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New Outlook on the Pest Management of Tea

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Abstract An intensive ten year study on the pest ecology of tea has spotlighted some aspects which explain the unsatisfactory chemical control of many pests of tea, such as, tea tortrix, mites and shot-hole borer beetle. Evidence from past experimentation has revealed that in many instances the use of insecticides for pest control in tea has proved to be neither ecologically feasible nor economically worthwhile.

It is suggested that in future pest control in tea should be oriented towards bio-cultural techniques of regulating pest populations.

Introduction

Subsequent to the overdependence on the insecticidal method in pest control in 1960's and the sad consequences of this approach, today we are becoming more and more aware of the importance of an ecological basis to pest control studies. Since then, many have attempted to pay lip service to 'Integrated control', meaning the definite inclusion of the use of insecticides, along with the combination of other methods. But, it is interesting to note that one who may be called the *father* of integrated control has now equated 'integrated control' with "just good entomology" and has advocated the need "to implement, at the practical level for the farmer, an ecologically and economically sound programme of plant protection."[21]

In Sri Lanka, in respect of tea entomology, the evaluation of results of ten years of pest ecological studies, particularly in relation to the most serious pest of tea, (*Camellia sinensis* L), the shot-hole borer beetle, (*Xyleborus fornicatus* Eichh.) has revealed substantial information on the unique aspects of the tea crop and its pest ecology. This paper deals with these unique aspects of the pest ecology of tea and explains the reasons for the unsatisfactory insecticidal control of many pests of tea, such as, shot-hole borer beetle, tea tortrix (*Homona coffearia* Nietner) and mites. Further, it focusses attention on the need to be mindful of the very salient ecological features of the tea crop itself, in relation to the ecology of the tea pests, with the adoption of an ecological approach to the pest management of tea [2, 3], so that control measures will be safer, effective and economical.

Experimental

The ten years of ecological studies on the shot-hole borer beetle pest, from 1962 to 1972, [4, 5, 6], revealed some surprising aspects of this pest. This led to the re-analysis of all insecticidal trials, for the last 15 years, on shot-hole borer beetle, [1, 9, 14] on tortrix [11, 16] and on mites [10, 17, 20]. Further, all experimentation reported in the Annual Reports for the years 1956—1970, of the Tea Research Institute of Sri Lanka have been considered and re-evaluated in detail. In all, 148 chemical trials have been re-analysed ; 83 on shot-hole borer beetle, 16 on tea tortrix and 49 on mites.

Results and Discussion

Some unique features of the tea crop

The tea crop has unique characters, which will influence its pest ecology in a very special way. These are :-

1. It is a perennial crop grown in extensive monoculture, in the tropical environment.
2. The harvest is vegetative and is collected at high frequencies, once every 4 days to 10 days, extending over a long period of time, varying from 2 to 4 years or more.
3. The very lengthy period of susceptibility of the crop to tea pests, as much as 2 to 4 years or more, practically the entire length of the pruning cycle.
4. The complete loss of crop for any length of time is unusual ;
5. The harvested crop of green leaf has a low unit value because the 23% out-turn in the manufactured tea fetches an average profit of only 40 to 60 cts/Kg., so that the returns from crop losses recovered do not compensate for the relatively high cost of insecticidal sprays.
6. The pest damage is not known to affect the quality of the final product.
7. The crop environment in tea includes effective natural control agencies of predatory and parasitic insects, pathogenic micro-organisms and

other biotic forms, which should be regarded as an asset in economic pest management and be preserved and developed.

