

## \*INTEGRATED APPROACH IN TEA PEST CONTROL IN SRI LANKA

P. Sivapalan

(*Tea Research Institute, of Sri Lanka, Talawakele, Sri Lanka*)

and

V. Delucchi

(*Entomological Department Swiss Federal Institute of Technology,  
Zurich, Switzerland*)

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India and Ceylon produce about 75 percent of the tea exported (Cranham, 1966). Tea is a perennial crop grown intensively over large areas from near sea level to an elevation of about 3,300 m. With the exception of trees grown for seed the plant is cultivated for the young shoots and is therefore periodically pruned as a low bush to keep it in the vegetative phase. The top of the bush is flat and is called the "plucking table." In a field of mature tea bushes, the ground is completely covered. The period between two prunings is known as a pruning cycle. The duration of this cycle varies from two to five years according to altitude, the shortest cycle occurring in the lowland. Different types of pruning are practised. In general a "hard pruning" (or low pruning or clean prune) takes place every three cycles and the bush is pruned down to 30 to 40 cm high. It is followed by two somewhat lighter prunings which bring down the bush to 45 to 60 cm high (Fig. 1). In areas with a three year cycle one third of the cultivated area is pruned every year. Pruning as practised in tea plantations not only influences the growth of the bush within the pruning cycles, but also considerably modifies the environmental conditions of the arthropods associated with the crop, by eliminating the source of food during several weeks and by changing the microclimate. Plucking consists in harvesting the young shoots (the bud with two leaves), the so-called "flush", and occurs all year round at an interval of one to two weeks depending on the growth rate of bush. Plucking has also an effect on the development of pests of the flush.

During the last 30 years, tea has undergone changes in cultural practices which are similar to those of many other crops. These changes concern (a) the use of fertilizers, which has increased from less than 100 kg/ha to 500-600 kg/ha since 1946; (b) the replacement of tea plants obtained from seed (seedling tea) by plants obtained vegetatively from rooted cuttings (clonal tea) since 1957, thus increasing genetic uniformity; and (c) the elimination of the shade trees since 1966. These changes in cultural practices have contributed enormously to the increase of yield, which has reached a maximum of 4,000 kg/ha in some of the vigorous young clonal fields, but have also magnified pest problems.

### 1. DEVELOPMENT OF XYLEBORUS POPULATIONS

In Ceylon the major pest is *Xyleborus fornicatus* Eichh. (Col.: Scolytidae) which occurs in almost all tea plantations up to 1,300 m elevation and has been a serious pest in most of them for the last 15-20 years. The young female makes a single

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\*Extracted from the proceedings of the FAO conference, *Ecology in relation to plant pest control* pp 183-196. FAO, Rome 1973.

gallery in young stems which have a thickness of 6 to 8 mm and lays the eggs in it. The hatching larvae are mycetophagous and feed on the *Ambrosia* fungus introduced by the female. The preimaginal development lasts about four to six weeks according to altitude and the adults of the new generation leave the gallery to disperse and infest new suitable branches. The generations overlap and new galleries are made throughout the year. The gallery of one female is not used by another female. Galleries in the thin branches affect the growth and can result in chlorosis of foliage, some defoliation and also die-back of shoots. Where a gallery is formed the branches are often broken during agronomic operations. Furthermore, infested bushes have poor reserves and recover with difficulty after pruning. This impoverishes the bush frame, leads to soil exposure and then to soil erosion. The impoverishment of the bush frame is accentuated by a secondary attack of wood-rot fungi and of scavenging termites, which develop in and widen the *Xyleborus* galleries. The development of *Xyleborus* population can best be followed from the pruning, which removes the greater part of the wood containing the pest. The quantity of the pest removed depends on the type of pruning. The reduction of sap flow after pruning seems to create unfavourable conditions for the development of the beetle for several months and population density remains very low. When the new "primary" branches become thick enough to permit the formation of galleries, e.g. 6 to 8 mm, the population starts to increase. In the meantime new "secondary" branches develop from the "primary" ones and are attacked by the beetle as soon as they reach a convenient thickness. So the infestation moves from the "primary" to the "secondary" stems and from these to the "tertiary" branches. In tea areas with a pruning cycle of three years, for instance, the peak of attack is observed 20 to 24 months after pruning, followed by a considerable decline during the third year. The increase of *Xyleborus* depends on the sap flow and the growth of the bush, which influence the growth of the ambrosia fungus in the galleries. Optimum conditions for gallery formation and development of the beetle exist therefore in vigorous stems. There is some evidence "that the accumulated attack renders conditions progressively less suitable" (Cranham, 1966), which means that there is an upper limit of gallery density beyond which the infestation automatically declines. In fields, where peak of attack in the second year after pruning is prevented by insecticidal spraying, the highest population density of the borer is observed in the third year. Seasonal changes of weather also influence population movements. The attack on "primary" and "secondary" branches has therefore an influence not only on the yield but also on pest density.

