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SOME SPRAY APPLICATION PROBLEMS IN TROPICAL PLANTATIONS

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Summary The success of crop protection spraying depends not only on the type of equipment employed but also on the way it is used in relation to the biological requirements, crop husbandry and to economic, climatic and other factors. General requirements, equipment and assessment techniques are discussed and examples given of spraying problems and methods of solving them in some tropical plantations.

INTRODUCTION

The success and efficiency of chemical application for crop protection in plantation crops depends on a number of inter-related factors of which the equipment employed is only one. Other important considerations are the technique of application used, whether high, medium, low or ultra low volume spraying, climatic and economic factors. One of the most important aspects of all is the manner in which the technique is put into practice in the field in the context of the biological requirements, the location and nature of the spray target, crop lay-out, height and density, and the mode of action of spray deposits.

General requirements for successful spray application in plantations are discussed together with the problems of satisfying these requirements in some tropical plantation crops.

GENERAL REQUIREMENTS

Crop protection in plantation and other crops involves a series of complex operations (often long and expensive) including biological investigation of the pests and diseases concerned, development of suitable chemical formulations; determination of optimum concentrations and timing of the applications. The final operation on which successful control depends, however, is the application of the chemical in the field; if the application is inadequate then all the other work will have been quite useless.

The basic requirement is that sufficient quantities of active chemical must contact, and in most cases enter, large numbers of pest organisms: these are usually distributed over large areas of the crop, though some may be in localised sites. The spraying operation must ensure this essential contact by depositing the spray liquid on the target surfaces, which may be that of the insect or fungus itself, the upper or lower surfaces of the leaves, the shoots or fruit depending upon the pest organism and the mode of action of the spray deposit. If the spray deposit releases active material which penetrates the leaf surface and is translocated to the site of action, as with a truly systemic chemical, then the initial distribution of spray liquid on the target surfaces is not so critical as that required for effective deposition of a relatively immobile protectant. Some fungicides may advantageously be redistributed by rain from the site of deposition to the site of action, but in tropical rain some fungicide deposits are removed from the plants and deposited on the ground.

Thus, detailed knowledge of the behaviour of the pest organisms and of the spray deposits and active chemicals is required for determination of the target surfaces upon which the spray liquid must be deposited in order to obtain control, and this is the cardinal factor in spray application.

Some of the target surfaces may be exposed and easily impacted by the spray liquid. Others, especially in dense plantation crops such as coffee, may be in protected positions shielded from the spray by foliage or other parts of the plants. The spray application technique itself and the spraying operation must be directed to achieve the required distribution of spray deposits on the target surfaces. One of the most common mistakes made in spray application, particularly in plantation crops, is the assumption that if the crop is "sprayed" then pest and disease control is assured. This is not so, the aim must be to deposit spray liquid on the targets within the crop.

Progress in the more effective use of crop protection chemicals in plantations is not accelerated by the widely-used practice of recommendations based on dose per acre or hectare (of land) and changes have been suggested by Morgan (1964) to relate the recommendations more closely to the spraying requirements basing these on the sprayed area rather than the land area: these two are widely different in some plantation crops and may lead to error factors of up to 8:1 in the quantity of liquid and chemical deposited in the sprayed area and up to 24:1 in the amount deposited on the crop surface.

SPRAY APPLICATION EQUIPMENT

There is now a wide range of application equipment available for use in tropical plantations ranging from the simple implement for use by individual farmers or labourers to aircraft requiring sophisticated organisation. The range of equipment can be divided into the following groups:

1. hand-operated, hand directed;
2. motor-operated, hand directed;
3. motor-operated, 'automatic';
4. aircraft.

1. Hand-operated, hand directed

Perhaps the simplest application equipment of all is a crude brush made of crushed plant stems used for dipping into a tin of liquid insecticide such as DDT and applied to a localised site for control of an active insect pest.

One of the most versatile and flexible pieces of equipment is the hydraulic knapsack sprayer, the basic design of which has remained virtually unchanged since its use in French vineyards in the 1880's, though there have been advances in detailed construction and in the materials used in manufacture. For many years the difficulties and problems of crop spraying in the tropics - consequent upon the climate, the terrain, the unskilled labour and remoteness of some plantations - has been echoed by the plea for a knapsack sprayer which is corrosion-proof, indestructible, weightless, infallible and of course, inexpensive. In reply, the prospective manufacturers understandably wish to know how many tens of thousands are required. Between these two extremes there is an area of compromise which usually involves adaptation of existing equipment.

The pneumatic knapsack is similarly employed, but is generally more effective when used in numbers and charged from a central point.

2. Motor-operated, hand directed

The most widely used of these is the motorised knapsack mist-blower, in which air from a fan is used to atomize the liquid delivered to a tube outlet and to blow the resulting droplets on to the crop. This type of machine has the important capability in tropical plantations of projecting low volumes of liquid over distances up to 20 ft under some conditions and the further advantage of creating turbulence in dense crops. The outlet can be modified in various ways to overcome particular problems. One of these modifications has been the substitution of the single outlet by a double or quadruple one for the spraying of the crop on each side of an alleyway as developed by Tapscott and Mapother (1960b) for tobacco in N. Borneo.

This type of sprayer can also be modified for the spraying of tall trees by increasing the outlet tube length and either pressurising the tank from an outside source of compressed air or adding a small pump so that the liquid reaches the delivery tube at the end of the outlet. Further simple modifications of this equipment can be made for low and ultra-low volume spraying by fitting flow restrictors in the liquid feed line.

An electrically-driven spinning disc may be used in certain cases where a very small volume (ULV) of material, either concentrated or diluted with oil, is distributed over the crop with the aid of wind drift. This method is of use at present mainly with insecticides on low crops: on tall ones the spray is deposited mainly on the windward side.

A light hand-held machine for ULV spraying consists of a droplet-generating spinning disc mounted on the spindle of a fan which blows the droplets to the crop and is more positive than the spinning disc alone.

In some crops, such as coffee, motorised headland pumps, each supplying spray liquid to four or more hand-operated lances, have been used and while in some cases the spraying is effective in others the spray nozzle apertures have been reduced in order to maintain working pressure of liquid from a small capacity pump through long hoses: the resulting small droplets are often prevented by dense foliage from reaching the target.

Much more effective hand spraying can be achieved by employing a tractor - to drive the pump, carry the tank and pull the hoses - though this may demand some alteration of planting lay-out.

Hand-directed spraying, whether hand or motor operated is potentially the most effective, though not necessarily the most economically efficient method of spraying for a wide range of conditions in tropical plantations. If the operator has been fully trained and is supervised, the spraying is under human control the whole time, and on complex crops such as trees, the spray is directed from many different angles thus overcoming the barrier formed by the outer foliage and delivering the spray liquid to the required targets by conscious effort. Thus, the operator himself is at least as important as the equipment he is using and he must know what the spray targets are.

3. Motor-operated 'automatic'

These tractor-operated machines are used in suitably laid-out plantations and are either hydraulic, some of which employ vertical nozzle assemblies spraying on each side and others horizontal over-crop booms, or some form of mist-blower employing a fan to blow the spray droplets on to the crop. The machines are much faster than hand-directed spraying and as far as the tree crops are concerned are quite different in that:

(a) each row of trees is normally sprayed from two directions only;

(b) each nozzle or outlet, though it may be adjustable, is usually rigidly set in one position during the spraying;

(c) no adjustment is made of liquid volume applied to each tree according to size or density;

(d) an appreciable proportion of the liquid may be sprayed through the spaces between the trees.

Careful adjustment of automatic sprayers is essential for effective spraying of closely planted trees such as coffee (Mapother & Morgan, 1968).

4. Aircraft

Aircraft spraying is now widely used for application of two main volume ranges, around 110 l/h and also 10 l/h ULV, employing either nozzle booms or spinning cages.

Problems associated with aircraft spraying of plantation crops in the tropics include deposition of much of the spray liquid on the tops of the crop plant and on the upper surfaces of the leaves. Though in tree crops some of the spray falls between the trees and impacts on the lower parts, deposition on dense coffee trees is mainly on the outside and, in a moderate wind, on one side only.

ASSESSMENT OF SPRAY APPLICATION

Once the spray targets have been determined, several techniques can be used to assess the application method or operation and to determine the best technique and optimum setting of the spray equipment. Some of these techniques are simple and can be used locally in territories lacking sophisticated technical facilities, others are best used in specialised laboratories.

The simplest technique employs a small amount of fluorescent tracer in the sprayer tank for a qualitative assessment of the location and distribution of initial spray deposits. Samples of the spray targets are removed from known zones of the crop plant, usually top, middle and base, inside and outside and the degree of cover, seen under u/v light, can be expressed as the % number of samples from each zone falling in the spray cover categories of heavy, medium, light (even or uneven) and no spray cover. The limits of visibility of fluorescent tracers in low volume sprays have been worked out by Tapscott & Mapother (1959a).

For assessment of levels of deposit, expressed as ug/cm^2, copper fungicide may be used and colorimetric methods employed to determine the levels of copper.

Gas liquid chromatography is used after extraction of insecticide or organic fungicides such as captan or captafol from each sample. This gives valuable information on the location and levels of initial deposits and on redistribution of active chemical.

Techniques developed by Conibear & Morgan (1962) are now available for collection of spray droplets and electronic sizing and counting methods are used for rapid droplet spectra analysis.

These techniques have been developed and used at Long Ashton and have enabled technical assistance in the solution of spray application problems in tropical plantations to be given through the auspices of the former Overseas Development Ministry, now the Overseas Development Administration of the Foreign and Commonwealth Office.

Two examples serve to illustrate ways in which this type of assistance may improve spraying in tropical plantations by using existing knowledge of application and assessment techniques provided that the basic biological work has been done and the spray targets have been worked out.

