction with an appropriate spray programme which avoids killing the predators or parasites.

Chemical Method

The use of conventional insecticides and acaricides are the most common method known to bring about immediate reduction in pest populations in the tea fields. The most commonly used pest specific pesticides recommended for controlling tea pests are presented below:

Red Spider Mite

Ethion 50 EC @ 750 ml/ha, Fenpropathrin 10 E @ 500ml/ha, Wettable sulphur 80% @ 1 kg/ha, Quinalphos 25 EC @ 750 ml/ha, Dicofol 18.5 EC @ 1000 ml, Ethion + Dicofol @ 500 + 500 ml/ha, Dicofol + Quinalphos @ 500 + 350 ml/ha.

Eriophyid Mite

Dicofol 18.5 EC @ 1000 ml/ha, Ethion 50 EC @ 750 ml/ha, Wettable Sulphur 80%

WP @ 1000 ml/ha, Neem formulation 0.030-0.15% Aza @ 1000 ml/ha, or Neem formulation 1% Aza @ 200-400 ml/ha or Neem formulation 5% Aza @ 100-200 ml/ha.

Thrips

Chlorpyrifos 20 EC @ 750 ml/ha, Quinalphos 25 EC @ 750 ml/ha, Fenthion 80 EC @ 200 ml/ha, Endosulfan 35 EC @ 1000 ml/ha, Quinalphos 25 EC + Dichlorvos 76 EC @ 750 + 250 mk/ha, Endosulfan 35 EC + Dichlorvos 76 EC @ 1000 + 350 ml/ha, Ethion 50 EC + Quinalphos 25 EC @ 500 + 350 ml/ha.

Tea Mosquito Bug

Endosulfan 35 EC @ 1000 ml/ha, Chlorpyriphos 20 EC @ 750 ml/ha, Fenthion 80 EC @ 200 ml/ha, Endosulfan 35 EC + Dichlorvos 76 EC @ 1000 + 350 ml/ha, Quinalphos 25 EC + Dichlorvos 76 EC @ 750 + 250 ml/ha.

Caterpillars/Mealy Bugs/Nettle Grubs/Aphids/Scale Insects

Fenvalerate 20 EC @ 180 ml/ha, Deltamethrin 2.8 EC @ 180 ml/ha, Cypermethrin 25 EC @ 120 ml/ha, Cypermethrin 10 EC.

Looper Caterpillar

Fenvalerate 20 EC @ 180 ml/ha, Deltamethrin 2.8 EC @ 180 ml/ha, Cypermethrin 25 EC @ 129 ml/ha, Cypermethrin 10 EC @ 250 ml/ha, Chlorpyriphos 20 EC @ 500 ml/ha, Quinalphos 25 EC @ 500 ml/ha, Endosulfan 35 EC @ 750 ml/ha.

Green Fly

Endosulfan 35 EC @ 750 ml/ha, Quinalphos 25 EC @ 500 ml/ha, Malathion 50 EC @ 1000 ml/ha.

Termite and Eelworms

Endosulfan 35 EC @ 750 ml/ha, Chlopyriphos 20 EC @ 1000 ml/ha, Phorate 10 G, 5 to 10 kg/ha depending on the age of the plant, is also effective.

Chemical control is essentially repetitive in nature and has to be applied a new with each pest outbreak. This leads to development of resistance pest species and other health and environmental problems. However, this method is quick in action and for the majority of pest outbreaks, chemical control remains the method by which the surest and most predicatable results are obtained. Keeping in view, pesticides that pose the least possible hazard and are effective in a manner that minimizes risks to people, property, and the environment may be used after carefful monitoring along with very low control measures. Recently, species/genus specific insecticides/acaricides with very low persistence (Fenazaquin, Bifenthrin and Imidaclaoprid) are being introduced.

Botanical Pesticides

These sprays are derived from plants and used to control a variety of pests and diseases. Over 50 years approximately 2400 plant species reported to possess pest control properties (Grainage and Ahmed, 1988; Gosh Hajra *et al.*, 1994). The extracts of *Azadirachta indica, Arthemisia vulgaris, Urtiva dioica, Polygonum runcinetum* and *Eupatorium glandulosum* may be used against controlling tea pests (e.g., Pink and Purple mites, certain caterpillars) either as toxicants or antifeedants.

The problem associated with much—hailed botanicals are their varying degrees of success in the field situation. In fact while a section of scientific community advocates in favour of them reporting their superiority in laboratory trials, other demonstrated their inefficiency in many a field trials.

All the above methods have proved to be successful to varying degree in controlling the relevant target tea pest species. However, in any ecosystem, there are several interacting factors, including environmental changes, interactions of the organisms that limit the full effectiveness of a particular control strategy to sustain the management for significant periods. Various methods of control adopted over the years have proved that any individual strategy by itself is inadequate to effectively and economically manage a pest for long period of time. The present ecological approach to pest management is based on an integration of all the available pest management strategies that are most suited for a particular agroecological conditions in the most compatible and ecologically acceptable manner.

PLANT DISEASES

BLISTER BLIGHT (*Exobasidium vexans* Massee)

Blister blight of tea is the most important disease caused by the fungus in the major tea growing countries. In India the disease is a serious problem throughout South India, Darjeeling in West Bengal, and Kangra valley in Himachal Pradesh.

The biotrophic fungal-pathogen attacks the tender leaves and shoots. Infected leaves develop blisters with a shiny concave upper surface and a white powdery convex lower surface. Blister coalescence induces leaf distortion and curling. Infection of tender stem results in withering and snapping off the shoots. Bushes recovering from pruning are severely affected by the disease, for all the leaves are tender and consequently prone to infection. Bushes located in north-eastern slopes and under dense shade are more susceptible to disease attack.