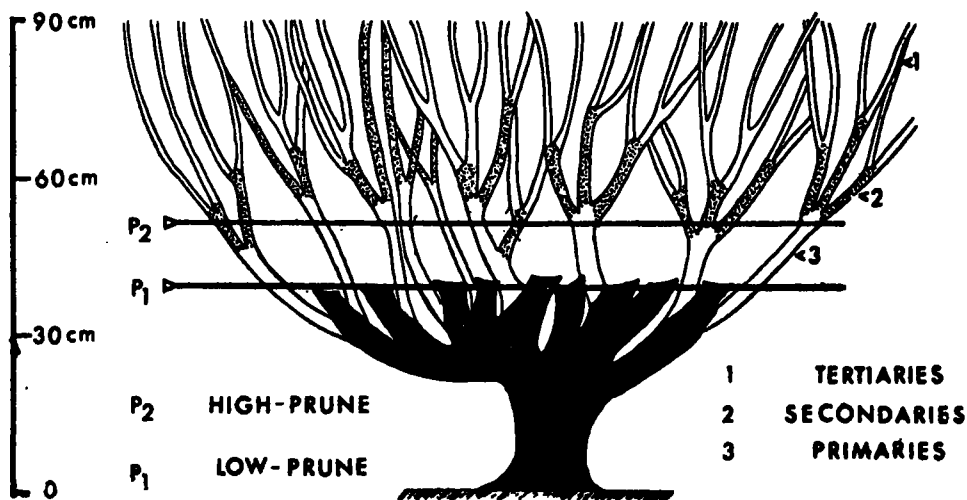


FIG. 1—Pruning levels and types of branches of a tea bush

## 2. THE INFLUENCE OF CULTURAL PRACTICES ON THE GROWTH OF THE BORER POPULATIONS

*Fertilizers* are applied periodically, three to six times per year, beginning about three months after pruning. The economic importance of *Xyleborus* has increased since 1946 with the greater use of fertilizers. It has been demonstrated experimentally that nitrogen application increases the yield but results also in a proportionately larger loss of crop from borer attack (Cranham, 1968), as young vigorous stems offer optimal breeding conditions. In areas where the borer attack is particularly serious the increased application of fertilizers has become an *uneconomic* cultural practice, leading in certain cases to a decline in yield. The situation has become even worse since 1957 with the introduction of high yielding clonal tea, the vigorous growth of which demanded higher doses of fertilizers.