There is considerable experimental evidence from chemical trials on both tortrix and mites, that should no chemical control be attempted, both pests are frequently brought under natural control, within periods of ½ to 3½ months [16, 17]. On the other hand, a classic example of the unleashing of secondary pests, by the use of persistent organo-chlorine insecticides is provided in tea in Sri Lanka [12], by the outbreaks of caterpillar pests such as tea tortrix, the twig caterpillar, (*Ectropis bhurmitra* Walker) and the looper caterpillar, (*Buzura strigaria* Moore), following the application of dieldrin for shot-hole borer control. Subsequently, the gradual restoration of their natural control, by just discontinuing the use of dieldrin sprays, is valuable evidence of the important part played by natural control of pests by beneficial organisms, both known and unknown[15], in the tea environment. It is also well known that heptachlor application used for shot-hole borer control unleashes the secondary pests of tortrix, twig and looper caterpillars, while DDT that was used to control these caterpillar pests unleashes mite infestations. This is certainly a tragic story of a vicious cycle of pests, brought about by a very injudicious pest control programme. The more important adverse aspect of the above pest control programme is the inevitable deterioration of the natural balance of pest/predator complex in tea, which in the long run, will inevitably lead to increasing costs of pest control. Here it is necessary to focus attention on the fact that in a tropical, perennial, extensive monoculture, such as tea, the adverse effects of the use of insecticides will, in the long run, be more drastic than in temperate crop environments or in tropical annual crops.

8. The rate of vegetative regeneration is extremely high in the tea plant in comparison with other perennial crops. Hence, its remarkable capacity to render a *vegetative harvest* at high frequencies, at intervals of a week or less, makes crop losses insignificant in time.

   This remarkable regenerative capacity in tea, which is unknown in other perennial crops, together with its longevity, renders the tea crop extremely suitable for cultural methods of crop protection, whereby cumulative secondary effects of pest damage, as in the cases of shot-hole borer and termites, can readily be minimized, by utilizing this natural regeneration of the plant.

9. Finally, another important factor that regulates insect populations is the pattern of heavy monsoonal and inter-monsoonal thunderstorm

rains experienced in the tea growing districts. These heavy showers not only by themselves reduce insect numbers, but also affect insect populations by bringing about a quick change in the temperature of the micro-climate. Further, it has been observed that pathogenic diseases of caterpillar pests are heaviest during wet weather conditions.

What does experimental evidence on the chemical control of tea pests reveal ?

The evidence that some serious pests like twig and looper caterpillars are kept under very effective natural control is of extreme significance. Because, in the regulation of these two caterpillar pests, all that was needed was to discontinue the use of the dangerous persistent insecticides, such as dieldrin in tea[15]. Similarly, the withdrawal of heptachlor and DDT sprays will contribute much towards the regulation of tortrix and mite pests, respectively.

In many instances of pest infestations, such as caterpillar pests or mites, the best course of action would be **not** to resort to chemical control. This would help the regulation of pests by means of natural agencies. Resort to the chemical control method will prolong the infestation by merely knocking down the peak infestations, while the chemicals will at the same time affect the natural parasitic/predator complex, thus causing deterioration of the natural balance in the crop environment. In many instances, pest infestations are naturally regulated, with time, even though chemical spraying is not resorted to. This, in combination with the fact that the temporary crop loss recovered by chemical spraying does not in the long run compensate in value for the expenses of chemical sprays alone, renders the spraying of chemicals for the control of pests in tea uneconomic and unrealistic.

The shot-hole borer beetle pest. The pest ecology of shot-hole borer beetle and attempts at its chemical control reveal important aspects of this pest.[4,6] The knowledge of the pest ecology of shot-hole borer beetle and the experience with the very limited levels of control of borer beetle populations and borer beetle damage, using dieldrin and heptachlor, indicated that beneficial chemical control of shot-hole borer beetle, which at the same time will be ecologically feasible, cannot be achieved. The loss of crop in borer beetle infested fields (estimated to be around 20% in the second year of the cycle) and the borer beetle damage of galleries in tea stems are serious enough to warrant control measures, but neither is this loss in yield economically recoverable, nor could the damage in galleries be appreciably prevented by the judicious use of insecticides. This makes it difficult to fix any practical ' economic injury levels ' and it will be even more difficult to fix ' economic threshold levels '. For these reasons an ' integrated programme ', *with the use of chemical control,* for the shot-hole borer beetle pest is unattainable. It is essential in the interest of an 'inter-related pest management system' to co-ordinate the management of the whole pest complex in tea, in an ecologically feasible manner, which in the long run will also be economically sound, by the accent on bio-cultural means of pest regulation alone, and the discontinuance of the chemical control of this pest. This approach will enable an increase of the environmental resistance against all pests and at the same time will also aim at the preservation and development of the most valuable natural pest regulatory means, so abundantly available for most of the tea pests. With our present knowledge of the pest ecology of shot-hole borer beetle, it is evident that we will be compelled to live with this pest and only regulate its population by cultural methods, so as to minimize the damage it causes.