Blister blight inflicts heavy crop loss, as the disease infects the young tea shoots harvested for tea manufacture. In Indonesia, crop loss from 20-25 per cent has been reported due to inadequate protection (Schweizer, 1950). An enormous crop loss amounting to 50 per cent of the total annual crop has been reported for unprotected areas from South India (Venkata Ram, 1968). Tea made from infected shoots undergoes quality deterioration due to the loss in appearance (leaf-style), infusion characteristics like briskness brightness and colour, and aroma corresponding to the disease intensity (Gulati *et al.*, 1993, Baby *et al.*, 1998, Gulati *et al.*, 1999).

Blister blight is a multicycle disease. The pathogen completes the life-cycle in 11-28 days and several generations of the pathogen occur during the blister season, which generally coincides with the monsoon period when weather conditions are ideal for the disease build up. Basidiospores are the only propagules of infection produced by the pathogen. Overcast sky, low sunshine, mist and moderate temperature are conducive for the disease development. High relative humidity is essential for spore production, infection and disease development (de Weille, 1959). Dew is ideal for spore germination (Gadd and Loss, 1950). Prolonged leaf-wetness is critical for infection. Spore discharge is enormous and primarily nocturnal (Shanmuganathan and Arulpragasam, 1966).

Management

With high economic consequences to the tea industry, blister blight warrants intensive control measures on extensive scale.

Cultural Practices

Adopting certain cultural practices help in reducing the disease. Avoiding excessive shade by pollarding branches of shade trees is an important cultural practice to reduce the disease severity (Murthy, 1996). Hard plucking during peak blister season, limited to two to three months in a year, reduced the disease without affecting the bush health (Eden, 1947).

The economic consequences of blister blight, in terms of yield loss, quality deterioration and control measures constitute a major constraint on cost-benefit ratio of the tea industry. An economical disease control less dependent on fungicides appears directly dependent on the development and availability of planting material with proven performance against blister blight pathogen. The development of biological control measures based on the natural tea-phylloplane microorganisms should be explored (Balasuriya and Kalaichelvan, 2000, Acharya *et al.*, 2001).

Breeding for Resistance

Identification and development of resistant tea cultivars blister blight have been the long felt need of tea industry to increase crop productivity. Efforts were made to get clones/jats resistant to blister blight (Venkataramani, 1950, Huysmans, 1952, Van der Knaap, 1952, Semangun, 1971, Debnath and Paul, 1994). China jat was reported relatively less susceptible than Assam jat (Majid, 1971). Susceptibility of UPASI released clones and garden selections to blister blight was tested at UPASI Tea Reasearch Institute. Cultivars SA-6, SP/4/5 and B/6/24 exhibited least susceptibility. However, clones exhibiting 'resistance' in one locality showed susceptibility in other areas (Agnihothrudu and Chandra Mouli, 1990). In a specific situation, Venkata Ram (1961) breakdown of resistance was observed in a tea bush after 12 years. Singh and Prodhan (1985) also rportedd on field performance of Tocklai released 17 clonal and one seed cultivar at Darjeeling. TRA/Phoobsering 312 and TS 378 (Nanda Devi) were reported 'fairly resistant' to blister blight. Under controlled conditions, clones of different locational origin manifested varying degree of susceptibility and some seed raised chinary nursery plants exhibited resistant disease reaction (CSIR Complex, 1985 IHBT, 1997). Hypersensitive disease reaction was obtained in UPASI

10 and UPASI/SA-6 (Gupta *et al.*, 1996). Although absolute resistance in tea clones/ seed stocks against blister blight is not reported, the difference marked in disease response of various cultivars suggests existence of natural variability in tea. Leaf-pubescence, internode-length, twing angle, and leaf-tannin content were postulated to contribute resistance against blister blight (Martosupono, 1991).

Little biotechnological work has been done to elucidate variability in the pathogen population(s) and identification of pathogen races. Differential disease response in some clones against pathogen populations collected from different areas suggested the existence of variability in the pathogen (Gupta *et al.*, 1996). Lack of information on pathogen variability had impeded the development of suitable strategy identification and development of durable resistant sources.

Chemical Control

A large number of chemicals have been tested for blister blight control at UPASI Tea Research Institute (South India) and Tocklai Experiment Station (North-east India) in India, and Tea Research Institute in Sri Lanka. Among copper fungicide formulations, those based on copper oxycloride or cuprous oxide, containing 50 per cent metallic copper, were superior to other formulations in the disease control. However, given their protective action, copper fungicides are not effective in the disease control under epiphytotic conditions, when the disease incidence is severe and inoculum load is high (Gulati and Satyanarayana, 1989). The combinations of nickel chloride with copper fungicides offered superior disease control than nickel chloride and copper fungicides sprayed alone (Venkata Ram and Chandra Mouli, 1983; Sugha and Thakur, 1998). Under dry weather conditions alarming build up of mites was reported with continued spraying of copper fungicides (Venkata Ram, 1966). Carboxin, oxycarboxin and 1, 4-oxathin derivatives provided excellent disease control in potted plants, but exhibited poor field performance (Venkata Ram, 1969). The superior performance of copper fungicides over organic fungicides under monsoon conditions was considered to be due to their high tenacity (Shanmuganathan *et al.*, 1974). Pyracarbolid and tridemorph were effective against blister blight on extended spray rounds (Venkata Ram, 1974, 1975). Venkata Ram and Chandra Mouli (1976) studied dosage interaction among copper nickel, and tridemorph (morpholine derivative), and recommended an integrated spray schedule rounds using protectant, eradicant and systemic fungicide. Application of Tridemorph on extended rounds at the beginning and end of blister season with copper-nickel combination at shorter intervals during the intervening monsoon spell, was recommended for effective and economic control of the disease in South India. Weekly sprays of Tridemorph plus the binder Vinofon-In in conjunction with copper oxychloride imparted good disease control during the blister season in Kangra valley (Gulati and Swtyanarayana, 1988). Practising black plucking instead of standard plucking during the blister season helped in reducing the fungicide dosage in the disease control (Gulati and Satyanaranyana, 1991). Among several EBI fungicides tested, Tridemorph, Bitertanol, Cyproconazole, Fenpropimorph, Hexaconazole and Propiconazole provided effective disease control (Agnihothrudu and Chandra Mouli, 1990, Dutta *et al.*, 1992, Agnihothrudu, 1995, Chandra Mouli and Premkumar, 1995, Premkumar *et al.*, 1996). Propiconazole and Hexaconazole showed high efficacy in combination with copper oxychloride in the disease control (Arulpragasam *et al.*, 1987, Chandra Mouli and Premkumar, 1997, Premkumar, 1997).