There is of course an interaction between the effects of nitrogen supply and of insecticidal spraying. It has been observed in many estates that chemical control of the borer improves the response of the tea bush to additional fertilizers. In 1961 the use of dieldrin was recommended in post-pruning sprays, i.e. when there is no foliage and residues of pesticides on the leaf may be avoided, and also the bush frame can be easily covered with insecticide. Dieldrin has a persistence of 15 to 20 months and this gives good protection against the borer during more than half of the pruning cycle in areas with a three-year cycle. This preventive treatment included at the beginning the whole pruned area, and in estates on a three-year cycle this involved about one third of the total tea acreage. As a side effect of dieldrin application, outbreaks of Lepidoptera, in particular of the tea tortrix *Homona coffearia* Nietn., have been experienced. These outbreaks usually develop a couple of months after dieldrin spraying and are particularly important when they develop during the dry season. As a consequence it is necessary to intervene against the Lepidoptera and to repeat the treatments if needed. Following dieldrin applications, DDT has been used. In tea areas the use of DDT has been the cause of outbreaks of mites, especially where treatments were applied at the beginning of the dry season. To save labour costs and to treat greater areas, knapsacks have been replaced by mist-blowers. This change in spraying technique has considerably augmented the drift of pesticides in untreated areas and has favoured the outbreaks of secondary pests. Three or four years after dieldrin application it became evident that the destruction of natural enemies of Lepidoptera was very serious and that the dieldrin spray programme over large areas had to be reconsidered. The use of dieldrin was abandoned in 1966. Of the possible alternatives to dieldrin, heptachlor was selected in 1968 with the return to knapsack sprayers. Because of the lower persistence of heptachlor, timings of spraying had to be redefined to protect the mid-period of the pruning cycle, when production, reaches its peak. To avoid the dry season and to delay as long as possible the application of heptachlor, pruning is done in July and insecticidal treatment carried out in March-April. The economic injury level for borer attack has been established at 40 percent of the sampled units; 250 sticks of pencil thick stems of 10 cm length (standard unit) per field are sampled at random and the intensity of attack is estimated. Loss of yield becomes evident when 40 to 60 percent of the sticks are infested, the level varying according to climatic conditions and other factors. Therefore, treatments, are applied when this level is attained and only in those fields where it is required.

During the last six years, the problems of tea protection have been complicated by the elimination of the shade trees to increase the yield, which began on a large scale basis in 1966. Below 1,000 m elevation, the suppression of shade trees lead to the

mass appearance of *Glyptotermes dilatatus* Bugnion. The infestation of the tea bush by this termite occurs through the branches, either using the *Xyleborus* galleries or dead wood. Above 1,000 m there is another termite, *Postelectrotermes militaris* Desneux, which attacks the tea plant through the roots. The large-scale removal of shade trees in recent years has resulted in a modification of the environment apparently most favourable to swarming termites in several respects. The removal of shade trees has resulted in a very significant decline in the population of birds that frequent tea fields and prey on swarming termites. Some of these shade trees that were replaced at regular intervals were suitable alternate termite hosts and served to cushion the attack on tea by hosting a significant proportion of the swarming termites. The sudden removal of the protective canopy provided by shade trees has also resulted in an increase in the general air temperature, a condition that seems to be more favourable to frequent swarming. Yields which had been increased between 1966 and 1970 by the elimination of shade trees have dropped by about 25 percent during the last two years and the problem of termites seems to have become even more important than that of *Xyleborus*.

### 3. NEW APPROACH IN TEA PEST MANAGEMENT

Economy being a key factor in tea pest management work, tea estates have been advised to categorize all their tea fields into three broad categories: (a) high yielding fields (yielding over 1,500 kg/ha) growing on good soils (category A); (b) moderately yielding fields (yielding between 1,200 and 1,500 kg/ha), growing on good soil but low yielding due to the poor variety of tea—fields suitable for replanting (category B); (c) low yielding fields (yielding below 1,200 kg/ha), growing generally on poor eroded lands—fields unsuitable for replanting (category C).

Fields in category C are the worst fields in which the cost of tea production is relatively high and an economic return is not normally obtained to justify the cost-inputs of various cultural practices. The fields in category B, earmarked for replanting within the next two cycles, are generally kept under a "care and maintenance" basis by minimizing the cost inputs of various cultural operations. No specific pest control measures are now recommended for fields in category C and those fields earmarked for replanting in category B. In certain poorly managed tea estates it is not uncommon to see more than half of the total acreage belonging to category C.

*Management of Xyleborus:* It has been mentioned that the damage caused by *Xyleborus* to tea is two fold: (a) *Primary damage:* this is the effect of the injury felt in the current cycle. Galleries in the newly formed branches affect the current growth and hence reduce yield. Branch breakage during agronomic operations also lead to loss of crop. (b) *Secondary and long-term effects:* wood-rot fungi invade unhealed *Xyleborus* galleries rendering them useless for further retention. This attack by wood-rot organisms is generally accompanied by the ravages of scavenging termites. Their cumulative effects during successive cycles impoverish the bush frame.