Therefore, the best possible solution to the shot-hole borer problem and the basis for the pest management techniques are as follows :

(*a*) Yield losses caused by shot-hole borer beetle could be remedied by extended pruning cycles alone, because, the yield loss caused by shot-hole borer beetle is chiefly in the second year, of which only around 10% could be recovered by the spraying of permissible levels of persistent chemicals, and in addition these yield losses diminish with time, with the extended pruning cycles. Experimental evidence is available of definite trends in compensatory yield increases, towards the end of three year cycles, in the untreated plots of experiments *ME* 3 (1966) and *ME* 5 (1966).[4]

(*b*) Experimental evidence in collaboration with the analysis of field data, in the Mid-Country, reveal that spraying of chemicals for shot-hole borer beetle is uneconomical.[4] It will be more economical **not** to spray for shot-hole borer beetle, *either* in a three year pruning cycle *or* in a four year pruning cycle.

(*c*) Therefore, rather than spraying for shot-hole borer beetle it will be advisable to extend the pruning cycle, to a fourth year in the Mid-Country and to a third year in the Low-Country. Analyses of field data, of the Mid-Country, show that a four year pruning cycle is as good as a three year cycle, yield wise, where the average annual yields are about the same. This practice will bring better economic returns and is agriculturally advantageous.

(*d*) The cultural method of pruning will remedy the more serious secondary damage caused by wood-rot. Wood-rot in tea takes about 10 years to develop into a serious condition. It is *partly* a secondary effect of borer beetle galleries and this could be remedied by the cultural method of selective clean pruning, into wet weather, with the retention of lungs, at each prune.

The tea tortrix pest. The tea environment consists of a wealth of natural parasites and pathogens of the tortrix pest[13]. However, frequently in localized areas, there are temporary infestations of the tortrix pest, which are brought under natural control in ½ to 3½ months time. So much so that it has been a problem to assess the effectiveness of chemical sprays on this caterpillar pest, because the experimental areas soon lose their infestations. It is extremely interesting that to commence and continue the chemical trials on the tortrix pest, the experimental areas had to be sprayed with dieldrin (an insecticide that was prescribed for shot-hole borer beetle control) to induce the pest.[16] The only experiment where an attempt was made to assess the yield loss caused by tortrix infestation (*E 70* — 1968, that was initiated as a mite experiment) was continued for a period of only 22 months. To enable assessment of the effect of loss of crop by the tortrix infestation, the treated plots during this period received 13 rounds of DDT for tortrix control and the 'untreated control plots' received 3 rounds of dieldrin to induce the tortrix pest. At the end of the experiment, that ran for only 22 months, a yield increase of only 247 Kg/ha (220 lb. made tea/a) or 14% was obtained. It is interesting to note a definite trend in compensatory yield increase, towards the end of a three year cycle, in the infestation induced plots. This experiment provided valuable insight into the chemical control of the tortrix pest, with the use of insecticides and indicated the uneconomic nature of this exercise. There are many more recorded instances of the failure to keep chemical trials of tortrix infestations continuing for sufficient lengths of time, in order to make any precise assessments[22], on account of the natural regulatory agents.