Cotton Spraying

Investigations were carried out by Kearns and Mapother (1965) in the Gezira, Sudan in 1963 and 1964 to evaluate the wide-angle Gezira nozzle then in use on a fleet of tractor boom sprayers. They found, by the use of fluorescent tracers and copper fungicide assessment, that this nozzle, in addition to giving an uneven pattern of deposit over the swath width, was unduly wasteful of spray liquid much of which was deposited in the form of large droplets on the ground. A replacement sealed nozzle/filter unit designed and made at Long Ashton applying the same liquid volume as the original nozzle - 7.1 gal/feddan (6.8 gal/ac) - deposited seven times the amount of spray material on the upper leaf surfaces and three times that on the under-surfaces of both top and middle zones of the cotton plants, and approximately the same quantities on the bottom zone.

Coffee Spraying

Following serious crop losses caused by coffee berry disease (Colletotrichum coffeanum) in Kenya, in collaboration with the Coffee Research Station at Ruiru, a study was made of methods of fungicide application, an important factor in control measures. Experience and application assessment techniques developed in fruit spraying in the U.K. were used to suggest ways in which coffee spraying for C.B.D. control could be improved. The essential work on the epidemiology and control of the disease, fungicides, spray programmes and timing has already been done by Bock, Gibbs, Griffiths, Mulinge, Nutman & Roberts, Vine, Waller, Wallis & Firman (1961-1971). At first, the main target for fungicide application was thought to be the shoots, where the fungicide acted as an anti-sporulant, but later work showed that disease control was erratic and dependent on flowering times and that continuing sprays to protect the berries were essential.

Initially, therefore, the direct spray targets were the shoots and berries; the leaves could be ignored in assessments of fungicide applications for control of this disease, as opposed to the requirement for control of coffee leaf rust (Hemileia vastatrix).

Over half the coffee in Kenya is produced on small holdings and the remainder on larger plantations. Existing spraying methods include hand spraying with hydraulic equipment and knapsack mist-blowers, automatic spraying with hydraulic machines, and tractor-mounted mist-blowers and by aircraft.

Some of these were examined locally using fluorescent tracer for qualitative assessment of spray cover. Chemical estimation for quantitative assessment of deposits of the two main fungicides used, copper and captafol, were carried out in the U.K. on shoot and berry samples sent by air from Kenya.

Some considerations of spraying techniques for C.B.D. control have been presented by Mapother & Morgan (1968).

A summary of copper deposits obtained on coffee shoots from top, middle and base zones of the trees by different application methods and modified equipment applying the same concentration of fungicide (0.5% a.i. copper) is given below.

TABLE 1

Method	Equipment	gal/ac	(l/h)	ug copper/cm^2		
				Top	Middle	Base
Hand lance	Original nozzle	120	1350	7.0	15.0	6.0
	Long Ashton nozzle	120		30.0	26.0	31.0
Hand-directed mist	Fontan knapsack mist-blower	60	675	14.0	24.0	16.0
Automatic mist	Power mist	40	450	0.7	1.2	2.0
	Wasp	60		1.0	2.8	1.8
	Conomist raised nozzles					
	10° to rear	120		7.5	9.5	18.0
	45° to rear	120		13.0	12.0	16.0

In the hand spraying, 4 and 5-fold increases in deposits were obtained on the top and base shoots, by changing the nozzles while keeping the volume/ac the same.

The tractor-mounted mist-blowers applying 40 and 60 gal/ac gave similar levels of deposits which were very much lower than those given by the hand-directed mist-blower spraying the trees with the same vol/ac from many different angles.

The raised outlets on the mist-blower applying 120 gal/ac gave more deposit on the tops of the trees when turned at 45° to the rear than at 10°.

The hand-directed mist-blower applying 60 gal/ac gave similar deposit levels on the top and base, and twice the levels on the middle zone compared with the tractor-mounted mist-blower applying 120 gal/ac.

A recently-introduced overhead boom hydraulic sprayer, the 'Monicamist', designed for multi-row spraying, which directs the spray mainly laterally over the tree rows on each side, was assessed by chemical estimation of copper deposit levels on 4 rows of trees to one side (Table 2). Shoot, leaf and berry samples were taken from the top, middle and base zones of the trees both on the side nearest the machine (a) and that furthest from it (b) in each row. The fungicide applied was a copper oxychloride at 3 lb active copper in 93 gal/ac.

TABLE 2

Copper deposits from multi-row sprayer ug/cm^2

SHOOTS

Row	Side	Top	Middle	Base
1	a	7.1	5.7	3.2
	b	5.0	3.0	5.0
2	a	5.7	3.0	3.3
	b	2.2	4.2	3.7
3	a	3.6	2.2	5.9
	b	2.2	3.3	2.4
4	a	2.8	1.8	2.8
	b	2.0	4.4	3.5

TABLE 2 (Cont.)

Row	Side	Top		Middle		Base	
		BERRIES					
1	a	-		-		0.7	
	b	1.8		1.2		1.0	
2	a	2.2		0.6		0.7	
	b	1.2		0.7		0.6	
3	a	1.5		1.2		0.8	
	b	0.7		3.1		0.3	
4	a	0.6		0.5		0.6	
	b	0.5		0.7		0.5	
		LEAVES (upper and lower surfaces)					
		Upper	Lower	Upper	Lower	Upper	Lower
1	a	13.2	2.8	12.2	1.3	3.7	0.5
	b	6.8	1.3	1.5	0.4	6.9	1.0
2	a	12.8	1.4	5.7	1.3	3.4	0.7
	b	12.3	2.5	7.3	0.7	4.6	0.5
3	a	6.7	1.3	10.3	1.2	8.2	0.6
	b	3.5	0.3	1.6	0.5	0.6	0.3
4	a	9.8	0.8	4.4	0.5	3.4	0.4
	b	10.8	1.5	0.1	0.2	0.7	0.1

Deposits on the shoots over the 4 rows and on the two sides of each row were fairly uniform: those on the upper surfaces of the leaves were appreciably greater than those on the lower surfaces. Only on the middles and bases of the furthest rows was there any difference in levels on the two sides of the tree row.

Deposits on the berries, however, were low, and since these are all important in disease control an experiment was conducted at the Coffee Research Station to obtain information on the redistribution of copper and captafol fungicides by tropical rain as a possible means whereby cover of shoots and berries could be effected when the fungicide was applied only to the top zone of the trees.

Top spraying and the normal overall spraying were done with a knapsack mist-blower applying 0.5% copper and 0.48% captafol in 33 gal/ac. A series of samples of shoots, berries and leaves were taken from the top, middle and base zones of the trees soon after spraying and also after measured amounts of rainfall. The copper and captafol deposits were measured in the U.K. by colorimetric and GLC techniques and gave indications of the redistribution trend of the two fungicides and of their removal from the trees by rain.

On the trees sprayed on the tops only, the first inch of rain, recorded 10 days after the spraying, reduced both the copper and the captafol deposits as shown in Table 3.

TABLE 3

Mean % reduction of fungicide deposits

	Copper	Captafol
Shoots	42	81
Berries	71	48

The figures indicate the differential removal of the two fungicides from the different samples. A further inch of rain after 19 more days removed very little of the remaining fungicide deposits from the top portions of the trees.

After one inch of rain there was an appreciable increase in deposit of both fungicides on the middle zone, presumably coming from the top zone, but negligible increase on the base zone.

Estimation of total fungicide dripping from the trees to the ground indicated that 10% of the total copper applied had been washed off by 2 in. rain but 90% of the captafol applied was washed off by the first half-inch of rain.

On trees sprayed overall in the normal way the deposits were generally more uniform over the tree, as expected, but deposits on the berries were less uniform than those on shoots and leaves. On these trees, as on those sprayed on the tops only, there was an appreciable reduction of captafol on leaves and shoots in all parts of the trees and from berries in the top zone. Copper deposits appeared to be less affected by rain, but appreciable amounts were found in the rain drippings beneath the trees.

Experiments over several seasons are necessary to establish the efficacy of over-crop spraying and the role of fungicide distribution in the control of coffee berry disease and coffee leaf rust: recent work in Kenya has indicated that aircraft spraying has given better control of C.B.D. than of leaf rust.

The potential of the new systemic fungicides in the tropics has been reviewed by Byrde (1970) and there is little doubt that fungicides with effective systemic or translaminar action would solve many application problems in tropical plantations.

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PROBLEMS ON THE USE OF INSECTICIDES IN THE TROPICS

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Summary When comparing chemical control of insects in the tropics and in temperate countries, two special problems are evident in the tropics. The first arises from the use of biologically active chemicals by less skilled operators, which increases risks to human beings and of pollution and increases difficulties in ensuring that the required dose of insecticide is accurately placed and maintained.

The second arises from differences in the biology, behaviour and distribution of some important tropical pest species, which often means that efforts by individual growers are ineffective and that only an organised attack on a large scale can lead to satisfactory control.

Fields of use of insecticides that can be considered include:-

a) public health
b) plant protection
c) stored products
d) veterinary and household

This talk refers primarily to the use of insecticides in public health and plant protection. Problems in their use on stored products differ from those of temperate countries primarily because infestations can build up faster and conditions of storage are often primitive and make effective treatment more difficult. Pest control in houses again is more difficult because pests have shorter life cycles and houses are more primitive.

Control of pests of stock also raises special problems, but in a general talk such as this, it is impossible to deal with them individually. It is perhaps reasonable to suppose that tropical conditions favour the development of resistance to insecticides in one very important group of cattle pests, the cattle ticks, because these will have brief life cycles, multiply quickly and frequent reinfestation will necessitate frequent chemical treatments. In fact, ticks have become resistant and difficult to control with insecticides in Australia, South America and South Africa.

