

# The Development of Pesticides

## A Chemical Manufacturer's Viewpoint

**F. S. Downing, Imperial Chemical Industries Limited, Jealott's Hill Research Station**

Despite the success of lindane, DDT and aldrin in controlling *Distantiella theobroma* and *Sahlbergella singularis*, the major insect pests of cocoa in West Africa, new compounds have continually been sought and tested by industry with the co-operation of the official cocoa research workers in West Africa. Fresh impetus has been given to this work with the discovery of resistance, albeit localised, by *D. theobroma* in Ghana (1) and *S. singularis* in Nigeria (2) to BHC and cyclodienes.

In this paper I shall outline the complex of chemical, entomological and medical tests essential to the discovery of any new pesticide, and then describe in more detail the test methods used against cocoa mirids, pointing out some of the difficulties, both technical and commercial, involved in finding a new cocoa mirid insecticide.

### Finding a new insecticide

Up to now all the new compounds generally known to have been field-tested against cocoa mirids have been effective against many other pests as well, and were selected by industry for their general potential in world agriculture or public health. In seeking these new compounds industry has to synthesise a large number of novel compounds and screen them in the laboratory against insects representative of the major pests of the world. Approximately one in 2,000 of these new compounds may be sufficiently toxic to insects to warrant further tests, but very few will ever satisfy all the requirements for commercial development.

Much of this screening work is empirical since too little is known of the physiology of insects to enable chemists to predict the structure of a new insecticide. Nevertheless, with experience it is sometimes possible to guess how the structure of a newly-discovered chemical should be modified to increase its efficiency or reduce its toxicity to man. The examination of new compounds in the laboratory therefore covers not only their toxicity to insects, but also other important properties which affect their efficiency, such as fumigant action, translocation in the plant, persistence on the leaves or in the soil, phytotoxicity and mammalian toxicity. The results give some idea of the types of insect complex, crop and application for which the compound is best suited. In addition, the properties of new chemicals are compared with those of established products, particularly in respect of those characteristics known to contribute significantly to their success.

Finally, new compounds are examined for properties not possessed by the standard insecticide, but which it is considered, from a detailed knowledge of the pest and crop, could be of advantage in achieving more efficient control.

### Lindane as a standard for new cocoa mirid insecticides

When looking for a new cocoa mirid insecticide, lindane is obviously the best comparative standard to use. The success of lindane has been attributed to:—

1. Rapid kill of the mirids
2. A fumigant effect (4, 8)
3. Absence of taint or residues harmful to the consumer in the harvested crop (4)
4. No phytotoxicity with young or old plants (4)
5. No adverse effects on spraymen (4)
6. Chemical stability when formulated as a spray concentrate
7. A high cost/efficiency ratio so that farmers get a good return for the cost of the spray (7, 9)
8. No build-up of secondary pests (4, 5)

The rapid kill of mirids by lindane has often been overlooked as a factor responsible for its success in cocoa. Farmers will, however, be encouraged to repeat their initial spray application by the excitement of seeing a pest die soon after treatment. The uneven cover likely when spraying is carried out by unskilled operators will be offset by the fumigant effect of lindane well described by Raw (8).

A low toxicity by ingestion or absorption through the skin is clearly important in cocoa since farmer spraymen, normally with scanty clothing, become drenched in the fall-out from mistblowers. Dermal and nasal irritation by the spray mist can also prevent the development of a potential cocoa insecticide, and the solvents and wetters in the spray must be as free from these disadvantages as the insecticide itself.