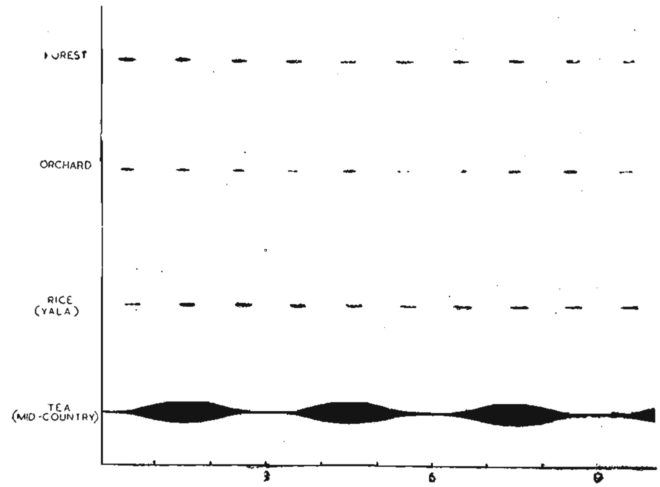
Mite pests. The results of all chemical trials on mites follow a somewhat similar picture to that of the attempts to control tortrix infestations with chemicals. In the case of mites too the experiments could not in many cases be continued because the untreated control plots lost their infestations. There are also several experiments that had to be discontinued on account of the deterioration of the mite infestation to very low numbers. Cranham[7], at the end of a three year period found no significant loss of crop due to mite attack. Again, Cranham[8] reported that in Uva, in the Gonamotawa mite trial, at the end of only 11 months the yield loss recovered was only 10%, in spite of the inducement of mites in 'untreated' control plots by the spraying of DDT (an insecticide prescribed for the tortrix pest control). Further, experiment *E* 49 (1967) on mites did not show any significant yield loss recovered at the end of the trial, although there were beneficial trends in yield up to the 22nd month. Experiment *E* 50 (1967) too gave similar results. Again, in experiment *E* 21 (1965), in Welimada, Uva district, which ran for a period of four years, where 21 rounds of Kelthane were used to control the mites in the treated plots and 21 rounds of DDT were given to the ' untreated control ' plots, to induce mites, the yield loss recovered was only 202 Kg/ha (180 lb. made tea/a) or 3% in spite of the achievement of over 90% population control[17]. Here again, it is interesting to note a definite trend in compensatory yield increase, towards the end of the four year cycle, in the infestation induced plots.

The significance of experimental evidence

The above experimental evidence, viewed as a whole, reveal important aspects of the chemical control of tea pests and their benefits. The most important of these is that although a temporary recovery of yield loss could be obtained by the knock-down effects of chemical sprays, in the long run, at the end of the pruning cycle, of 3 to 4 years or more, the yield loss recovered is either nil or meagre and uneconomic. Another important aspect is that the benefits achieved by the use of insecticides are further reduced by the side-effects they cause. Further, the evidence indicates, that even should no chemical treatment be administered, in many instances of tortrix and mite pests, a natural decline of the pest populations does occur.

The explanation for the above should be sought in the unique aspects of the tea crop, as well as its pest ecology. The lengthy period of the susceptibility of the tea crop explains the difficulty of achieving the profitable protection sought by the use of insecticides (*Figure* 1). The pest populations in tea

FIGURE 1. **Patterns of crop susceptibility***



*A diagramatic representation of the periods of crop susceptibility in tea compared with that of a tropical annual crop such as rice (Yala) and orchard and forest crops in the N. Temperate zone.

TABLE I — ~~Aspects to be investigated~~ **before the recommendation of a pesticide**

Aspects needing investigation	*Normal considerations*	*More important points often overlooked*
1. Evidence of control	*A significant* population kill	1. What *quantum* of damage reduced ? 2. Trends in several well distributed experiments are more important than significant results in one or two experiments
2. Taint) Residues) Health aspects)	These obtain only a cursory attention	These should be fully investigated
3. Side-effects	Evidence of slight side-effects ignored - A pesticide recommended provisionally - From then on the provisional recommendation is not reviewed in the face of accumulating evidence	1. A slight indication of side-effect, should be sufficient to warrant the removal of a pesticidal recommendation. 2. Pesticidal recommendations must be regularly reviewed.
4. Results of spraying	1. *Protection* primary consideration. 2. *Production* given secondary and cursory attention	1. *Protection* important only if it affects production in the long run. 2. *Production* should be the primary aim, not *protection.*
5. The economics of spraying in relation to yield	Not sufficiently considered	1. Yield ' increases ' from experimental plots should be related to averages for fields on the commercial basis. 2. Yield ' increases ' in short periods in pruning cycle should be related to average yields of pruning cycles. 3. The yield ' increases ' must further be related to yield averages in the various districts, involving various lengths in pruning cycles. 4. Unit costs should be related to costs on large commercial estate scale ; where small yield increases will add to lowering the C.O.P. and thus turning a marginal gain in unit costs, to considerable profit on a commercial scale.
6. Practical considerations	Very little consideration given	The final results obtained from small carefully conducted experimental plots, should accommodate the economics of operations on larger commercial scale, with regard to (1) Dosage of chemical ; (2) Profit margins expected ; (3) Feasibility of recommendations.