Chemical Control Based on Forecasting

Attention was focused on disease forecasting to reduce the number of fungicide sprays in blister blight management (Kerr and Shanmuganathan, 1966, Kerr and de Silva, 1969). Based on the relationship between relative humidity and spore production, ejection and germination, fungicide spraying could be suspended when the average RH over 3-days remained less than 83 per cent (Huysmans, 1952). Likewise, Homburg (1953) suggested discontinuing fungicide application when the daily RH averaged below 80 per cent over 5-days and resumption of the fungicide treatment when RH exceeded 80 per cent on a period of 3-days. In Indonesia and Sri Lanka, the sunshine data was also employed as a guide to forecast the disease build up to postpone fungicide sprays (Visser *et al.*, 1959, Mulder and de Silva, 1960). However, the forecasting systems could not be successfully adopted in South India due to the highly conducive weather conditions of south-western monsoon for the disease development to discontinue or postpone fungicide application.

Recently, two computerized linear multiple regression models, based on climatic factors, atmospheric spore load and disease incidence have been developed, to predict the incidence of blister blight in relation to fungicidal sprays (Premkumar and Muraleedharan, 1998).

BLACK ROT (*Corticium theae* Bernard and *Corticium invisum* Petch)

Black rot is an important disease of the mature leaf and stem in the pains of north-east India and the mid elevations in South India. The disease is more common in the badly ventilated areas and those left without cleaning of the dead snags. The fungus produces slightly raised irregular patches on the leaves, brown, yellowish to chocolate brown and grey on the upper surface and evenly brown or grey on the lower surface. The fungus produces basidiospores in fructifications on the lower surface of leaves, which appear dusty due to the spore production. The infected leaves turn black as they rot during the wet weather. The dead leaves, though detached from the stems often remain suspended onto the bush, held together by mycelial chords. The fungus persists from season to season by the sclerotia embedded in the cracks and crevices in the stem bark. The infected bushes suffer loss of yield and vigour and debilitation.

Cultural Practices

The disease incidence is less in the pruned tea. Following pruning, the dead twings should be cleaned out to remove any resting stages of the fungus. Ventilation should be improved and over dense shade thinned out.

Chemical Control

Effective management of the disease is achieved by spraying copper fungicides during the active infection phase, taking special care to ...

drench the frame, followed by spraying Vitavax 75 WP and Hiltavax 75 WP in the late season (Dutta and Barthakur, 1992). Spraying thiophanate-methyl and benomyl is also effective (Takaya, 1976).

ANTHRACNOSE [*Colletotrichum theae-sinensis* (Miyake) Yamamoto = *Gloeosporium theae-sinensis* Miyake]

Anthracnose is a serious disease in Japan. The fungus produces reddish brown lesions on the leaves. The diseased leaves usually fall off. Foliar spray of benomyl and thiophanate methyl was found to be effective in disease management (Hamaya, 1981).

NET BLISTER BLIGHT (*Exobasidium reticulatum* Ito and Swada)

Net blister blight is another serious disease reported from Japan and Taiwan only. Infected leaves develop on the under surface white reticulate lesions which are slightly protuberant along the veins. The infected leaves may fall off and petioles may die back during severe outbreaks of the disease, resulting in reduced yield in the first crop in the following year. Copper fungicides, chlorothalonil and captafol provide effective disease control (Hamaya, 1981).

OTHER LEAF DISEASES

Brown blight and grey blight, incited by *Collectotrichum camelliae* Massee and *Pestalotiopsis theae* (Sawada) Steyaert, respectively, are very common on old and damaged leaves. These diseases are of little economic consequence and fungicidal control measures not required. The leaf spots caused by *Cercospora theae* (Cav.) Breda de Haan and *Cercosporella theicola* are also the minor diseases of tea. Leaf scab (*Elsinoe theae* Bitancourt and Jenkins), sooty mould (*Meliola camelliae* (Cattaneo) Sacc., *Capnodium theae* Boedijn and *Capnodium footii* Berk. and Desmaz), red rust *(Cephaleuros virescens* Kunze = *Cephaleuros parasticus* Karsten (alga), Phyllosticta leaf spot (*Phyllosticta theae* Speschnew and *Phyllosticta erratica* Ellis and Everth), and several other less important minor disease have also been reported (Agnihothrudu, 1995, Chandra Mouli, 1999, APSnet, 2003).

Bacterial disease have also been recorded in tea: bacterial shoot blight (*Pseudomonas syringae* pv. *theae* (Hori) Young, Dye and Wilkie) from Japan (Hamaya, 1981), Bacterial canker (*Xanthomonas campestris* pv. *theicola* Uehara, Arai, Nonka and Sano) from Japan; and crown gall (*Agrobacterium tumefaciens* (Smith and Townsend) Conn. from Kenya (Sudoi and Langat, 1992). *Pseudomonas teashirensis* and *Pseudomonas theae* have also been reported from Japan and Georgio, respectively.