Considering first some general problems, the use of insecticides in tropical and temperate conditions can be compared under three headings:-

1) Safety to people
2) Application and persistence
3) Environmental contamination

1) Safety to people

Although highly toxic insecticides such as parathion and endrin are widely used in tropical countries, it is much more difficult to use them without serious hazards to the operators because it is too hot to wear adequate protective clothing. Primitive and badly maintained spraying-equipment also often add to the risk. Hazards during transport and storage are also increased because the poisons are often not carefully segregated. Removing these dangers is difficult because the nature of the hazards and the ways to avoid them are often not understood by those likely to be at risk.

It is therefore specially desirable that under these conditions only chemicals that have little toxicity to people or stock should be used, and the chemicals should be formulated in ways that also lessen the risks.

2) Application and persistence

Insecticides are applied as sprays, dusts, or granules to the aerial parts of the plant and surfaces above ground, and as granules and liquid or powder seed dressings below ground. In temperate countries, much is known about the amount of insecticide that reaches the target area and how long it stays there. The relationship between the amount of chemical present and the degree of control of the pest obtained is, therefore, reasonably well established.

Although some work has been done to study the behaviour of the chemicals in the tropics, because of the differing circumstances from one country to another and because of the great range of crops and the ways in which they are grown, information on this subject is scanty and control methods are therefore largely speculative.

In addition to the difficulty of knowing how effective treatments are, practical problems of applying insecticides in tropical countries are complicated by different agronomic methods and different environments. Some of these complications arise from the practice of growing crops such as coffee and cotton by peasant farmers in very small patches, making it impossible or uneconomic to use any but the smallest hand applicators. Even if crops, such as coffee, are grown in larger plantations, often the variation in growth and pruning methods is such that the designing of machines able to cover parts of all plants effectively is very difficult. Another application problem arises from the high temperatures and hence great atmospheric turbulence in the tropics. Applying fine sprays or dusts in such conditions is a very wayward and imprecise process. Such treatments should be, but are not always, confined to the cooler parts of the day.

In addition to the extra difficulties of ensuring that enough insecticide reaches the target area, there can also be great differences in the residual life of the deposits in temperate and tropical conditions. Results at Rothamsted indicate that temperatures reached on surfaces exposed to the sun in the tropics would be such that non-systemic insecticides applied in commonly used formulations would not persist "in situ" for much more than a week. Fig. 1 is a generalised graph from results obtained under a range of temperatures and windspeeds. It demonstrates that the rate dieldrin is lost from a surface follows a simple exponential curve, so that, for any one set of environmental conditions, a constant proportion of the amount present on the surface is lost at any given time.

Fig. 2 shows the percentage loss of dieldrin deposit, irrespective of the initial amount, that may occur under temperate and tropical conditions in twenty four hours. The two strictly comparable figures are 25% at 20°C and 95% at 40°C at the same windspeed (60 m/min). Thus in tropical conditions, the greater part of even the most persistent insecticides may be lost from their target surface in a few days. There is a qualification to add, that when the deposit is reduced to approximately 0.005 $\mu g/cm^2$ on a glass surface or 0.01-0.02 $\mu g/cm^2$ on a cotton leaf, it no longer obeys these rules, but remains firmly bound to the surface for very long periods. This is likely to apply to insecticides applied as sprays of wettable powders or emulsions, or as dusts.

It should be borne in mind however that this statement refers to situations where the insecticide is applied to surfaces exposed to the sun, which is necessary in most agricultural applications in the tropics. In applications for tsetse control however, insecticides are often applied to the places where the tsetse themselves shelter and are hence some of the coolest and most protected sites. Even in the tropics deposits of insecticides such as dieldrin can persist for four or five months at a sufficient level to kill tsetse flies resting on bark on the lower side of two inch thick horizontal branches within clumps of trees.

Apart from these exceptions, the data indicate the need for some means of formulating the chemical so that its persistence "in situ" can be controlled.

At Rothamsted, a considerable amount of work has been done on microencapsulation. It has been shown that it is possible to encapsulate an insecticide in a non-volatile envelope of a mixture of hardened gelatin and gum acacia in such a way that the microcapsule is virtually non-toxic by contact, but is toxic to insects ingesting it (Phillips, 1968). It has also been shown that by the incorporation of suitable stickers in aqueous spray suspensions of microcapsules the formulation may be made to have considerable resistance to weathering (Potter, 1969). This type of formulation would appear desirable for sprays for the control of leaf-eating pests in the tropics and in baits for the control of such species as the leaf-cutting ants. It has the advantages of conferring greatly added safety to man, and selectivity to insects, by protecting beneficial ones such as predators, parasites and pollinators.

Where contact kill is required, leaking capsules can be prepared which will release the poison over a period of time. This reduces the advantages of added safety and selectivity but gives a useful control of persistence.

Fig. 3 gives some data obtained at Rothamsted; it shows that under reasonably warm conditions, over 90% of DDT from a standard wettable powder was lost from the target area in 35 days, while leaking capsules lost about 20% of their DDT in the same period. The amount leaking from the capsules required to provide a continuous lethal film of contact poison will depend on the species of insect. However, as a guide, we would point out that the amounts shown in Fig. 3 would be highly toxic to housefly adults in bioassay tests (Ward, Gillham & Potter, 1960), where the LC50 is about 1.23 ± 0.02 µg/cm^2 on glass and 2.82 ± 0.16 on cotton leaf.

3) Environmental Contamination

The work just referred to is concerned with the persistence of the insecticide at the site of insect attack and hence its effectiveness for controlling the pest.

Persistence of standard formulations at the site of application is likely to be short under tropical conditions; it does not necessarily follow that the environment as a whole is not contaminated by the poison. In fact the situation may be worse than in cooler conditions because of the need for more frequent or heavier applications of the poison to obtain satisfactory pest control.

Once the poison has been removed from the target area, unless there is a greater rate of decomposition in tropical conditions, the difference between contamination in tropical and temperate areas seems likely to be in the rate of movement of the contaminant from one zone of contamination to the next. Edwards (1970) gives a scheme illustrating the circulation and recirculation of pesticides in the environment. This is a dynamic picture and shows that the rates of movement of insecticide are likely to be greater in the tropics than in temperate conditions. However, there appears to be very little data on the extent of this movement and the rates at which it occurs. Since very large quantities of persistent insecticides have been, and are still being, used in agriculture and for malaria control, information on what happens to the insecticide that volatilises from its site of application is important in terms of environmental contamination, possibly on a world scale. It has been estimated that 2/3 of the DDT produced in the last 25 years still remains as DDT or the stable pollutant DDE (Anon, 1971).

Alternative methods

In many tropical countries, unskilled and uneducated labour is necessarily involved in the transport and application of dangerous chemicals, and large quantities of these chemicals are needed to obtain adequate pest control. There is thus heavy contamination of foodstuffs and the environment, and a greater need for alternative methods of control than in temperate countries. However progress in cultural and biological control and in the production of resistant varieties always seems slow and may be rendered more difficult by the introduction of new varieties which, although high yielding, are more susceptible to damage by pests (Pradhan, 1971). There may be greater promise in the development of chemical methods other than the use of insecticides, e.g. in the use of behaviour-controlling substances, such as sex pheromones, or anti-feeding substances.

Apart from the general problems of using insecticides in a tropical environment, some of the major pests pose special problems because of certain features of their biology or of the circumstances in which they occur. In a talk such as this it is only possible to mention a few examples that occur in important pest species.

(i) Locusts. The solitary phase is difficult to find and to control; and the migratory phase, moving in swarms over large areas, requires special techniques and organisation. Individual small scale efforts are necessarily of limited value.

(ii) Leaf-cutting ants. The nests are inaccessible and not easy to locate. The development of effective baiting techniques seems to be the most promising line of approach.

(iii) Pests of irrigated rice. In areas such as India where inland fish are an important source of protein in the diet and are grown in irrigation water, the problem of chemically controlling the insect pests without harming the fish is difficult.

(iv) Termites. Because of their inaccessibility, destruction is very difficult and "control" is generally a question of prevention of entry to a house or other structure by ant-proof construction.

(v) Cotton pests. Some problems occur because of the differing importance of individual species of a group of pests in different parts of an area. For example, bollworms are important pests of cotton throughout Eastern Africa. However in Zambia, Malawi and Southern Tanzania the red bollworm *Diparopsis* is the chief pest; in East and North Tanzania, American bollworm *Heliothis* is the most important; and in Uganda *Earias* and the pink bollworm *Platyedra* are also important.

(vi) Special problems arise in the field of malaria control. This disease is now confined to tropical and subtropical areas. The advent of DDT, which could be used to give a cheap persistent insecticidal deposit on the walls of houses, gave promise of the eradication of malaria. However, some important vectors, such as *Anopheles gambiae* in Africa, were found to be difficult to kill with DDT because they are irritated by sublethal doses which thus produce a repellent effect. Also many vectors in all parts of the tropics have developed resistance to this and other insecticides, so that many problems remain.

(vii) Tsetse flies pose many special problems and illustrate the difficulties that may rise in the tropics owing to the scale of the operation and the nature of the terrain. First, they are able to survive at very low densities; less than 1 fly per acre is not uncommon for the savanna species. At this level they can transmit diseases to man and his animals. Secondly, they cover very large areas of country: it is estimated for example that 2/3 of Tanzania is infested by tsetse flies, and about 4,000,000 square miles in the whole of Africa. The low density problem is tackled by trying to discover where the flies generally rest, so that applications of insecticide can be concentrated on these areas; and the problem of scale has led to the use of aircraft for the widespread application of insecticide.