also reach their normal peaks and decline, as is the general rule in agricultural pest populations. By the use of pesticides, what is achieved is the immediate knock-down of a part of the population peaks and in many instances this is followed by a prolonged infestation, sometimes on account of the effect of the insecticides on the beneficial natural parasitic insect populations. Therefore, an attempt has been made in *Table* 1 to illustrate the various aspects that should be investigated before the recommendation of a pesticide for any particular pest of tea.

In the past, in tea entomology, there was the habit of indiscriminate attribution of the cause of deaths of tea plant to various pests. One such instance is that the attack of shot-hole borer beetle on young clonal tea is a contributory cause of the death of the clonal plants during severe droughts. It is now known that the death of clonal plants, during a severe drought is chiefly determined by the factors of the type of clone and soil, and it is already shown that there is no relationship between clonal susceptibility to shot-hole borer beetle attack and drought casualties[6]. Similarly, we should be wary of the view that the defoliation of tea bushes consequent of mite attack, is the primary cause of death of these tea bushes in a severe drought, unless this view has the backing of experimental evidence.

Another interesting feature is that dry weather encourages pest infestations and at the same time aggravates the adverse effects of the pest infestations on the crop, at a time where the crop yields are already low, on account of the drought. This creates the false impression that the main cause of the crop loss is the pest infestation and not the drought conditions, thereby exaggerating the actual loss of crop on account of the pest alone. It is true that insect attacks cause loss of crop on account of the drain on the nutrients and/or moisture stress. This is not greatly felt in wet weather, but in dry weather, any loss of nutrient and particularly water stress is more adversely felt by the plant which will tend to show appreciable amount of *temporary* loss of crop. But, no sooner the rains come the plants show quick vegetative regeneration and compensation in yield losses. Therefore, pest infestations during droughts in tea receive a false and undue importance.

The limitations of the insecticidal method of pest control in tea

When all the experimental evidence over the last fifteen years is viewed from the new orientation of the pest ecology of tea, it appears that the routine application of insecticides for many of the tea pests is uneconomical and untenable for the following reasons:

(*a*) The cost of spraying, even one round of a chemical, is more than the anticipated returns from the crop loss recovered, over the entire pruning cycle. This is all the more so, on account of the increasing costs of production and decreasing profit margins, in combination with the increasing costs of spraying chemicals.

(*b*) The apparently large loss in crop is short-termed and in time this loss is compensated with renewed vegetative growth so that at the end of the pruning cycle there is very little or no loss of crop.

(*c*) The evidence that in time the pest attack is controlled under the influence of natural agents, as in the case of tortrix and mites, **or** is diminished to uneconomic injury levels, like in the case of shot-hole borer beetle, as the pruning cycle advances.

(*d*) The chemical spraying causes the deterioration of the environment, by weakening the natural pest regulatory agents. It also leads to the increasing dependence on the use of more chemicals, making the whole operation still more uneconomic.

What should therefore be the new outlook on pest management in tea ?

Pest control in tea, which in the past has been over-dependent on the insecticidal method, with the emphasis on mere protection, should in the future be oriented towards bio-cultural techniques of regulating pest populations, directed primarily on economic production, so that we arrive at safe, effective and economic means of pest management in tea. The procedures that can be adopted are :—

(1) The immediate ban on the use of chlorinated hydrocarbon insecticides, such as DDT, heptachlor and dieldrin, in pest control in tea. This is already done for tea in N. India, by the Tocklai Experimental Station. Gasser[19] advocated this as the primary step necessary for any programme of 'integrated control'.