Phloem necrosis, caused by *Phloem necrosis virus* (*Camellia Virus* 1), has been reported from Sri Lanka (Mulder, 1960) and possibly in India from Darjeejiling (Raychaydhuri, 1967). Yellows of tea leaves, suspected to be a viral disease, has been recorded from Japan (Hamayam, 1981). A graft transmitted yellow mosaic disease of sporadic incidence in pruned and unpruned tea plants, associated with polyhedral virus particles, has been recorded from Kangra valley (Zaidi *et al.*, 1992).

STEM DISEASES

Of the stem disease, wood rot, stem and branch canker, collar canker, thorny stem blight, and die back are the most ubiquitously reported stem diseases of importance.

WOOD ROT [*Hypoxylon serpens* (Pers: Fr.) J. Kick, *H. nummularium* (Bull: Fr.), and *H. vestitium* Petch]

The fungus enters the branches and stems of mostly the old tea bushes through sun-scald injury. The affected portions become dry, brittle and defunct. The fungus produces irregular, slightly raised, whitish-grey to dark encrustations on the affected wood. Selective pruning of dead and drying branches and paining of the large cut ends the fungicidal paste, containing copper oxychloride in raw linseed oil, are practiced for the disease control. Rejuvenation pruning is recommended in the affected areas to build up the bush health.

BRANCH CANKER (*Macrophomina theicola* Petch)

The diseased patches appear as slightly sunken lesions surrounded by one or more rings of callus growth on the branches. The bark death and wood discolouration occurs in the affected patches. Prolonged dry weather and poor soil predispose the bush to the disease attack. Avoid pruning during the dry weather. Cankered branches should be removed and the cut ends treated with wound dressing.

COLLAR CANKER (*Phomosis theae* Petch)

The disease occurs primarily in young plantations 2-8 years old. Cankers develop by the gradual death of the bark at or around the infection sites in branches or collar, killing the branches or the entire bush. Certain clones are found to be more susceptible while some clones are more tolerant than others to the disease. Dry weather and poor soil are the predisposing factors for the disease. Some cultural practices like deep planting, pegging or bending, and pruning time markedly influence the disease incidence.

STEM CANKER (*Poria hypobrunea* Petch)

Unprotected pruning cuts, sunscald lesions and wrenched off branches are the entry portals for the casual fungus. The disease spreads slowly down to the root, killing the bush in about 8-15 years. The parts affected by the disease are highly prone to attack by termites. The removal of snags and polishing the heavy cuts with copper fungicides paste at each pruning are recommended for the disease control. The biological control of the disease has been successfully tested with *Trichoderma* spp.

THORNY STEM BLIGHT [*Tunstallia aculeata* (Petch) Agnihothrudu]

The fungus enters the host through wounds, mainly the pruning cuts. The fungus produces fructifications as black thorny projections from the bark of affected stems. Control measures are identical to those followed for the stem canker.

DIE BACK (*Leptothyrium theae* Petch)

The disease causes die back of branches in the bushes recovering from pruning. The infected branches break off easily. The fungus gains entry into the host through the pruning cuts. Spraying copper fungicides or application of copper paste to the cut ends, immediately after pruning protects the bushes from the disease.

ROOT DISEASES

Root diseases are hidden killers, infinitely difficult to treat and eradicate. Root diseases are common wherever tea has been planted after clearing the forests. The fungi causing tea root diseases are non-host specific and spread to the healthy bushes through direct root contact with the diseased woody material or stumps left while clearing the jungle or shade trees, and after uprooting the diseased bushes or by the airborne spores from other diseases sources. Root diseases destroy the roots, leading to sudden death of the whole bush or a part of it while the withered and dried leaves remain attached to it for sometime. The infected bushes do not exhibit any aerial symptoms for a period of 2 to 3 years till recording sudden death. Meanwhile the infection focus spreads to the neighbouring healthy bushes. Depending on the spacing and planting arrangement, one to nine bushes may perish in any one patch in the tea garden. Spread of the disease from a shade tree or more than one closely situated focus of infection can kill many more bushes (Sarmah, 1960). A surveillance on the primary root diseases revealed that over 93 per cent of the total bush mortality in Upper Assam was due to the primary root diseases (Barua *et al.*, 1989).

Primary root diseases directly cause the death of the bushes attacked by them. Secondary root diseases attack the bushes already debilitated by some other cause and perhaps accentuate their death. Adverse soil conditions such as poor aeration due to poor drainage and impaired bush health and vigour due to depleted starch reserves in the roots, untimely pruning, over plucking, and high incidence of foliar diseases and pests could be the predisposing factors for the development of secondary root disease. Charcoal stump rot incidence is also more common in the bushes struck by the lightening. Discerning the involvement of primary root and secondary root diseases in the death of an infected bush is very important for taking appropriate control measures, as uprooting of healthy suspects is required to be undertaken only in the case of primary root diseases.

Black root rot, red root rot, brown root rot, charcoal stump rot and Armillaria root rot are the common primary root diseases reported from the major tea growing countries. Among the secondary root diseases violet root rot and diplodia root disease are also common.

CHARCOAL STUMP ROT [*Ustulina deusta* (Hoffm.: Fr.) Lind]

The disease is the most common of the root rot diseases. The disease is capable of causing sudden death of the entire bush. Development of white fan-shaped mycelial patches overlying the wood underneath the park, wood traversed by typical double black lines, and effused carbonaceous fructifications at the collar region are the characteristic symptoms of the disease.

BLACK ROOT ROT (*Rosellinia arcuata* Petch)

The disease generally causes sudden death of the bush. The distinguishing features of the disease are black, more or less woolly mycelial strands on the root surface, white star-shaped mycelial patches overlying the wood. Black lines are also seen in the wood.