The cost inputs of *Xyleborus* management programmes have to be matched not only with the benefits derived in the current pruning cycle, but also with the long-term benefits of protecting the tea bush frame. The following improvements have been introduced, not only as a measure to curtail the indiscriminate use of insecticides, but also to increase the efficacy of control measures in sections of fields that warrant this:

(a) At the time when dieldrin and later heptachlor was recommended to control *Xyleborus*, the aim was to obtain maximum protection of the total infestation phase in the cycle, which in a three-year cycle lasted from about the end of the first year to about the early part of the third year from pruning (10th to the 28th month from pruning).

Recent studies have shown that the gallery density is greatest in the "primary" branches, less in the "secondary" branches and still less in the "tertiary" branches (Fig. 2). Even though in terms of total available wood (wood suited to *Xyleborus* attack) the bulk is comprised of "secondary" branches, the preferred wood is the "primary" branch and a direct correlation has been found between total galleries and available "primary" wood (Fig. 3).

In addition to the "primaries" supporting the highest density of galleries, it is the basal parts of these "primaries" that are retained at subsequent prunings and wood-rot sets in through these branches and contributes to the long-term debilitation. Furthermore, the damage in the "primaries" reflects through the "secondaries" and "tertiaries" and ultimately in the entire section of the cropping table supported by the respective "primary" branch.

*The damage to the "primaries" has now come to be recognised as the most important, calling for protection.* The damage in the "secondaries" and "tertiaries," which support a lower density of galleries, is recognized as the "tolerable damage," not warranting protective measures.

Control measures are therefore now *not* geared to give protection over the entire phase of infestation. With the earlier recommendation of heptachlor, on account of its relatively low persistence and in order to give protection over the maximum period of the infestation phase, spraying was necessarily delayed up to 12 months from pruning, even at the expense of an ineffective spray coverage when less than 50 percent of the spray deposit actually reaches the target frame at this stage of recovery from pruning.

Having now recognized the importance of protecting the "primary" wood rather than the "secondaries" and "tertiaries," and as these "primaries" are subject to attack during the early part of the pruning cycle (from about the 10th to the 18th month from pruning), treatment is now advanced to about five to six months from pruning, when also a better spray deposit can be given (Fig. 6).

(b) In order to estimate for treatment in the following cycle, sampling of standard units is carried out just prior to pruning. This indicates the degree of damage to which the fields have been subjected in the earlier cycle and also gives an idea of *Xyleborus* distribution.

The economic injury level is now better established according to climatic zones (elevation zones) and according to yield potential of the respective fields. *Xyleborus* damage is most serious at elevations between 300 m and 1,000 m. The injury level for the high yielding fields (category A) in this elevation range is established when over 40 percent of the sampled units are found infested. The corresponding value for the moderately yielding fields (category B) in this elevation range is established at 60 percent. With fields situated at elevations below 300 m and above 1,000 m, the injury level is established at 60 percent for the high yielding fields (category A) only. The remaining fields are left untreated as no economic returns could be expected from such fields following treatment.