(2) The practice of the application of prophylactic sprays should be discontinued. Prophylactic sprays were prescribed for the prevention of the tortrix pest, following dieldrin applications, and still continue to be done for mites.

(3) Any pesticide should be recommended only after a thorough investigation, in all its aspects (*Table* 1), and particularly only if its benefits, both from the point of protection and economics, could justify the cost of the sprays and any adverse effects it causes to the crop environment. It is suggested that the routine application of pesticides be discontinued and replaced by supervised directed spray pro-

grammes, only in cases of large scale outbreaks of insect pests or in very specific instances.

(4) There is the need for more dependence on the bio-cultural methods, which to-date have not been fully investigated. Therefore the necessity arises to develop the environmental resistance against pests and at the same time, to encourage the successful colonization of beneficial biotic populations. Another important approach is the diversification of the environment which could be adopted by the planting of trees, as shade where necessary or as wind belts or even as boundaries. The growth of suitable cover crops is an added means of creating a favourable environment for the development of the beneficial insect populations, because, thereby we provide insect parasites, particularly of the useful hymenopterous insects, with sources of food and shelter.

(5) Finally, there is the need for intensive long term ecological research on the other pests of tea, similar to that being carried out on the shot-hole borer beetle of tea. Research needs to be directed towards cultural means of pest regulation and methods at improving the environment.

Bio-cultural methods of pest control in tea

The immediate, short-term results of insecticidal applications, in killing insect populations, irrespective of the quantum of protection and economic benefits accrued towards increased production, have led many to believe that pest management cannot be achieved without the use of insecticides. This is also true of pest management in tea.

The above attitude to pest control overlooks the more important aspect of the natural environmental resistance to pests, brought about by predatory insects and organisms within the crop environment. It ignores the fact of the slow development, over the years, of natural beneficial insect populations. On the other hand, it also ignores their very gradual deterioration and the consequent imbalance of pest populations which are largely dependent on the agro-cultural methods we adopt down the years. The most hazardous of these agro-cultural methods is the use of non-selective persistent pesticides. In tea, we have good examples of introduced biologically useful parasitic insects taking control of pest populations. One such instance is the natural control of the tortrix caterpillar pest by the introduced *Macrocentrus* parasite.[18] But, what is equally important to realise is the less known or unknown insect/parasite complex in tea that is responsible in keeping several likely pests under check, such as twig and looper caterpillars and perhaps many other unknown pests.

Some attempts to control shot-hole borer beetle by cultural means have failed in the past because these have been applied without a sufficient knowledge of the ecology of the pest. Therefore, those who appear to have little faith in the bio-cultural methods, through an ecological approach, exaggerate the limitations of this approach and assume that in many instances we cannot free ourselves from the dependence on insecticides in tea, while they are unaware of the serious limitations of the gainful use of insecticides in tea.

The cultural method of removing damaged parts, of the tea plant that rapidly regenerates, by suitable pruning which induces new vegetative growth, can be readily applied to minimize damage caused by pests, such as shot-hole borer beetle or termites, that takes many years to develop into serious proportions. Therefore, on account of the highly regenerative capacity and longevity of the tea plant and the very slow build-up of pest damage, the cultural method of pest regulation by pruning takes advantage of the time lag in the development of the pest damage.

Similarly, a ready method of regulating the tortrix pest is the introduction of *Macrocentrus* parasite. However, since 'central breeding' of the parasite for large scale distribution will be a costly process it is suggested that cocoons of the parasite could be merely collected from neighbouring estates, where the attack is nearly under control, at its late stages, and introduced into other fields with new infestations of the pest. This simple method will only require the co-operation of the planters, in any particular district, in sharing the information as regards tortrix infestations and as from where the cocoons of the parasite could be collected at any particular time. The Tea Research Institute could act as a co-ordinating agency to assist planters in obtaining the cocoons of the parasites at the right time. This would be a better means of regulating the tortrix pest than the ineffective and dangerous practice of routine insecticidal applications and should merit trial.