BROWN ROOT ROT (*Phellinus noxius* (Corner) G. H. Cunningham = *Fomes noxius* Corner)

The disease may cause gradual or sudden death of the infected bush. The disease is identified by the presence of tawny brown mycelium, underneath the bark. Thin brown reticulate lines develop in the wood. In the advanced stage of disease, roots become very soft and spongy. Diseased roots are encrusted with firmly attached soil and stone particles intermixed with brown mycelium.

RED ROOT ROT (*Poria hypolateritia* (Berk) Cooke

The death of the diseased bush may be gradual and partial or sudden and entire. The infected roots are invariably encrusted with soil particles. Red to black strands of mycelium grow on the root surface. White mycelial patches sometimes develop overlying the wood. Red lines or sheets traverse the wood. Roots become soft and spongy as the disease progresses to the advanced stage.

ARMILLARIA ROOT ROT [*Armillaria mellea* (Vahl: Fr.) Kummer]

The infected roots show longitudinal spilt at the collar region, and the cracks on the bark are filled with white mycelial growth. The fungus develops ribbon-like compact rhizomorphs either black or brown in colour.

VIOLET ROOT ROT (*Sphaerostilbe repens* Berk. and Broome)

Water logging and poor soil aeration are the predisposing factors for the disease development. The root lenticels in the affected bushes are enlarged, root tips turn inky black, bark peels away and prominet violet coloured rhizomorphs can be seen overlying the wood. Improving soil drainage and soil aeration helps in controlling the disease.

DIPLODIA ROOT DISEASE (*Lasiodiplodia theobromae* (Pat.) Griffon and Maubl. = *Botryodiplodia theobromae* Pat.)

Bluish discoloration of the wood in the sliced root is very characteristic. Root surface is covered with small coal black hairy cushions of the mycelium, giving a sooty appearance at the advanced stage of the disease. The disease i more common in sandy loam soils.

MANAGEMENT STRATEGIES FOR PRIMARY ROOT DISEASES

The primary root diseases cause total loss by ultimately killing the infected bushes. These diseases are difficult to diagnose due to the lack of any aerial symptoms till the infected bushes are moribund. The root rot pathogens are highly recalcitrant to treat.

Cultural Practices

Recommendations include uprooting the dead bush along with apparently healthy ring of bushes (suspects), removal of all wood debris from the soil, and rehabilitation of the area for 18-24 months under non-hosts Guatemala grass or Mana grass before undertaking replanting (Tea Encyclopaedia-Ser. 70/1 file under 1.3, 1971).

When a large area is affected, as an immediate measure of isolation 45 cm wide and 120 cm deep trench should be dug to include a mantle of healthy bushes around the diseases pocket.

Ring barking of shade trees to deplete their roots of the starch reserves for rapid colonization by other saprophytic micro-organisms has also been suggested as a preventive measure in the control of root rots.

Biological Control Measures

In the recent years, attention has been paid towards the development of bological control against the root disease. *In vitro* studies on the biological interactions of *Trichoderma* spp. and *Gliocladium virens* against major root pathogens suggested potential for developing bioagents for controlling root disease. Among the various *Trichoderma* spp. tested, *T. harzianum* was found to be the best antagonist to *Poria* and *Armillaria,* and T. *viride* to *Rosellinia. Gliocladium virens* exhibited antibiosis to all the pathogens (Baby and Chandra Mouli, 1996). Onsando and Waudo (1994) also reported on the antagonistic potential of *T. koningii, T. longibrachiatum* and *T harzianum,* based on the inhibitory effects of *Trichoderma* isolates on *in vitro* growth of *Armillaria*. However, *in vitro* antagonism of *Trichoderma* spp. to *Amillaria* was not reproducible *in vivo* (Otieno, 1998). The outcome of the field-scale experiments for control of plants was observed in treated soils up to 60 and 84 months in infilled and replanted areas, respectively (Barthakur, 1999).

Their early detection, accurate identification and quantification in crop system (asymptomatic/presymptomatic tea bushes, soil and other matrices) are critical to successful timely diagnosis before much damage has been done and control of these diseases. In recent years, highly specific immunoassays using polyclonal antisera or monoclonal antibodies have been used to identify plant pathogenic fungi should also be explored from the point of view of developing integrated disease management.

Chemical Control

Soil fumigations were undertaken with Vapam (sodium N-dithiocarbamate), Metham sodium (sodium N-methyl dithiocarbamate) and Durofume CP 1:1 (methyl bromide and ethelene dibromite 1:[illegible], methyl bromide, D.D. Trapex, WN 12 to arrest the disease spread (Venkata Ram, 1961, 1965, Shanmuganathan, 1969, Satyanarayana, 1973). These chemicals tested mainly against *Poria hypolateritia, Ustulina deusta, Fomes noxiuz, F. lamaoensis,* and *Rosellinia arcuate* were found to be more or less satisfactory in controlling the primary root diseases. However, these treatments are uneconomical in view of high cost structure (Satyanarayana and Barua, 1975, Satyanarayana, 1987) and subject to criticism due to non-selective action and harmful effects on the beneficial soil microflora (Barthakur, 1999). Soil drenching of the affected area with mancozeb or carbendazim effectively controlled the black root rot (Chandra Mouli, 1993).

WEEDS IN TEA PLANTATIONS

Weed management in tea is the second most expensive input after plucking. Tea plantations are highly labour intensive. Unlike other crops, the tea leaves are plucked routinely at 7-10 days plucking interval and the period of heavy crop coincides with the period of fast weed infestation, affecting the deployment of labour for plucking. In nursery, the environmental conditions are congenial for plant growth and thus attract fast weed growth competing with tea plants. It calls for extra labour for nursery success. Basu (1974, 1975) had reported that in tea nurseries weeds infested with *Meloidogyne incognita* and/or *M. javanica* may infect tea seedling and there was possibility of spread of infestation to mature tea.