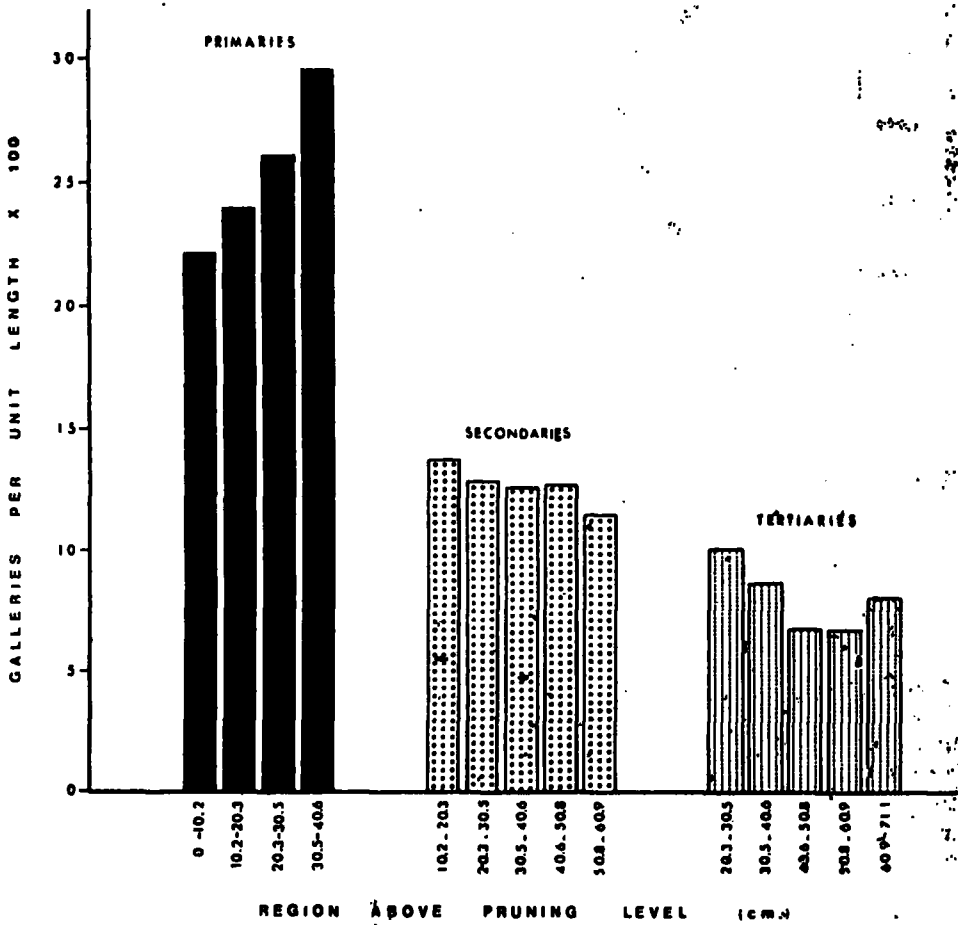


FIG. 2—The distribution of the density of galleries of *Xyleborus forficatus* in primary, secondary and tertiary branches.

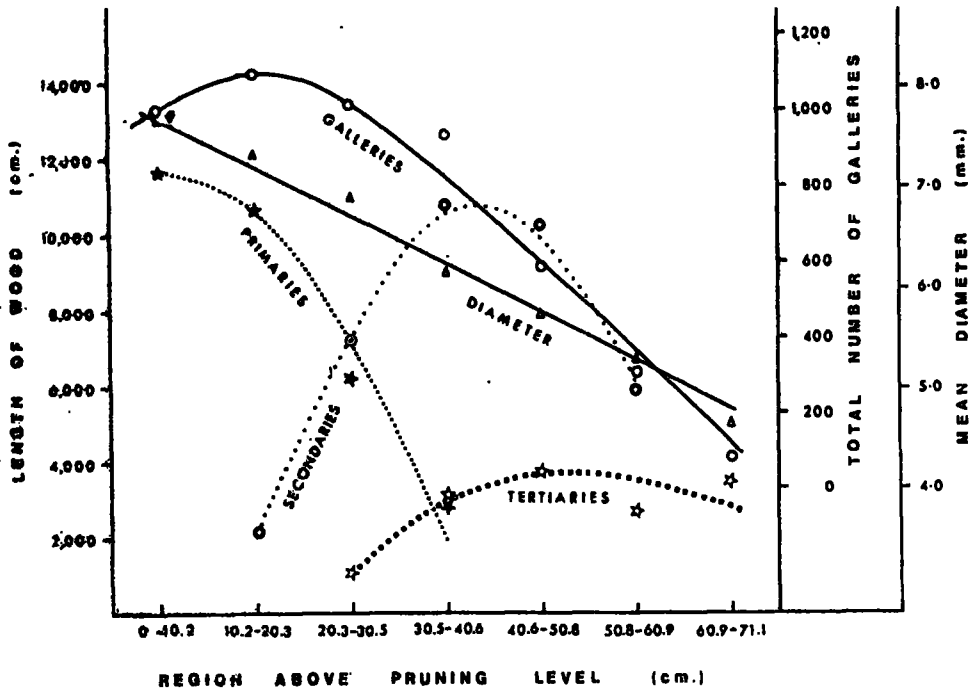


FIG. 3—The distribution of galleries in the new wood formed in one pruning cycle: galleries in the different regions above pruning level correlated with mean diameter and the respective length of primary, secondary and tertiary wood. The total gallery distribution is shown to be influenced mainly by the pattern of the available length of primary wood.