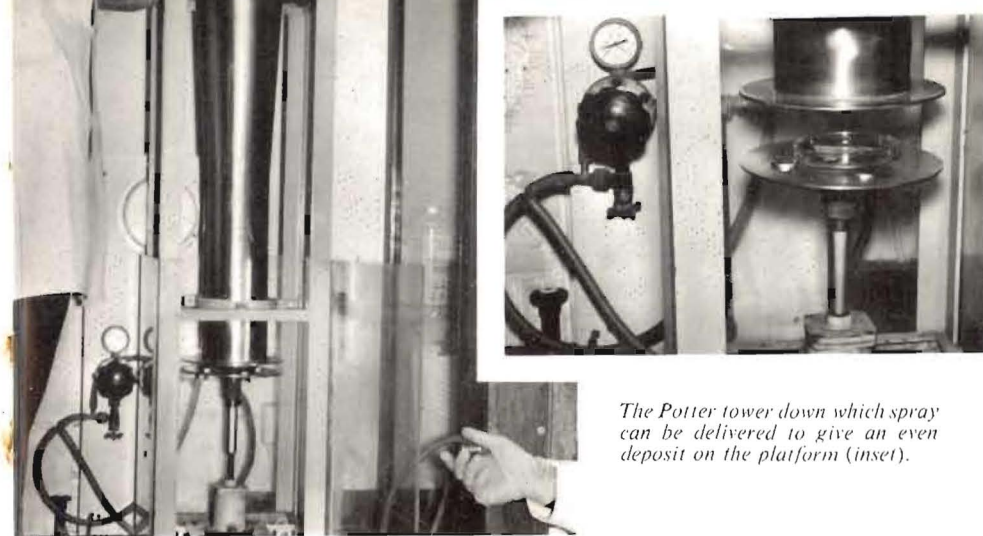
The build-up of secondary pests in the farmer's cocoa has not occurred where lindane has been used, although the reasons why are not known. Entwistle *et. al.* (5) showed that heavy applications could upset the biological balance by killing predators and parasites of the pests. From this one concludes that the average farmer application rate must be low enough to avoid such an undesirable action. This is perhaps a reasonable assumption since only four applications are made each year, and, as lindane has only a short persistence on plants, the insect population of the farmer's cocoa would be exposed to the insecticide for a few days only. During the rest of the year the treated crop could be recolonised by predators and parasites from nearby untreated areas, while cocoa mirids which are local in habit would be less likely to reinvade very rapidly.

### Laboratory tests for a mirid insecticide

The laboratory methods for detecting the properties required in new cocoa mirid insecticides are fairly simple, but the work is complicated by the fact that, because industrial laboratories are sited away from cocoa-growing areas, neither *D. theobroma* nor *S. singularis* can be reared in sufficient numbers for their tests. The closely-related cotton stainer *Dysdercus fasciatus* is commonly used instead, but I have found that this insect can differ markedly from *Distantiella* in its susceptibility to pesticides, so that repeat tests on the pest itself in West Africa are essential.

To determine the toxic level of any new compound to cocoa mirids, two laboratory methods are commonly used:—

1. A single, measured drop of insecticide, usually in acetone solution, is placed onto the back of each insect from a micro-syringe, or



The Potter tower down which spray can be delivered to give an even deposit on the platform (inset).



Plastic rings lined with PTFE attached to cocoa pods with plasticine so that mirid nymphs can be trapped on the cocoa pod.



Young cocoa plants minus leaves on which mirid nymphs are trapped by lining the plastic funnels with PTFE.

- Insects are sprayed in a spray-tower (Fig. 1) with a water emulsion of the insecticide similar to that normally used in the field. The tower method is better where possible field dosage rates must be predicted, while the micro-drop technique will show up finer differences between compounds. With either method the insecticide acts by penetrating the insect's cuticle (contact action) and/or by inhalation (fumigant action). The extent to which either method of entry predominates is important, because an insecticide with a strong fumigant action can be sprayed in smaller volumes than one with contact action alone. To measure the fumigant action, insects are held on fine gauze, close to, but not touching, a treated surface.

The persistence of the insecticide on the plant can also help to compensate for poor spray-cover in the field, since an insect not hit directly may die subsequently when it walks over a lethal deposit. The appropriate persistence measurements must be done on cocoa since pesticides have different lives on different plants and even on different parts of the same plant. Thus, with cocoa, persistence must be checked on the pods, green shoots and bark, all of which are commonly inhabited by the mirids (3). Figs. 2 and 3 show persistence tests on pods and shoots. The insects are trapped on the treated surface within plastic rings and funnels lined with poly-tetra-fluoro-ethylene, which produces a virtually frictionless surface over which the insects cannot walk.

While this entomological work is progressing mammalian toxicity and metabolic studies will have continued. The possible hazard to spray operators is initially deduced from experiments with rats and later other animals, and before a product is used, commercially long-term feeding tests determine the hazard to the consumer from continued ingestion of any residues found in the crop. The determination of residue levels cannot begin until a method of analysis has been found which is sufficiently sensitive to detect a low concentration of the chemical. Usually this method of analysis has to be modified for different crops, and the high fat content of cocoa is frequently a problem.

The importance of the constituents of a spray concentrate other than the pesticide is often not realised. These must be carefully investigated since they can determine whether or not a spray will corrode the sprayers, remain stable when diluted long enough for an even rate to be applied, damage the plants or cause taint, or perhaps increase the toxicity of a pesticide to the sprayers.