In 2-year old clonal tea, adverse effects of predominate weeds *viz., Paspalum conjugatum, Eupatorium riparium* and *Ageratum haustonianum* on stem height, and length and total number of primary branches appear as early as 2 months from the infestation (Soedarsan *et al*, 1976). These effects were attributed to the dense root system and high regeneration rate of these three species. Yellowing and reduction of the tea leaf area was also observed in case of infestation with *P. conjugatum* and *A. haustonianum*. It was also reported that retarding effects of *Imperata cylindrica, Artemisia vulgaris* and *Panicum repens* appear over a longer period.

In south India, weeds adversely affected the growth of tea plants, as evidenced by reduction in height, number of leaves, leaf area and dry weight. Growth inhibition was in the order of *Crassocephalum crepidioides* > *Bidens biternata* > *Cynodon dactylon* > *Paspalum conjugatum* > *Conyza ambigua* > *Panicum repens*. Among the three phenological stages studied (the peaks of the vegetative, flowering and fruiting stages), weeds at their peak flowering stage caused the maximum reduction in the growth of tea plants (Ilango and Satyanarayana, 1996).

In the newly planted tea, weed control during April-September is essential for establishment of the plants. The weed competition during this period has been reported to cause nearly 50% reduction in the number of primary branches and about three and half times decrease in the yield in the second year (Rao and Singh, 1977). Work at TRA (1978) had shown that weeds in the young tea accumulated 13090 kg dry matter/ha in the first year and 8400 kg in the second year and removed as much as 252 kg and 151 kg nitrogen/ha, respectively. When weeds were controlled during the critical period of weed infestation, weed dry matter and nitrogen removal between October and March was only 1890 kg and 34 kg/ha, respectively. Another study indicated that nitrogen uptake by young tea plants was higher in weed free plots under herbicide treatment followed by manually weeded plots

There are no ultimate statistics available regarding economics of weed control in tea, however, certain reports indicate that depending on the intensity of infestation, weeds were estimated to cause yield losses between 10 and 25 %. Weed control in tea by herbicides was found to be advantageous with a cost benefit ratio of 1:10 and even more (Sinha and Borthakur, 1992). Ghosh and Ramakrishan (1981) had concluded that the cost of weed management with herbicide was lower than that with the traditional garden practices (manual). Rattan (1996) had opined that mulches are effective but often pose practical and economic problems. On the other hand, mechanical control measure damage the roots of tea.

Weeds also retard the efficiency of farm workers. Certain weeds like *Bidens pilosa* and *Rubus* spp. often reduce the plucking efficiency of workers. In heavily infested tea sections, shoots of weeds get inadvertently harvested along with tea shots, which may affect the quality of made tea.

In tea plantation, grasses generally predominate the weed flora followed by broad-leaf weeds (Singh *et al.*, 1994). In India, studies in young tea have revealed that the critical weed competition period was April to September and delay in weeding during this period adversely affected branching, growth and yield of young tea (TRA 1978, Sinha and Borthakur, 1992). In Sri Lanka, the critical period for weed competition in young tea was between 8-16 weeks after planting and the threshold period of competition was 12 weeks after planting (Prematilake *et al.*, 1999). The major weeds from different tea growing areas of the world are as follow:

Grasses: *Imperata cylindrica, Paspalum conjugatum, Setaria palmifolia, Cynodon dactylon, Saccharum spontateum, Panicium repens, Pennisetum clandestinum, Arundinella bengalensis, Axonopus compressus* and *Paspalum scrobiculatum.*

Broad Leaf Weeds: *Borreria hispida, Polygonum chinense, Borreria alata, Eupatorium odoratum, Mikania micrantha, Mikania cordata, Ageratum conyzoides, Ageratum haustonianum, Scoparia dulcis, Oxalis acetosella, Artemisia vulgaris* and *Commelina benghalensis*

Other Weeds: Sedges are not serious weeds in tea plantation (Singh *et al.*, 1994) Ferns like *Pteridum aquilinum* and *Nephrodium* spp. have been reported to infest tea plantation. In the tea gardens having high humidity and limited sunny days throughout the year, mosses tend to cover soil surface under the canopy and a large part of tea trunk branches (Ronoprawiro, 1976, 1981).

MANAGEMENT

Cultural Practices

The chinary or china hybrid tea bushes bear many stems arising from collar level, which develop the soil pockets providing shelter to weeds. Such soil pockets are more evident in the gardens practicing the faulty application of inorganic fertilizers (mostly ammonium sulphate or urea) in the middle of the bush and eventually thinning the number of primaries at the centre of bush frame. As such, the weeds growing in these pockets escape various manual and chemical treatments for weed control. If such weeds are perennial grasses or bushes, the problem is further aggravated because they can be pulled out successfully along with their underground propagules nor they can be dug out which otherwise may damage tea stems too. Also, application of herbicides over bush frame to control these weeds is a risky operation.

Wider plant spacing and vacancy also cause higher weed infestation. Increase in tea plant spacing, from 15 to 150 cm, was found to increase weed infestation (TRA, 1978). Highest weed infestation in tea plantation occurs in pruned or deeply skiffed sections as the ground gets exposed. Pruning or deep skiffing needs to be done in every 3-4 years depending on the pruning cycle.