(viii) Simulium control has been well established in temperate countries such as Canada and the U.S.A. but in the tropics it poses special problems because of the continuous breeding cycle of the insect. For example, a much lower dose of insecticide is required to kill the larvae than the pupae; in temperate climates, only larvae are present in the rivers in springtime, whereas in the tropics there are always pupae as well.

To summarise, chemical control of insects in the tropics has its own special problems which can be considered under two general headings.

The first concerns the use of highly biologically active chemicals in tropical conditions in developing countries. This results in increased risks to human beings, and of environmental contamination. Furthermore there is increased difficulty in placing the required dose of insecticide on the target sites and ensuring that it stays there for the time required to give satisfactory control of the pest. This is due, not only to the climatic conditions, but also to the wide variation in the scale of application and difficulties in organisation where large scale operation is necessary.

The second concerns the problems produced by special aspects of biology, behaviour and distribution of some important tropical pest species, where separate small scale efforts must necessarily be ineffective and only an organised attack on a large scale can lead to satisfactory control.

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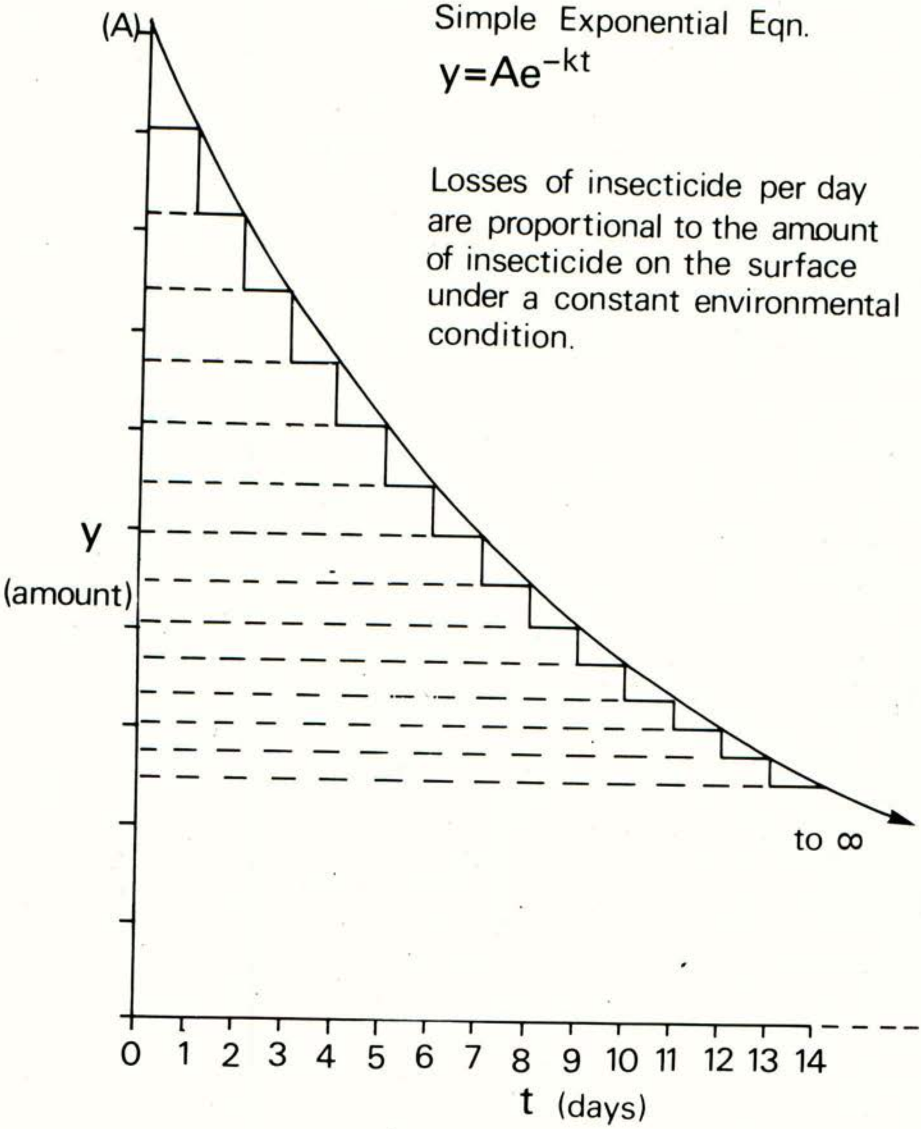
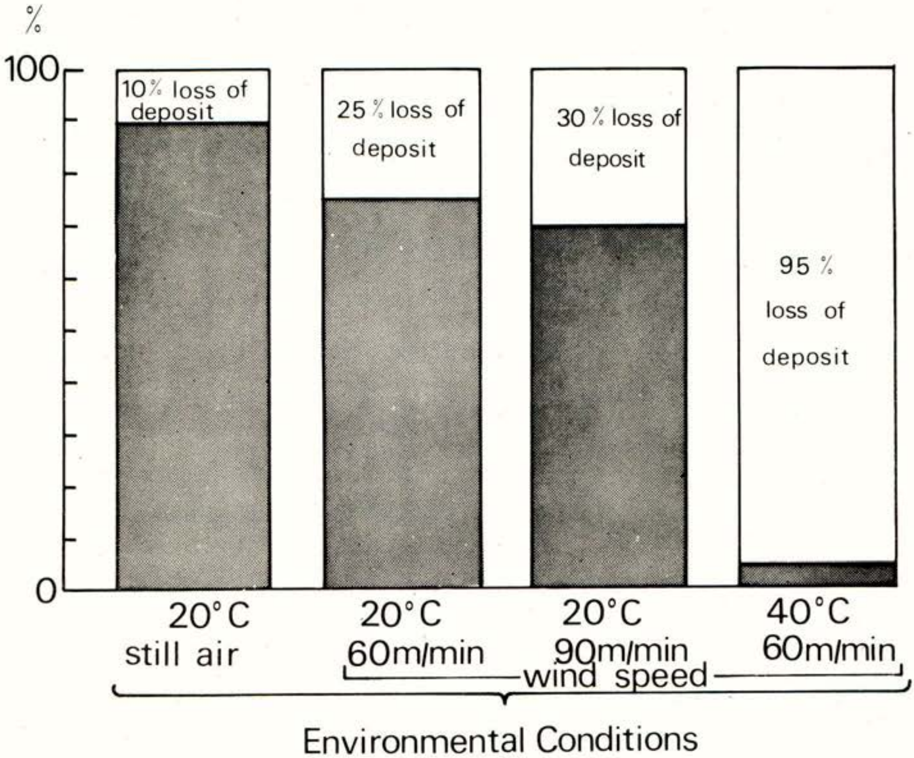
Persistence of DDT on cotton-leaf surfaces in (i) wettable powder (ii) microcapsule formulations under constant cyclic conditions (28 °c day/20°c night, 55–60 % R.H., 10 hours daylight).

Days after treatment	WETTABLE POWDER — Amount (µg) and % DDT left on leaf surface.		MICROCAPSULES — Amount (µg) and % DDT left inside microcapsules		MICROCAPSULES — Amount (µg) and % DDT on outside of microcapsules	
	(1)	(2)	(1)	(2)	(1)	(2)
0	2000 (100%)	400 (100%)	25 (100%)	25 (100%)	0 (0%)	0 (0%)
7	361·9 (18%)	183·6 (46%)	22·3 (89%)	21·5 (86%)	0·4 (2%)	0·9 (4%)
14	281·2 (14%)	178·9 (45%)	21·9 (88%)	21·6 (86%)	0·6 (3%)	0·9 (4%)
21	206·9 (10%)	150·8 (38%)	19·1 (76%)	20·0 (80%)	0·9 (4%)	0·9 (4%)
28	270·3 (13%)	149·0 (37%)	17·7 (71%)	20·3 (81%)	1·2 (5%)	1·0 (4%)
35	184·1 (9%)	142·7 (36%)	19·8 (79%)	19·2 (77%)	1·2 (5%)	1·1 (5%)

(Figures are the means of 3 replicates)

Results from two separate experiments (1) and (2) are shown


Simple Exponential Eqn.
y=Ae^-kt
Losses of insecticide per day are proportional to the amount of insecticide on the surface under a constant environmental condition.
(A)
y
(amount)
to ∞
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
t (days)



Dieldrin on cotton-leaf surfaces. Percentage losses over 24 hrs. for any deposit level under 4 different environments.

(Proc. 6th Br. Insectic. Fungic. Conf. (1971))

TROPICAL CROP PROBLEMS
THE INTRODUCTION OF COTTON INSECT CONTROL

in Malawi

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Summary Spraying of cotton by progressive small scale farmers has increased steadily in Malawi and yields of approximately 894 lbs/acre (100 kg/ha) seed cotton are obtained. The spray programme is based on scouting to determine when to spray and which insecticide to apply. Knapsack sprayers are used with tail-boombs so that the volume increases from 5-20 gals/acre (56-224 litres per hectare) according to plant height but the concentration of insecticide remains constant. Insecticide is supplied in packets each with sufficient chemical for one knapsack tank of spray. The need for the farmer to measure chemical is eliminated and this reduces the risk of contamination from opened packets. Further expansion of sprayed cotton will be considerable with the introduction of special Development Projects. Further research is presently concerned with ultra low volume spraying, and the development of control techniques using the sex pheromone of *Diparopsis*.