#### Field trial for a mirid insecticide

Field trials initially involve a few acres of cocoa and build up to large development projects if a chemical is successful. Unfortunately, no method exists for the accurate comparison of compounds in the field, and in the past tests have frequently been repeated with inconclusive results, except to increase the total development cost.

Field trial assessments have commonly depended on the counting of mirids before and after several acres of cocoa have been sprayed. Such counts can never be carried out with a high degree of accuracy since it is only possible easily to reach mirids up to 10 feet from the ground, and these may not be an adequate sample of the whole population. Furthermore, the very small, dark brown to black mirids hiding in crevices are not readily seen, in the dim light beneath the cocoa canopy, and to count all of them would require long and diligent searches not possible in trials. Their numbers are also very small, not more than two to three per tree on average. With such opportunities for error only very big

differences between compounds can be detected with confidence, and only the rare, outstandingly good compound is going to be obvious.

In searching for alternatives to lindane to control resistant mirids, research workers may therefore have to choose between compounds with apparently similar insecticidal efficiencies, if they are not to wait for an outstanding compound which might never appear. Their choice may then depend on other factors such as safety to the operator, the effect on predators, and in particular the absence of taint in the crop. Chemical structures provide no clue as to whether a compound will taint cocoa, and even if they did, a test on the spray formulation used in the field would still be essential. The taint test is at present too large, complex and expensive to be initiated before the insecticidal efficiency of a compound in the field has been established. The procedure will be described in a later paper in the *Cocoa Growers' Bulletin*; it is essentially empirical and must be carried out on the finished chocolate, so that a considerable area of the crop must be treated. A small-scale method to be used early in the development of a compound could assist in reducing the cost of developing new chemicals substantially by eliminating those which taint, before expensive field trials are done.

#### Commercial considerations

It will be clear that the cost of developing an insecticide is borne by the chemical manufacturer, the cocoa research institutes and the chocolate manufacturers. Galley and Stevens (6) estimate the cost to the manufacturer of developing a new agricultural pesticide to be from £½ million to more than £1 million. This figure includes costs of manufacturing, for example those arising from plant design and construction, not discussed in this paper.

In the writer's view insecticides which are highly selective for cocoa pests will not easily be found or developed in spite of the strong desire in many quarters for such compounds. It will be appreciated that a chemical killing specifically *Distantiella* and *Sahlbergella* would only be of use in cocoa in West Africa, and the risks involved in developing a product for such a restricted outlet will be obvious, especially while resistance to lindane and aldrin remains localised.

However, it need not be too readily assumed that new general insecticides will necessarily upset the biological balance in cocoa. Lindane is a good example of a chemical killing a wide range of species that causes no build-up of secondary pests, perhaps because of its short persistence and the way it is applied. Selectivity may also be achieved with systemic insecticides which kill the mirids as they suck the sap. These could be successful in young cocoa, but in mature trees there could be considerable problems in ensuring that the whole tree became toxic to the mirids while preventing excessive residues building up in the pods, which are their favoured habitats. Fairly general insecticides with properties enabling them to be applied selectively are therefore the most likely chemicals to be developed, when they are required, for the future control of cocoa mirids.

#### REFERENCES

- Dunn, J. A. (1963). "Insecticide resistance in the cocoa capsid *Distantiella theobroma* (Dist.)." *Nature*. London, 199, 1207.
- Entwistle, P. F. (1964). "The distribution of mirid species and of resistant mirids in Nigeria". *Proc. Conf. Mirids and other pests of cocoa*, Nigeria 1964, 9-17.

3. Entwistle, P. F. (1965). "Cocoa Mirids, Part 1. A world review of Biology and Ecology". *Cocoa Growers' Bulletin*, 5, 16.
4. Entwistle, P. F. (1966). "Cocoa Mirids, Part 2. Their control". *Cocoa Growers' Bulletin*, 6, 17.
5. Entwistle, P. F., Johnson, C. G., and Dunn, E. (1959). "New pests of cocoa (*Theobroma cacao* L.) in Ghana following applications of insecticides". *Nature*, London, 184, 2040.
6. Galley, R. A. E., and Stevens, J. G. R. (1965). "Pesticide Research Today". *PANS (C)* 11 (4); 366.
7. Hammond, P. S. (1957). "Capsid control on mature trees". *New Gold Coast Farmer*, 1, 109-115.
8. Raw, F. (1959). "Studies on the chemical control of cocoa mirids. *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* (Hagh.)". *Bull. Ent. Res.* 50, 13.
9. Stapley, J. H., and Hammond, P. S. (1959). "Large-scale trials with insecticides against capsids on cocoa in Ghana". *Emp. J. Exp. Agric.* 27, 343.