Physical and Mechanical Methods

In Tea Nursery: Planting of single leaf bud cutting of tea by inserting through a black polyethylene mulch beneath a cover of hoop-supported polyethylene cloth has been reported to provide satisfactory weed control at the nursery stage (Smale, 1991). Similarly, Tabagari and Kopaliani (1984) also recorded improved weed control both in vegetatively propagated as well as seed-propagated tea nurseries by mulching with black plastic, tea factory residues or peat.

In Young Tea: In high rainfall areas, clean weeding may lead to the risk of soil erosion, thus under such conditions the aim should be to control noxious weeds but leave a non-competitive ground cover of soft weeds (Sutidjo and Lubis, 1971).

Mulching with black low density polyethylene (LDPE) sheet (Pirtskhalaishvili and Kimutsadze, 1972, Zarnadze, 1972, Korzun, 1981, Tabagari and Kopaliani, 1984) was more effective for weed control in mature as well as young tea. Similarly, Singh *et al.*, (1993) had concluded that in young china hybrid tea planted on slopes, LDPE mulch totally suppressed weeds in the inter-row spaces. LDPE mulch also enhanced plant growth and yield of tea compared to no mulch.

For best results, Tea Research Foundation of Central Africa (1975) had suggested an integration of herbicides, mechanical methods and mulching. Scarborough and Kayange (1977) had reported that in young tea, hand weeding was most effective treatment providing about double growth as compared to unweeded plots.

In Mature Tea: Zarnadze (1972) had reported that rubber mulch checked weed growth and increased yield of mature tea by about 39% while peat mulch was not so effective. In Sri Lanka, weed density was found to be significantly reduced by the *Flemingia congesta* mulch (1 kg dry matter per sq m) 3 months after the treatment (Prematilake *et al.*, 1998).

In north east India, cultivation with a deep hoe in June and December on heavy soil on flat terrain was reported to provide higher average annual yield while weed control throughout the year by cutting with a sickle gave the lowest yields (Sarkar *et al.*, 1983), However, deep hoeing and scraping, in areas of high intensity rainfall lead to devastating soil erosion on hill slope and often damaged the feeding roots of tea located in upper 10-15 cm soil profile (HPKV, 1986). At times after deep hoeing circular basins were created for manuring and irrigation which caused water-logging and subsequently root-rot diseases resulting, in casualty of the bushes. Similarly Bursulaya *et al.*, (1990) had reported that owing to shallow root formation by the tea

India before 1980's, scraping of the above ground weed growth by spade, hand pulling (especially of brushes, and perennial grasses like *Imperata* and *Saccharum*), annual deep hoeing (15-20cm), and removal of weeds by a single toothed fork were the various manual methods of weed control in tea plantations. Sickling was never in practice until mid 1980's (Thakur, 1993).

Sandanam and Jayasinghe (1977) had observed that forking out of *Imperata cylindrica* rhizomes up to a depth of 45 cm gave long-lasting control. Slashing the grass to ground level at intervals of 4-6 weeks resulted in low degree of control in terms of visual assessment of top growth and a high degree of control in terms of suppression of rhizome development, which was comparable to the most effective chemical methods.

In Pruned Tea: In pruned sections mulching the inter-rows with the prunings provided best results in terms of weed management (Kogua, 1975, Tabagari *et al.*, 1988).

Biological Methods

There is conspicuous lack of efforts towards biological control of weeds in tea plantations deploying bio-herbicides or other bio-control agents. Only brief information is available on the biology of a beetle *Chabria* sp. (Chrysomelidae, Coleoptera), on *Borreria hispida*, a common weed of tea fields in northeast India (Debnath, 1998). However, there had been some studies on the use of smother crops or harvested organic mulch materials for weed management in tea.

Slashing of intercrops or weds (before flowering) and using them as mulch material was reported to be effective in weed management. Mulching with straw, tea pruning-litter (Kogua, 1975, Tabagari *et al.*, 1988) was found superior to hand weeding in mature as well as young tea.

Replacing summer hoeing by mulching with bracken (*Pteridium aquilinum*), at 40 t fresh weight/ha, was reported to reduce infestation of perennial weeds (Purtskhvanidze, 1973)

The spray of alke-strain of Tobacco Mosaic Virus on herbicide resistant *Solanum carolinense* was used for combating the weed (Izhevskii *et al.*, 1981).

Sandanam and Rajasingham (1982) had reported 89 and 51 t/ha soil loss with clean weeding during the first and second years respectively compared with 7 and 1 tea with guatemala grass (*Tripsacum laxum*) mulching, and 2 and 2 t/ha, with Mana grass (*Cymbopogon confertiflorus*) mulching. Soil loss with intercropping treatments was 32 and 5 t/ha with *Crotalaria striata* and 11 and 2 t/ha with *Eragrostis curvula*, compared to 28 and 2 t/ha respectively under selective manual weeding with minimum soil disturbance. Soil loss in the third and fourth years was more than 2 t/ha with all treatments. They also observed that tipping weights were highest with bare soil or selective weeding and lowest with *E. curvula*. Leaf yield in the second year tended to be higher with Mana grass mulching. Mulching also increased soil moisture content.

Chemical Methods

The common herbicides used in Indian tea plantations are paraquat, glyphosate, simazine 2, 4-D sodium, 2, 4-D amine, diuron, dalapon and MSMA. Linuron, methazole, metribuzin, dichlormate, dinoseb, oxadiazon, butachlor and fluchloralin herbicides were also used in tea, however, they were trivial in performance in tea plantations. Though, most of the herbicides approved are safe to tea, phytotoxicity on tea may occur due to the reasons (Sinha and Borthakur, 1992) like application of herbicides at rates higher than the recommended doses, improper or non-targeted spraying, spray drift, leaching of pre-emergence herbicides by heavy rains, and age of the tea bush.