INTRODUCTION

In Malawi, the cotton crop is raingrown by a very large number of small farmers, and in the absence of insect control yields of seed cotton have been generally low, less than 447 lbs/acre (or 500kg/ha) owing to damage principally by the red bollworm (*Diparopsis castanea* Hmps.) American bollworm (*Heliothis armigera* Hbn.) and cotton stainers (*Dysdercus spp*.). Research has shown that yields of cotton can be substantially increased to 1341 lbs/acre (1500 hk/ha) and over by spraying insecticides considerably increasing the profitability of cotton production (Tunstall and Matthews, 1966). The translation of these results into commercial practice has been progressively achieved (Gower and Matthews, 1971; Rice, 1971) (Table I). In the Southern Region where most of the cotton is grown, just over 8000 farmers, representing 16 per cent of registered growers, sprayed their cotton in the 1970-71 season. Estimates for the season are that total production in the Southern Region will be 18700 tons (19,000 tonnes) seed cotton, of which approximately 50 per cent is from sprayed cotton at an average of 894 lbs per acre (1000 kilogrammes per hectare).

* On Secondment from Imperial College, London to the Foreign and Commonwealth Office (Overseas Development Administration).

TABLE 1

AREA YIELDS AND PRODUCTION OF COTTON IN SOUTHERN REGION OF MALAWI

Year	Total Area Acres	Area Sprayed %	Yields, lbs/acre seed cotton			Total Production tons
			Unsprayed	sprayed	All	
1964	84710	0	315		315	12079
1965	91205	0.54	433	993	435	17711
1966	109120	2.22	192	827	207	10051
1967	115816	4.72	127	999	169	7759
1968	92402	9.48	127	976	207	8545
1969	90216	13.97	258	975	358	14374
1970	107017	15.2	272	901	367	17476

Some of the principles on which the commercial programme in Malawi is based, are discussed in this paper.

PEST ASSESSMENT

Cotton is subject to attack by a wide range of insects, whose relative status changes not only with plant development during the season, but also varies from year to year and from district to district. Any fixed schedule of spray application is, therefore, liable to include sprays when insects are not causing economic damage, and conversely sprays may not be applied when they are needed. To overcome this difficulty a system of scouting for the main insects has been devised so that crops are inspected regularly throughout the season and sprays are recommended when pest infestation exceeds certain criteria (Matthews and Tunstall, 1968).

The status of the two main bollworms, Diparopsis and Heliothis, is assessed by scouting for the eggs because young larvae can easily escape detection as they penetrate buds and bolls, the bracts of which do not flare until several days after damage has been done. Twelve plants along each diagonal are inspected for the eggs which may be found over most of the plant in the case of Diparopsis, whereas Heliothis eggs are generally more restricted to the upper part of the plants. Carbaryl sprays are recommended as soon as Diparopsis eggs are found, especially between the sixth and eighteenth week after germination. Sprays earlier than the sixth week are avoided unless jassids reach an average of two nymphs per leaf or elegant grasshoppers (Zonocerus elegans)warrant control. Sprays late in the season may be needed if pest attack continues, especially if the yield potential of the crop is high. As carbaryl is ineffective against Heliothis in Malawi, an important part of scouting is in the need to time the change to DDT when Heliothis eggs exceed 0.5 per plant or there are two or more counts over 0.25 per plant. Generally the number of eggs increases rapidly once the main infestation of Heliothis starts, and in practice the lower criterion is used to allow time to warn farmers to change insecticides. Mixtures of carbaryl and DDT are not applied unless Diparopsis, Earias or Dysdercus populations require control during a Heliothis infestation.

As the area of sprayed cotton has increased, trained scouts are no longer able to visit all farms and only a sample of three farms is scouted twice weekly in each scouts area. Although, with a minimum of training, the ability of scouts to detect bollworms eggs is variable, the main changes in an infestation are usually detected without difficulty. Some farmers are able to assess pest infestation themselves and to facilitate this a simple peg board has been developed (Beeden, 1971a) on which the farmer moves matchsticks along three rows of twenty five holes. On one row the plants inspected are counted and the numbers of eggs of the two species of bollworms are recorded on the other two rows (painted blue and yellow representing the colours of the eggs of the respective bollworms for ease of reference.

Unfortunately, the use of carbaryl and DDT for bollworm control can lead to an upsurge of other pests, especially red spider mite. Scouts are instructed to follow a zig-zag path since mite attacks can start anywhere in a cotton field beginning with a small patch or a single plant. The need for early detection is stressed. At present binapacryl is the recommended acaricide and spot treatment of initial infestation is considered important. If aphid infestations occur the aphicide, menazon, can be added to either carbaryl or DDT. With regular sprays especially of carbaryl for bollworm control, cotton stainer infestations have not been a serious problem except in areas where there is good rainfall late in the season.

SPRAY APPLICATION

The most vulnerable stage of Diparopsis larvae to insecticide is the short period between egg hatching and penetration of a bud or boll inside which the larvae spend most of their life. With eggs distributed over most of the plant and even on bracts of bolls later in the season, good coverage with insecticide is considered essential. Initially trials were conducted using a knapsack sprayer with lance fitted with two nozzles. The lance was moved up and down plants while walking but coverage depended on the reliability of the operator. The tailboom was designed to ensure that adequate coverage was maintained at all stages of plant growth and that green bolls near the base of the plant and the young buds were equally protected. All the operator has to do is to use an additional pair of nozzles for each 1 ft (30 cm) of plant height. As the tailboom is mounted at the rear the operator walks through unsprayed cotton and is generally less contaminated with spray than if a lance is used (Tunstall and Matthews, 1965). The volume of spray increases from 5 gals/acre (56 litres per hectare) with one pair of nozzles to 20 g/ac (224 litres per hectare) with four or five pairs of nozzles for large cotton, but the concentration of spray remains constant throughout the seasn, at 0.5 per cent a.i. for carbaryl and DDT and 0.1 per cent for binapacryl and menazon. The insecticides are supplied as wettable powders in polyethylene sachets, each sachet containing sufficient insecticide for one knapsack sprayer tank of 3 gallons (13.5 litres). This system of packaging eliminates the need for the farmer to measure the insecticide and also considerably reduces the risk of contamination from opened insecticide containers on the farm. A mixing drum graduated to three gallons and fitted with a filtered funnel is supplied with the sprayer. Initially some of the sprayers failed to stand up to regular field use throughout the season. The durability of a wide range of knapsack sprayers has now been tested and sprayers must now conform to the Central Africa Standard for knapsack sprayers CAS No N6:1069.

EXTENSION DEVELOPMENT

In many areas of Malawi the depredations of insects made cotton growing totally unattractive to even the poorest farmers and in these areas cotton spraying made the most rapid progress at first, but with the more intensive extension effort now being made within special Development Projects, the area of sprayed cotton is rapidly in the traditional cotton areas of the lower Shire Valley and Lake Shore. The Chikawa Cotton Development Project, financed by the International Development Agency (Beeden 1971b) and the Salima Lake Shore Project with Federal German aid are already well established and a further scheme on the Karonga Lake Shore is to commence soon. Apart from providing housing, boreholes, and roads, an important feature of the projects is the establishment of a credit fund for the supply of insecticides and sprayers. Only the sprayer price is subsidised. Recovery of credit is extremely good and is now over 90 per cent. There is an extensive training programme for staff and also courses for farmers. Various technical circulars are issued including 'Advice Notes' for extension staff, and two reference books have been published, the Cotton Manual (Gower, 1970) and the Cotton Handbook (Matthews, Tunstall and Munro, 1971). Although the emphasis with cotton production has been the introduction of spraying, the extension effort has focused attention on other problems, notably the marketing of the larger cotton crop, the maintenance of soil fertility and the need for soil conservation.

DISCUSSION

When the initial research into chemical control of insect pests commenced in 1958 many people considered that this technique with its sophistication and relatively high cost might not be suitable for small scale farmers with low incomes. However, in Central Africa as a whole there is a wide range of farming conditions from the subsistence farmer to the large estate producer and the research effort aimed at providing a control measure suitable for each system of farming. The presence and influence of highly capitalised farms undoubtedly gave rise to the policy of attempting to obtain the highest potential yields under all farming systems in contrast to other countries where undue stress may have been placed on the low level of input which the subsistence farmer was considered capable of achieveing. Events have justified this policy and in Malawi the average input for spraying in 1969 was £6.6 per acre (£16.36 per hectare) giving an average return of £22.8 per acre (£56.39 per hectare) compared with a return of £5.5 (13.64) from unsprayed cotton (Gower and Matthews, 1971). Only the progressive farmers are spraying but, nevertheless, total production in 1969 was estimated to have increased by at least 40 per cent compared with the estimate of production on the same acreage if no spraying had been done.

The progressive farmer is keen to learn and supported by well organised extension service and credit facilities he is prepared to invest in a crop provided there is a satisfactory economic return.

The introduction of insect control by enabling the crop potential to be realised has paved the way for the introduction of fertilizers which had given little or no return under unsprayed conditions. Yields of sprayed cotton were increased by 258 lbs/acre (289 kg/ha) by application of a fertilizer mixture (Matthews,1971) and the profitability of cotton production was further increased.

A major problem with spraying in Malawi is the need for large quantities of water at the end of the rains, and there is now considerable interest in the use of ultra low volume spraying. Yields comparable with the tailboom have been achieved in trials with the same insecticides and timing of sprays, by using a battery driven spinning disc sprayer applying 2.23 g/acre (2.5 litres per hectare) at 0.5 ml/sec using 6 ft (1.8 metre) swath for plants exceeding a height of 20 inches (50 cm). This new technique is to be assessed in a pilot project during the 1971-72 season. If successful, ultra low volume ground spraying will enable insect control to be practised by a large number of farmers living in those areas where poor water supplies have handicapped the introduction of spraying.

An assessment of aerial spraying of groups of small farmers' cotton arranged in large blocks has been in progress for two seasons and trials have included ULV aerial application but further major expansion of this method of insect control will depend on the introduction of the large irrigation schemes which are planned.