(c) Recent studies have shown that the distribution of *Xyleborus* infestation in any given field is uneven; by adopting a stratified sampling technique, using 2 ha as the sampling area (sampling unit), it has been found that a "mean infestation" of 40 percent could range from as low as 10 percent in some sections to as high as 80 to 90 percent in other sections of the sampling unit. A more selective treatment is thus made possible by taking advantage of this uneven distribution. In the past, whole fields were sampled as one unit and when the infestation exceeded 40 percent, the entire field was treated (blanket spraying).

(d) A relatively clean prune (low prune) is given once every two or three cycles, as against less rigorous lighter prunings. Proper sanitary measures such as the elimination of cankers, deadwood and snags are carried out following a rigorous low prune. A greater proportion of "primary" type of wood is formed in the cycle following such prunes. As the "primary" type of wood supports the bulk of the *Xyleborus* population, the total population of *Xyleborus* is greater in cycles following such rigorous prunes. Protection against *Xyleborus* becomes critical following such prunes.

In cycles following light prunes, a relatively small amount of the "primary" type of wood is formed, and the bulk of the new wood, which is of the "secondary" and "tertiary" type, supports a relatively lower total *Xyleborus* population. Protective measures become less critical following such prunes.

Therefore, the total population of *Xyleborus* can be regulated by the type of prune. Although from the point of view of the total population it is advantageous to adopt lighter prunes, repeated light prunes is not a good cultural practice as the resultant growth becomes ultimately too twiggy, supporting a poor flushing table.

*Protection against Xyleborus is recommended only after a rigorous low prune.* In sections of fields that warrant chemical control, insecticidal applications are therefore given once in every two or three cycles, and not at every prune as was done in the past.

(e) Localized spraying is recommended only with the use of hand operated knapsack sprayers. Mistblowing of insecticides is not recommended. When chemical control is to be adopted proper attention is paid to the existence of several species of useful parasitic and predatory insects that help regulate the occasional and potential pests. Spraying against *Xyleborus* is to be undertaken only at the time when the reproductive potential of the seasonal and potential pests is at their lowest, and this is generally so with the approach of the wet monsoon months (Fig. 6). Spraying in dry weather, when the reproductive potential of the seasonal and potential pests is on the increase, is totally banned (Fig. 5).

(f) Fields in category B, which are earmarked for replanting, are replanted with only the approved *Xyleborus* resistant and tolerant varieties. This is strictly enforced in regions where *Xyleborus* is a serious pest (between 300 and 1,000 m). Several clones have already been selected for good *Xyleborus* tolerance and this programme of selection is continuing.

When replanting with tolerant clonal varieties, in order to avoid the development of a "super monoculture," more than one approved clone is used in blocks of about five ha each.

*Management of seasonal pests:* The pests that break out during certain times of the year (seasonal pests) in Ceylon tea areas comprise: the tea tortrix (*Homona coffearia* Nietner); nettle grubs (*Macroleptera nararia* Moore); and mites [predominantly tea red spider mite *Oligonychus coffeae* (Nietner) and the tea scarlet mite (*Brevipalpus californicus* Banks)].

The occurrence of these seasonal pests is not universal in all tea growing districts and their outbreaks are determined by climatic factors. The commonest among these seasonal pests is the tea tortrix. This species was one of the most serious pests in Ceylon tea until 1936, when a braconid parasite was introduced from Indonesia. This parasite, *Macrocentrus homonae* Nixon, was released only at two locations and within two years it was found in all districts where tortrix was found naturally present. During this short period, the tortrix populations were reduced from the status of a major pest to that of a minor pest. This was one of the most successful instances of biological control known anywhere in the world. *Macrocentrus* being a polyembryonic form, despite the fact that its population has been affected by native species of hyperparasites (*Ceraphron fijiensis* Ferr.; *Tetrastichus* sp.), it yet continues to be the dominant controlling factor.

With the onset of the dry weather, when the reproductive potential of the tea tortrix increases, the population of *Macrocentrus* is insufficient to bring about an economic control (Fig. 4). There is economic damage particularly in the fields of category A that are in the second year from prune (peak yield period). With the onset of the dry month the tea develops a special natural flavour the unit value of which is relatively high; losses during this period of high flavour season are therefore of greater significance.