Pre-emergence Herbicides

Nurseries: Apart from manual weeding in tea nurseries, application of simazine-atrazine-fluchloralin, oxadiazon, methazole herbicides for chemical weed control had been recommended by TRA (1978). These herbicides were suggested to be applied @ 2kg/ha in April at 3 weeks before planting of clonal cutting. Treatments may be repeated after hand weeding when weed cover exceeded 50%. Mixtures of simazine or atrazine with oxadiazon or fluchloralin were found more effective.

In Young Tea: Chemical weed control in young tea is distinct from that in mature tea, as young tea plants are relatively more susceptible to herbicide treatments and the weed flora is more diverse and intense. Ghosh and Ramakrishnan (1981) observed that in young tea, oxyfluorfen at 0.125 kg/ha applied pre-emergence in May followed by oxyfluorfen (0.06 kg) + either paraquat (0.24 kg) or 2,4-D (0.8 kg/ha) as post-emergence controlled most of the problem weeds throughout the season. Presence of moisture on the soil surface had been found to improve the bioefficacy of pre-emergence herbicides, in general.

It is normally advised that young tea plants should be shielded from the herbicide spray since they are more likely to be affected than older plants. Also, application of dalapon and diuron in tea younger than 3 years is not recommended (CSIR Complex, 1985, 1990, Sinha and Borthakur, 1992).

In Mature Tea: Oxyfluorfen at 0.25 kg/ha provided good control of broad-leaved weeds in mature tea without any phytotoxicity when it was applied to clean soil or to growing weeds. Oxyfluorfen was comparable to simazine or diuron, each at 2 kg/ha (Rao and Kotoky, 1981). In mature tea, pendimethalin 0.75, oxyfluorfen 0.44, simazine 1.25, or atrazine 1.25 kg/ha were more effective pre-emergence treatments for suppressing seed-borne weeds (CSIR Complex, 1992, 1993). Subsequent weed growth in either of the cases could be controlled with spot treatment of 2, 4-D and /or paraquat (Singh *et al.*, 1992).

In Pruned Tea: Autumn application of pre emergence herbicides (simazine, diuron and oxyfluorfen), before pruning was found effective for better weed management in pruned sections and was as effective as spring application (Rao and Kotoky, 1980, Sinha, 1985, Sinha and Borthakur, 1992).

Post-emergence Herbicides

Glyphosate: Glyphosate was evaluated to be the most effective plantations. More than 90% of glyphosate is used in tea plantations (Rao, 1983). It controlled many perennial weeds including *Imperata cylindrica, Setaria palmifolia* and *Cynodon* (Rahman *et al.*, 1975, TRA, 1976), when applied at 1.5 to 6 kg/ha (Rao *et al.*, 1976, 1977, Awasthi and Rao, 1979). Normally, glyphosate was used at 1.5-2.5 l/ha (HPKV 1989, AICRPWC, 1990 a, b). Kabir *et al.*, (1991) had also observed that glyphosate 0.92 or 1.23 kg/ha provided effective weed control in tea of Darjeeling area.

UPASI (1978) concluded that glyphosate was a promising herbicide against hardy perennial grasses and deep-rooted broad-leaved weeds and was not toxic to tea bushes even when sprayed directly on the bushes at a rate of 1.68 kg a.e./ha (Sharma and Satyanarayanan, 1976) However, studies at IHBT, Palampur had indicated that in case of seed-raised china hybrid tea plantations, use of glyphosate even at the rate of 1.03 kg/ha may cause phytotoxicity. The susceptible tea bushes had showed loss of crop for 1-2 pluckings.

Glyphosate was also found effective in controlling brush weeds like *Lantana camara*- a troublesome weed in tea plantations in Himachal Pradesh (Singh *et al.*, 1997).

2, 4-D Sodium: About 60% of the 2,4-D marketed in India is used in tea gardens (Rao, 1983). Most of the paraquat-resistant broad-leaved weeds could be controlled by 2,4-D at 1.12 kg/ha (Sharma, 1975, 1977), 2,4-D sodium at 0.8 kg/ha was very effective on its own. Addition of paraquat 0.3 kg/ha made it more effective against grasses (TRA, 1978, CSIR Complex, 1989).

Paraquat: Paraquat is a unique contact herbicides for tea plantations being quick in action and rain fast, without adverse effect on beneficial soil microbes (CIC, 1989). It causes desiccation of the green tissues of the plants. Repeated application of paraquat (0.3 kg/ha) at short interval (weekly or fortnightly, depending upon rate of regeneration in weed) may kill even the persistent weeds.

Rotation of Herbicides: Sharma (1977) had observed that the prolonged and continuous use of some of the herbicides led to a situation where resistant weed species and their population tended to increase. The shift in weed flora under different herbicide treatment should be monitored regularly for deciding suitable herbicide rotation to particular weed problems (Sharma *et al.*, 1981, Sinha, 1985). Under such situations rotation of herbicides is generally recommended for broad spectrum of weed control.

BENEFITS OF WEEDS IN TEA CROP MANAGEMENT

There are some reports accounting the utility of weeds in tea plantations. Manipura (1971) and Sutidjo and Lubis (1971) had supported the weed infestation in high rainfall area, leaving a non-competitive ground cover of soft weeds by selective weeding reduces the risk of soil erosion. Deori *et al.*, (1997) had reported increase in root dry weight of tea (in pots) when treated with *Ageratum conyzoides* roots powder and rock phosphate.

In young china hybrid tea planted on slopes, mulch of grassy weeds effectively controlled weeds in the inter row spaces of tea and it was statistically comparable to LDPE mulch in terms of yield (Singh *et al.*, 1993).

Sidhu (1985) observed that for integrated control of the gryllid *Brachytrupes portentosus* on tea in north-east India, retaining of some weeds on the ground during the peak period of its activity in March-June was more effective as it formed an alternative food source for the pest.

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