The sowing of a variety with jassid resistance and the use of a closed season to reduce the number of diapause pupae of <u>Diparopsis</u> providing a carry over to the following season, and to control <u>Pectinophora</u> are good examples of the integration of other techniques which with scouting, restricts insecticide use to a minimum. Research is in progress on the isolation and synthesis of the sex attractant of <u>Diparopsis</u> (Moorhouse, Yeadon, Beevor and Nesbitt 1969) and ultimately the use of the pheromone, possibly, in conjunction with chemosterilization of trapped males (Campion, 1971) may reduce the reliance on insecticides.

Finally, the importance of a team approach to tackling the insect control programme must be mentioned, as it has enabled a coordinated study of the biology of the pests, toxicology of insecticides, development of spray application and scouting techniques, and the economics of pest control. The research results were followed by a full assessment of the spray programme in large scale trials on farms. These trials on farms were most important and facilitated the initial extension programme. The close link between research and extension services has been maintained, and there has been the fullest cooperation in translating research results into commercial practice.

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Proc. 6th Br. Insectic. Fungic. Conf. (1971)

SYSTEMIC FUNGICIDES
NEW SOLUTIONS AND NEW PROBLEMS

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"The history of man is the record of a hungry creature in search for food"

Hendrick van Loon, "The Story of Mankind", 1921

I. INTRODUCTION

For more than a century already, chemistry by having provided fertilizers, insecticides, fungicides and herbicides has been the decisive factor in securing the food supply for an ever increasing world population.

Notwithstanding considerable progress during the same period in agricultural husbandry and in the breeding of disease resistant plant varieties, there is to-day no better method for the control of fungal plant diseases than the use of suitably designed biologically active chemicals, called fungicides.

All present day agricultural fungicides do what their name implies: they kill fungi which damage plants. Nevertheless in agriculture our real goal is not to kill fungi but merely to protect higher plants. From the fact that among the around 100.000 classified fungal species no more than about 200 are known to cause serious plant diseases, one has to conclude that in nature all higher plants have very effective mechanisms at their disposal to protect themselves. Or, alternatively, that only very few fungal species dispose of successful mechanisms of attack. In other words, one has to accept a high mutual host/parasite specificity, which modern research has been able to reduce to genetically-determined factors both in the fungus and in the plant. This implies that the successful attack of a fungus on a plant is dependent on the establishment of a very specific biochemical interrelation between the two organisms concerned.

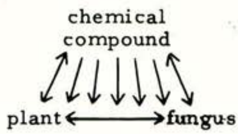
It should be realized that only in very few cases natural resistance is based upon the presence in plants of fungitoxic compounds. However, in several cases the penetrating fungus sets going a sequence of processes which result in the topical formation of fungitoxic agents from non-active precursors available in the plant.

In the past a variety of quite successful agricultural fungicides have been developed. A few incidental cases excepted, they all have in common that the fungus is incapacitated before it enters the plant. This means that until quite recently far more success had been achieved in protecting plants than in curing them. These "classical" protectant fungicides for many years have fulfilled a splendid job in crop protection at tolerable risks and are likely to do so for many years to come.

Although the idea was much older, not before 1940 the purposeful search was started for fungicidal compounds which can enter the plant and protect it from within, the systemic fungicides. Originally Horsfall and his group followed up this idea for the combat of vascular diseases - in particular Dutch elm disease - which cannot be fought by means of protectant fungicides since penetration of the fungus is very difficult to prevent. Later on the idea was extended to include two further practically important goals. In the first place the development of curative agents which are active not only in the pre-, but also, to a limited extent, in the post-penetration stage. Such curative agents are of importance in fighting certain foliar diseases, e.g. the now much debated use of organomercurials against apple scab, and in particular for the combat of deep-seated infections in seeds. Systemic compounds of this type should act quickly and need not have a long life-time once within the plant. Secondly, because of the large number of protectant sprays required during the growing season, it was hoped that true systemic fungicides could be developed which lend prolonged internal protection, also of newly grown parts, once they have been applied to and taken up by the plants. This requires compounds which after being taken up are stable, either as such or in the form of active biochemical transformation products, and thus remain active within the plant for a long period of time. During the past few years considerable progress has been made towards this latter goal. After a long period of modest progress all of a sudden and almost simultaneously about ten remarkably effective types of systemic fungicides have bloomed into existence. These compounds vary between extreme and rather restricted chemical stability, and they range from highly specific to broad spectrum systemic fungicides. Moreover, some of them exert a surprisingly low mammalian toxicity and negligible phytotoxicity at the required concentrations. With the probability of even more such compounds around the corner it would seem that the combat of fungal plant diseases, after many decades of placid progress, has now entered an entirely new era.

The search for systemic fungicides has had another, maybe in the future equally important, consequence. One line of approach towards systemic fungicides has been the search for systemic compounds in general, i.e. compounds which have the innate property to be taken up by the intact plant - either through the foliage or through the roots - and which are transported from the application places to other parts of the plant. During such work it was observed that a number of quite divergent types of systemic compounds - such as certain plant growth regulators, special amino acids and in particular the compound phenylthiourea - exercise a favourable influence upon several fungal plant diseases. Nevertheless, in the usual tests they show scarcely any fungitoxicity, nor are they converted within the plant into fungitoxic compounds.

Some moments ago I emphasized that the successful attack of a fungus on a higher plant involves the establishment of a specific biochemical relation between the two species, which can be disturbed by killing the fungus. In principle it is possible, however, to disturb this relation in a much more subtle way. It should be pointed out that chemical compounds under suitable conditions are subject to chemical modification. In fact, studies of the working mechanisms of biocides have shown that in many cases not the original compound, but rather some conversion product is the really active molecule. To specify this point I present a diagram, illustrating the triangular relation chemical compound/fungus/plant:



It is evident that in particular systemic compounds are not only vulnerable to purely physical or chemical modification, but also to biochemical transformation by the living systems, since they operate by definition within the plants. The diagram intends to emphasize how chemical compounds and their chemical and biochemical conversion products may interfere with the relation plant/fungus, not only by a direct influence on either of the two organisms concerned, but as well by disturbing in several ways the specific biochemical interrelationship between the metabolic systems of these organisms.

The following picture summarizes the ways in which non-fungitoxic systemic compounds may increase the plant's resistance against fungal attack:

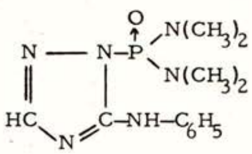
systemic compounds increasing the plant's resistance by

- changing the plant's metabolism
- interference with the biochemical relation plant - parasite
- inactivating toxins or tissue-destructing enzymes

It should not discourage us that at present the practical successes of the systemic compounds are very modest in comparison with those of the new systemic fungicides. After all, the development of the latter has required almost three decades after the first modest realization of the idea. What the future is of the systemic compounds for the practical fight of plant diseases thus remains to be awaited. The systemic fungicides, on the other hand, are a reality at this moment. It is my task to review the present situation and to evaluate their future rôle in agriculture.

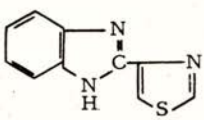
II. SURVEY OF THE PRESENT SYSTEMIC FUNGICIDES AND SOME REFLECTIONS ON THEIR MODES OF ACTION

Since 1964 a perplexing variety of notoriously successful systemic fungicides has appeared in quick succession on the agricultural scene. They belong to quite different chemical classes, but have in common that they are all substituted heterocycles. Now, fungicides containing heterocyclic ring systems were certainly not new. Glyodin, 2-heptadecyl-2-imidazoline acetate, discovered in 1946 at the Boyce Thompson Institute (Wellman and McCallan, 1946), has found extensive use as a protectant foliage fungicide. In fact, the first practically applied systemic fungicide was a heterocyclic compound as well. It is the compound "Wepsyn 155", 1-bis-(dimethylamido)phosphoryl-5-phenylamino-1,2,4-triazole, described by van den Bos, Koopman and Huisman (1960) at Philips-Duphar. Wepsyn and a few closely related compounds are systemically active against powdery mildews and against apple mildew.

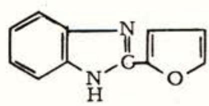


Wepsyn 155

Prominent among the new systemic fungicides are some derivatives of benzimidazole, viz. thiabendazole, fuberidazole and benomyl. All three are active against a wide range of fungal pathogens. Thiabendazole, 2-(4'-thiazolyl)benzimidazole had originally been developed by Merck & Co. as an anthelmintic. Staron and Allard (1964) described its systemic fungitoxicity for the first time.



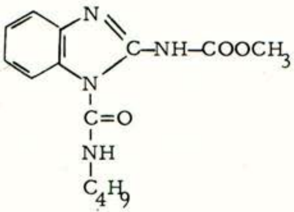
Thiabendazole



Fuberidazole

This broad spectrum systemic fungicide is reported to have the remarkable quality of being translocatable in two directions. Fuberidazole, the furane-analogue of thiabendazole is particularly effective as a seed treatment (Schumann, 1967).

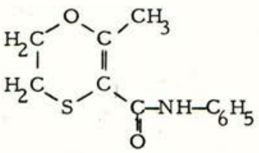
The systemic activity of the at present most striking fungicide benomyl, 1-(butylcarbamoyl)-2-benzimidazole carbamic acid methyl ester, was reported first by Delp and Klopping (1968) (Du Pont de Nemours).



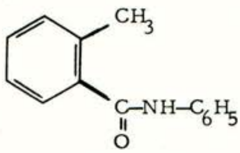
Benomyl

Among all the new systemic fungicides this is certainly the one with the most noteworthy properties. It is highly active against a wide range of foliage diseases, including powdery mildews and also against many soil-borne pathogens. Neither thiabendazole and fuberidazole nor benomyl are active against Phycomycetes, e.g. Phytophthora infestans (potato blight), Plasmopara viticola (vine downy mildew) and Pythium spp. A few things more will be said about benomyl in some moments. First I shall mention briefly the other new types of systemic fungicides. There is little reason to deal with these in much detail because of the excellent and very complete review written by Dr. D. Woodcock (1971), which appeared briefly before this Conference.