Tea estates are advised to maintain a very close vigilance for early signs of tor-trix outbreaks in fields of category A, particularly in those that are in the second year from prune. Spot chemical treatment of affected patches is recommended. "Blanket" spraying of entire fields is discouraged. Fields in category C, which are kept untreated offer ample breeding sites for rapid build up of *Macrocentrus*, which then find their way into infested pockets in the high yielding fields. With the ban imposed on the use of DDT in tea fields, the recommended insecticide is trichlorophon (Dipterex). Unlike DDT, Dipterex does not induce outbreaks of mites.

*Management of live-wood termite species:* *Glyptotermes dilatatus*, the species of live-wood termite affecting low elevation tea (below 1,000 m), poses a serious threat to several of the low elevation tea plantations. The damage is most significantly felt in the recently planted young tea areas.

The attack is initiated by winged swarming termites which find access to the heart-wood of a branch through a weak spot, such as an old *Xyleborus* gallery, tips of branches that have died back following pruning, cankers and snags. Tea bushes in a partially debilitated state may offer several such weak spots for ready termite access. Chemical control has proved to be ineffective and uneconomical.

The seriousness of this problem is very much reduced by the adoption of proper cultural methods. The key factor in the control of live-wood termite depredations is the prevention of fresh attacks. By minimizing, if not eliminating, all possible access points, attacks could be reduced very drastically. Tea estates that have curtailed such important sanitary measures are the ones that have suffered severe termite infestations. All deadwood, cankers and snags have to be cleaned out at the time of pruning.

Tea bushes that are severely affected and in which the gallery system reaches the main trunk, become sources of flying swarmers. Tea fields with a relatively high proportion of bushes in this state of attack pose a real threat. The timely elimination of such bushes or even entire fields is a useful precautionary measure.

Young tea fields that are in close proximity to infested fields are the ones that suffer extensive damage. Replanting strategies are now carefully worked out with the proximity of termite infested fields being one of the critical factors that determine the selection of an area for replanting.

It is now being recommended to plant specifically selected shade trees (*Erythrina lithosperma*) in the younger fields and also as barriers around the newly planted and unaffected older fields. These are to be subject to a regular programme of replacement, before such trees become themselves a source of termite swarmers.

Dieback from pruning provides the most accessible weak spots that serve as excellent points of entry for live-wood termites. This is in fact one of the primary sources of entry. In many instances it has been possible to establish a relation between the severity of live-wood termite infestations and the extent of dieback following pruning. It is now being recommended that pruned branches be routinely treated with effective fungicides to prevent the establishment of wood-rot organisms that bring about dieback.

Tea estates that are adopting the above cultural practices are already seeing the beneficial effects and live-wood termite depredations are on the decline in these estates.

Chemical control measures that include the spraying of persistent insecticides and the introduction of fumigants into galleries are now discouraged as these have proved to be uneconomical.

## POPULATION DYNAMICS OF TEA PESTS

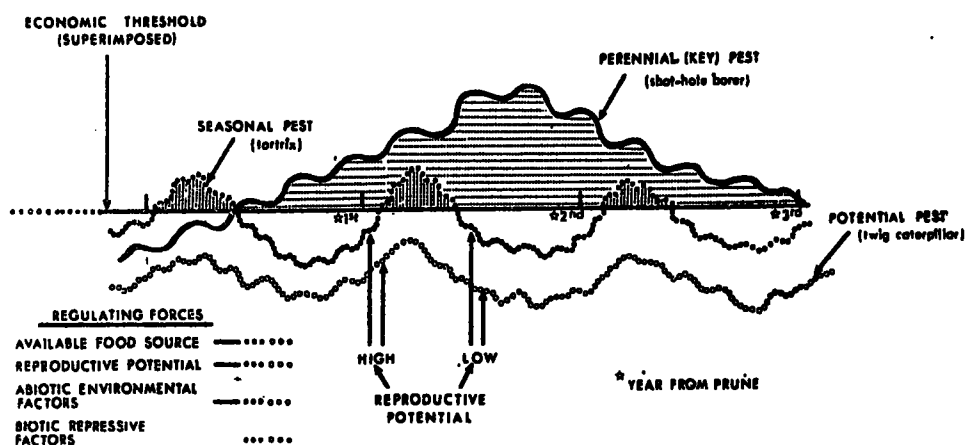


FIG. 4—Population dynamics of the key pest (solid line), the seasonal pests (solid dots) and the potential pests (open dots) in a tea field on a three-year cycle. The estimated economic thresholds of all pest categories are superimposed for convenience.