As for mite pests, on the evidence provided above, it would be seen that prophylactic sprays and even routine sprays will not be of much benefit. Again, it is suggested that chronic and repeatedly mite attacked fields could be treated at pruning time with a good spray of any sulphur based pesticide, which would have other advantages on the crop too. Of course, this is only meant as a suggestion worthy of trial, experimentally.

It is therefore significant that we look at pest management in tea, from a long term standpoint, with the background knowledge of the ecology of the crop and pest-ecology of each pest problem individually as well as collectively. This calls for an ecological approach to tea entomology, with increased economic production as the main goal.

References

1. CALNAIDO, D. (1969). Report on the Mid-Country Station. *Rep. Tea Res. Inst. Ceylon,* 1968 (2) p. 141-149.

2. CALNAIDO, D. (1971). *Tea Quart.* **42** p. 175-181.

3. CALNAIDO, D. (1972). *In : Towards increased productivity on tea land in Ceylon.* Proceedings of Symposia, **1** p. 16-18. Talawakelle: Tea Res. Inst.

4. CALNAIDO, D., RANASINGHE, M. A. S. K. *and* THIRUGNANASUNTHARAN, K. (1972). *Proc. Cey. Ass. Advmt. Sci.* **28** (1) p. 53-54.

5. CALNAIDO, D., RANASINGHE, M. A. S. K. *and* THIRUGNANASUNTHARAN, K. (1972). *Proc. Cey. Ass. Advmt. Sci.* **28** (1) p. 54.

6. CALNAIDO, D., THIRUGNANASUNTHARAN, K. *and* RANASINGHE, M. A. S. K. (1972). *Proc. Cey. Ass. Advmt. Sci.* **28** (1) p. 52-53.

7. CRANHAM, J. E. (1961). Report of the Entomologist for 1960. *Rep. Tea Res. Inst. Ceylon* p. 58-65.

8. CRANHAM, J. E. (1962). Report of the Entomologist for 1961. *Rep. Tea Res. Inst. Ceylon* p. 71-80.

9. CRANHAM, J. E., KANAPATHIPILLAI, P. *and* KATHIRAVETPILLAI, A. (1968). *Bull. ent. Res.* **57**, p. 619-641.

10. CRANHAM, J. E., RANAWEERA, D. J. W. *and* RAJAPAKSE, G. B. (1962). *Tea Quart.* **33** p. 189-195.

11. CRANHAM, J. E., RANAWEERA, D. J. W. *and* RAJAPAKSE, G. B. (1962). *Tea Quart.* **33** p. 196-201.

12. DANTHANARAYANA, W. (1967). *Tea Quart.* **38** p. 153-177.

13. DANTHANARAYANA, W. (1971). Report of the Entomology Division. *Rep. Tea Res. Inst. Ceylon* 1969 (2) p. 108-123.

14. DANTHANARAYANA, W., FERNANDO, N. *and* SHANMUGAM, C. (1968). *Tea Quart.* **39** p. 94-114.

15. DANTHANARAYANA, W., *and* KATHIRAVETPILLAI, A. (1969). *J. appl. Ecol.* **6** p. 311-322.

16. DANTHANARAYANA, W *and* RANAWEERA, D. J. W. (1968). *Tea Quart.* **39** p. 50-60.

17. DANTHANARAYANA, W. *and* RANAWEERA, D. J. W. (1970). *Tea Quart.* **41** p. 19-33.

18. GADD, C. H. (1941). *Tea Quart.* **14** p. 93-97.

19. GASSER, R. (1966). *Proc. FAO Symposium on integrated pest control, Rome* 1965 **2,** p. 109-114.

20. RANAWEERA, D. J. W. (1958). *Tea Quart.* **29** p. 125-128.

21. SMITH, R. F. (1971). The impact of the green revolution on plant protection in tropical and sub-tropical areas. *Ent. Soc. America.* 1970 *Founder's Memorial award lecture,* California. 19 pp.

22. TEA RESEARCH INSTITUTE OF CEYLON (1957-1971). *Rep. Tea Res. Inst. Ceylon* 1956—1970.