In 1966 von Schmeling and Kulka of Uniroyal announced the development of carboxin, 2,3-dihydro-5-carboxyanilido-6-methyl-1,4-oxathiin, the effects of which were described by Edgington et al. in the same year.



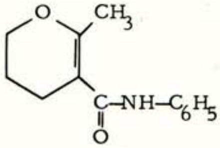
Carboxin
("Vitavax")



Mebenil

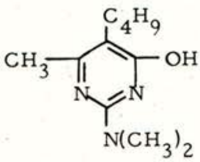
Carboxin (or "Vitavax") is particularly effective against deepseated basidiomycetic infections of seeds (e.g. smut in wheat and barley). The corresponding sulphone ("Plantvax") has a slightly different biological spectrum. The structure of carboxin is somewhat related to that of mebenil, 2-methylbenzanilide, developed by BASF (Pommer and Kradel, 1969), which is effective against rust on cereals.

Likewise in the class of substituted benzanilides belongs the new systemic fungicide 2-methyl-5,6-dihydro-4H-pyran 3-carboxanilide:



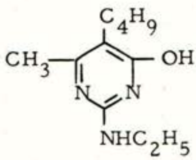
described by Stingl, Härtel and Heubach (Farbwerke Hoechst) (1970). All these substituted benzanilides are effective against similar types of plant diseases. The methyl group seems much more essential for activity than the nature of the ring.

Two hydroxypyrimidine derivatives dimethirimol ("Milcurb") and ethirimol ("Milstem") announced by ICI in 1968 (cf. Elias, Shephard, Snell and Stubbs, 1968) are specifically effective for the control of mildews. Dimethirimol is used as a soil treatment against certain powdery mildews. Ethirimol is particularly effective as a seed dressing, giving excellent systemic protection against cereal mildews.



dimethirimol

("Milcurb")

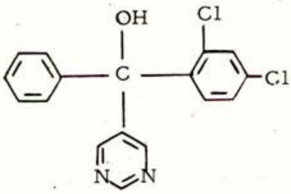


ethirimol

("Milstem")

Both compounds are fairly stable in soil, are rapidly taken up an translocated but do not accumulate, since they are broken down, or at least inactivated as fungicides, within a few days in the plant.

Another pyrimidine derivative is the broad spectrum systemic fungicide EL-273, developed by Eli Lilly & Cy. (cf. Brown (1970)). It is α-(2,4-dichlorophenyl)-α-phenyl-5-pyrimidinemethanol:



EL-273

A number of further promising systemic fungicides I can only mention in passing (Table 1).

Table 1

New systemic fungicides

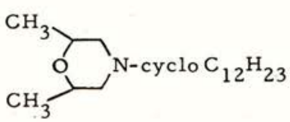
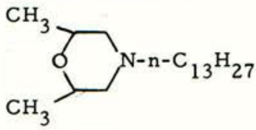
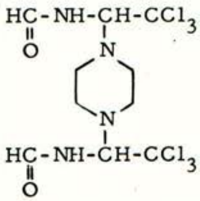
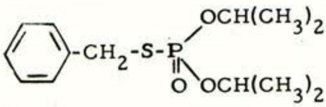
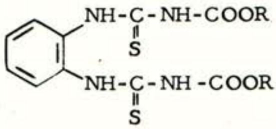
Developed by	Structure	Disease
Nippon Soda	$ClCH_2\overset{\displaystyle O}{\overset{\|}{C}}-NH-CH_2CN$ Udonkor	powdery mildew
BASF	 dodemorph	mildew

Table 1 (continued)

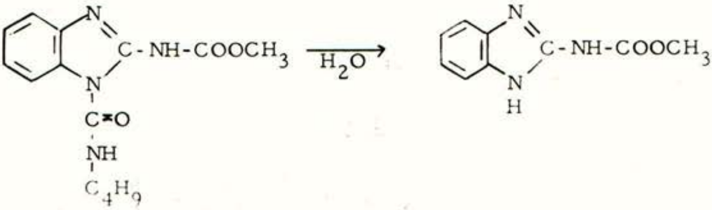
New systemic fungicides

Developed by	Structure	Disease
BASF	 tridemorph	mildew
Boehringer/Cela	 Cela W 524 triforine	powdery mildew apple scab
Kumiai	 Kitazin P	rice blast
Nippon Soda	 R = CH_3 or C_2H_5 the thiophanates	broad spectrum, like benomyl

Not mentioned in the table are a few very effective antibiotics with systemic fungicidal action. Prominent among these are Blasticidin S and Kasugamycin, both discovered in Japan, which are successfully used against rice blast.

Amongst the systemic fungicides listed in the table the last mentioned ones, the thiophanates, seem to occupy an exceptional position since they are no heterocyclic compounds, but instead disubstituted benzene derivatives. It was found that both methyl and ethyl thiophanate are broad spectrum fungicides which have the same antifungal spectrum as benomyl, be it on a somewhat lower level of activity.

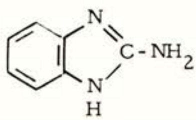
It was reported by Clemons and Sisler in the USA (1969) that benomyl is unstable in aqueous systems. The butylcarbamoyl group is quickly split off by hydrolysis with formation of benzimidazole carbamic acid methyl ester (BCM):



benomyl BCM

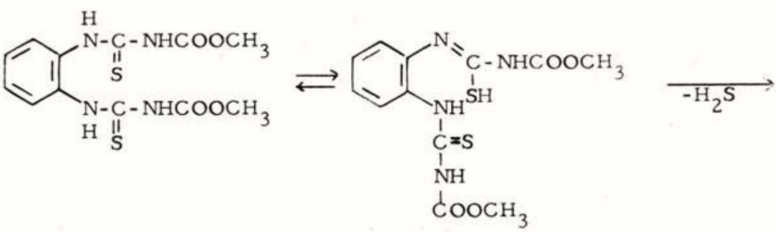
Both the antifungal spectrum and the level of fungitoxicity of benomyl and BCM are identical. Following treatment with benomyl the only fungitoxic agent found within plants is BCM and it must, therefore, be accepted that the systemic action of benomyl is entirely due to BCM which latter compound is extremely stable both in vitro and within plants. Since the butylcarbamoyl group is already removed under very mild conditions it is unlikely that it does play a rôle in the systemic action of benomyl. The only thing to suggest at present is that the butylcarbamoyl group may serve as an inbuilt formulation factor, preventing perhaps too quick an absorption of the fungicide by the plant.

It is interesting to note that the parent compound 2-aminobenzimidazole

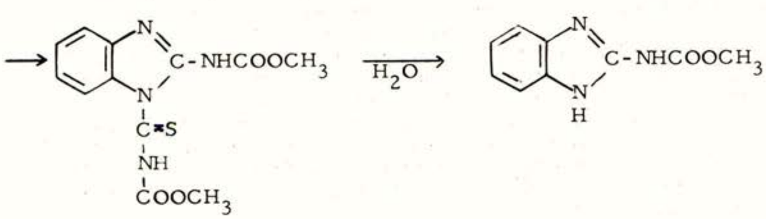


is devoid of any fungicidal or miticidal activity but is, contrary to benomyl and BCM, rather phytotoxic.

I now return to the thiophanates. Taking into account the identity of the anti-fungal spectra of benomyl and BCM with those of the thiophanates, it occurred to Dr. Kaars Sijpesteijn at Utrecht that the following chemical conversion should be considered:



methyl thiphanate thiol form

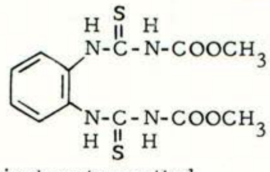
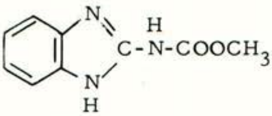
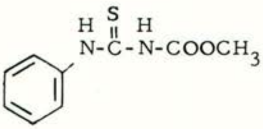
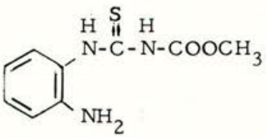


a thiocarbamoyl analogue of benomyl BCM

At our Institute Selling, Vonk and Kaars Sijpesteijn (1970) could indeed demonstrate the formation of BCM from methyl thiophanate under mild chemical conditions, as well as that of the ethyl analogue of BCM from ethyl thiophanate.

In Table 2 the minimal inhibiting concentrations against a few fungal species are given for methylthiophanate (1) and BCM (2). Two structurally related compounds 3 and 4 are included.

Table 2

	Compound	Min. inh. conc. (ppm) Aspergillus niger	Penicillium italicum	Cladosporium cucumerinum
1.	 thiophanate-methyl	5	0.5	2
2.	 BCM	0.5	0.05	0.2
3.		> 500	> 500	> 500
4.	 NF 48	2	0.2	1

It can be seen that on a weight basis methyl thiophanate is about 10 times less active than BCM, but that the antifungal spectra are similar. Compound 3 is inactive contrary to compound 4 which is about twice as active as methyl thiophanate and, again, has the same antifungal spectrum. Obviously, the inactivity of compound 3 is due to the lack of the orthoamino group in the benzene nucleus, which is required for the formation of the benzimidazole ring.

Further work of Vonk (1971), using spectroscopic methods and the study of pH effects, proved beyond doubt that the fungitoxic action of methyl thiophanate both in vitro and in the plant is entirely due to its transformation into BCM. As an illustration in fig. 1 the influence of pH is shown on the chemical conversion of methyl thiophanate into BCM.