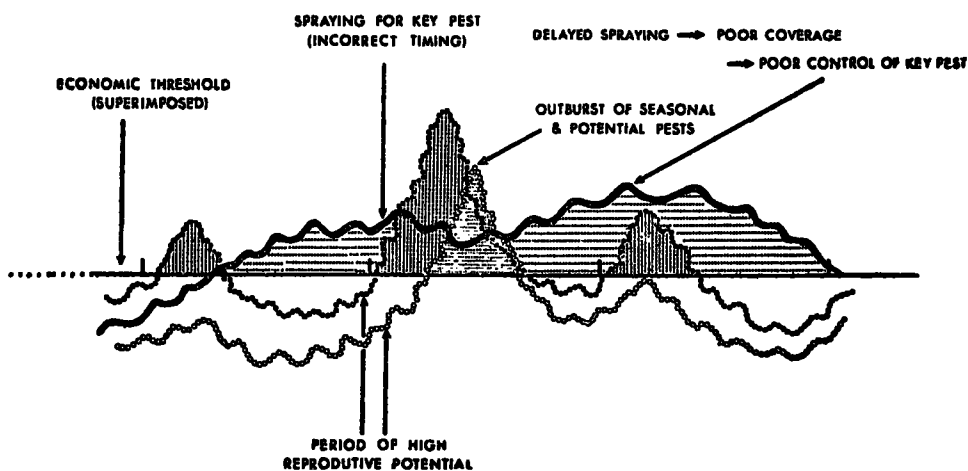


FIG. 5—Population dynamics of the key pest, the seasonal and the potential pests in a tea field on a three-year cycle and the influence of incorrect timing of insecticidal application against the target pest (key pest, solid line) on the repressive mechanisms of the seasonal and potential pests (solid and open dots, respectively). The economic thresholds of all pest categories are superimposed for convenience.

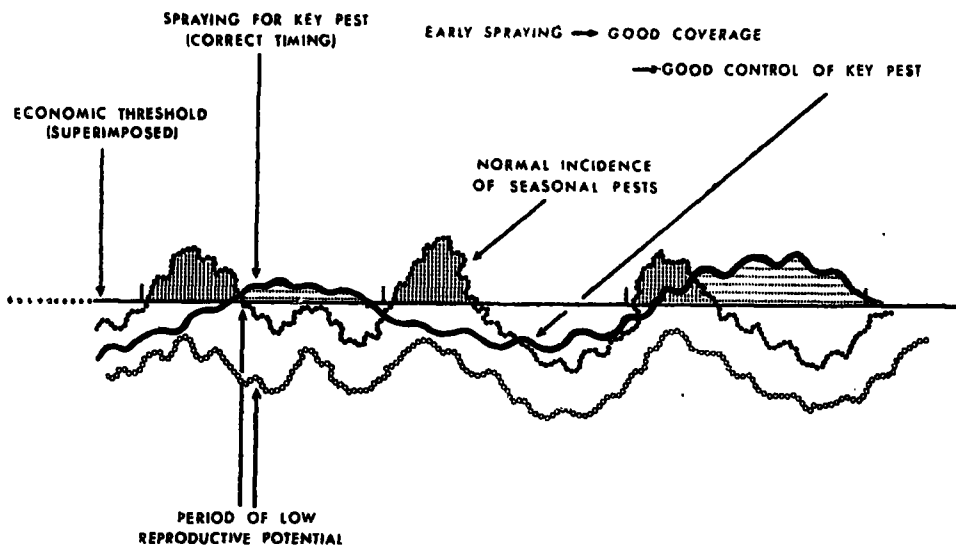


FIG. 6—Population dynamics of the key pest, the seasonal and potential pests in a tea field on a three-year cycle and the influence of correct timing of insecticidal application on the target pest (key pest, solid line) and on the seasonal and potential pests (solid and open dots, respectively). The economic thresholds of all pest categories are superimposed for convenience.

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