Figure 1

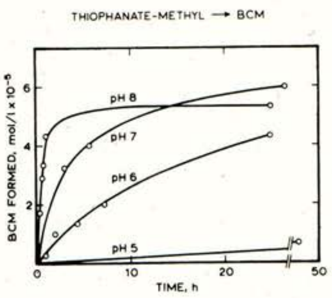
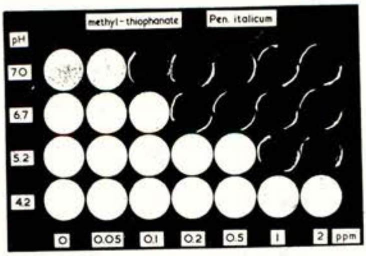


Figure 2 shows the effect of pH on growth inhibition of Penicillium italicum by methyl thiophanate.

Figure 2



The correlation between the two pictures is striking. Both benomyl and methyl thiophanate are thus precursors of the really active fungicide BCM.

Little is yet known about the biochemical modes of action of the several new systemic fungicides. Two years ago Dr. Kaars Sijpesteijn reported here on her analysis of the general principles underlying the biochemical modes of action of the available agricultural fungicides, both protectant and systemic. Quite generally three types of compounds must be distinguished in relation to the biochemical mode of action:

1) Compounds which interfere with the energy-producing processes, such as the inhibitors of cell respiration and also the uncoupling agents. Such compounds usually kill fungi and are thus fungicides in the proper sense.

2) Compounds which interfere with biosynthetic processes and thus in a direct way with growth, i.e. with the building up of new cell material. Such compounds may inhibit the synthesis of amino acids, growth substances, purines, pyrimidines and similar essential low molecular weight cell constituents. However, also the inhibition of the biosynthesis of macromolecules such as proteins, DNA and RNA may be involved. In general compounds of this type at the lowest inhibiting concentrations are rather fungistatic than fungicidal.

3) Compounds which disrupt cellular structures, mostly by impairing membrane functions. Owing to this the effective compartmentalization within cells is disturbed and cell constituents may interfere in an undesirable way or leak out.

Dr. Kaars Sijpesteijn reached the remarkable conclusion that fungicides which interfere with the energy-producing processes, e.g. inhibitors of cell respiration, on the whole are protectant fungicides. On the other hand most of the true systemic fungicides appear to interfere with biosynthetic processes and thus in a direct way with growth.

She argued that metabolism in higher plants and fungi is basically similar at the enzyme level. Consequently, fungicidal inhibitors of energy-producing processes may be equally damaging towards higher plants once they penetrate the plant. On the other hand, compounds which, like the true systemic fungicides, interfere with biosynthetic processes are much more active towards the fast growing fungi than against higher plants, which grow much slower and where growth processes are, moreover, very localized.

Time does not allow me to deal in detail with what is known about the biochemical modes of action of the systemic fungicides. Therefore I summarize in tabulated form the present views on this subject (Table 4).

Table 4

The present views on the biochemical mode of action of systemic fungicides

Compound	Inhibitory action possibly based on interference with
benomyl (and BCM) methylthiophanate thiabendazole fuberidazole	biosynthesis of DNA
chloroneb	biosynthesis of DNA
carboxin	respiration; biosynthesis of DNA and RNA
dimethirimol ethirimol	folic acid mediated C-1 transfer reactions
azauracil	biosynthesis of UMP
sulphanilamide	biosynthesis of folic acid
griseofulvin	cell division
cycloheximide	biosynthesis of proteins
kitazin	biosynthesis of chitin
pimaricin dodine	disrupture of cell membranes
wepsin	?
triforin	?
tridemorph	?

It should be realized that at increasing concentrations of the active compounds more and more processes may be involved and that at high concentrations all compounds will tend to diminish in specificity. Inhibitors of biosynthetic processes are likely to be less phytotoxic because at the effective antifungal concentrations they are less toxic towards the slow growing plant tissues than against the fast growing fungal hyphae.

III. SOME REFLECTIONS UPON THE FUTURE OF SYSTEMIC FUNGICIDES

There should be little doubt regarding the tremendous future impact of the new systemic fungicides on agricultural and horticultural practice. At present it would seem that an old dream has become true and that we merely have to reap and use the exciting results of past research to secure the future protection of our crops. Consequently, apart from the necessity to exploit the present approach in full, one might ask whether we should not stop looking for other possibilities or, at least, lay in a little pause in our research efforts towards chemical crop protection. My personal answer is an emphatic no!, and that for more than one reason.

As already indicated, I believe that the possibility to interfere with the specific biochemical interrelationships between fungi and plants has been insufficiently exploited. One particular reason for the continuation of this approach is, that compounds having this capacity do not need to be toxic towards fungi and thus may protect plants against their specific fungal invaders without causing undesirable ecological shifts. Another reason is, that compounds which are not active against organisms per se are not likely to favour the selection of resistant strains.

This brings me to an effect which so far was virtually unknown for protectant fungicides, but which, within the few years of their existence, has become manifest among several -if not all- classes of the new systemic fungicides: the emergence of resistant fungal strains. As mentioned before, true systemic fungicides, with few exceptions, are compounds which interfere with biosynthetic processes and all evidence available at present indicates that they do so in very specific ways.

The protectant fungicides, being inhibitors of rather general cellular processes are mostly working via "multi-site" mechanisms. Apart from developing effective detoxification mechanisms or barriers against penetration fungi have little chance to develop resistance against such mechanisms. For the highly specific inhibitors of biosynthetic processes, i.e. the truly systemic fungicides, this situation is basically different. Dekker, at Wageningen, made a very detailed study of the experimental systemic fungicide 6-azauracil, which inhibits one particular enzyme, involved in the biosynthesis of nucleic acid. He suggested that mutation in one gen leads to resistance to this compound. The lower the specificity of a fungicide is, the more mutations are required to develop resistance. This implies that at equal mutation frequency the chance to meet a highly resistant mutant is much larger for the highly specific systemic fungicides than for the protectant fungicides of low or moderate specificity. As already said, within a few years quite a number of cases of resistance towards the new systemic fungicides have been reported in the literature. In some cases, where clearly the mode of action of the compounds is the same, cases of cross-resistance have been found, e.g. against the benzimidazole derivatives benomyl, thiabendazole and fuberidazole, and the benzimidazole precursors, the thiophanates. Of course, one good defense against the potential danger of resistance development should be the simultaneous, or perhaps the alternate, use of systemic fungicides having basically different biochemical modes of action. One difficulty is, that the compounds which might be considered in this respect are in the hands of competing companies.

Another aspect which needs attention is the persistence of some of the new systemic fungicides or of their biologically active conversion products. Particularly in food crops no residues should be left and thus too high a persistence is undesirable. On the other hand the ideal situation is to protect plants during the growing season as a result of just one or only a very few treatments. Unless one accepts extremely high persistence this apparant contradiction can only be solved by developing ingeneous formulation and application techniques. Apart from causing undesirable residual effects, highly persistent systemic fungicides might exercise an undue selection pressure on a restricted population and thus strongly favour the development of resistant strains.

A further consequence of the high biochemical specificity of the systemic fungicides, even of the broad-spectrum types, is that notwithstanding their high activity against a few or several classes of fungi they are completely inactive against other classes. As an example I recall the inactivity of all benzimidazole derivatives against the Phycomycetes. In particular following soil application with persistent fungicides this may lead to very severe ecological shifts which in their turn may result in the appearance of plant diseases not occurring within the natural balance of the undisturbed eco-system. Here again, suitably composed mixtures of active compounds might offer one possible answer. What I have said is mostly true for the soil application of systemic fungicides. Unwanted ecological shifts are much less likely to result from foliage applications of such compounds. Here, however, we meet another complication, viz. that, with very few exceptions, the presently available compounds are translocatable from the roots to the foliage, but not, or very little so, in the reverse direction. This implies that following foliage application there is no or an insufficient redistribution of the active compounds to newly grown parts of the plant. It would seem that in this respect a very important step towards the systemic protection of plants has still to be made.

I realize that my analysis of the present situation is far from complete. It merely was intended, however, to establish what had been achieved and to indicate in what direction future research should go. Notwithstanding the exciting progress made with the development of systemic fungicides I do not think that the days of the protectant fungicides are over. Further, I believe that new lines of approach can be derived from the study of the biochemical mechanisms of natural resistance and susceptibility of plants against fungal attack. This, however, is a theme that I shall not discuss today. In addition, as indicated before, the possibility of developing systemic compounds, interfering with the biochemical interaction between fungus and plant should be exploited further.

In conclusion, I venture to say that in the fight of fungal plant diseases powerful new weapons have been discovered, but that further breakthroughs may be expected within the coming five or ten years.

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DISEASE AND PEST CONTROL IN BRITISH FORESTS: AN OUTLINE

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Summary In British forests, disease and pest control is mainly by the careful choice of resistant species or varieties, and by silvicultural means. Direct biological control methods are used eg to control *Fomes annosus* in pines by inoculating stumps with its competitor *Peniophora gigantea*, and to control the pine sawfly by means of a naturally occurring virus. Chemicals are used in the forest to control *Fomes annosus* from the time of the first thinning, and to protect newly planted stock from attack by *Hylobius abietis* and *Hylastes* spp. Occasionally it has been necessary to spray forest areas to control infestations of the Pine looper moth, most recently with tetrachlorvinphos. Chemicals are also used on a very limited scale to control a few diseases and pests in nurseries and Christmas tree plantations, and to prevent the infestation of felled produce, particularly by ambrosia beetles.

The area of forest in Great Britain is rather over 2 million ha, which is just under 7½ per cent of the total land area, and only about a tenth of the area under arable and permanent pasture.

Many tree species are represented in our forests, including hardwoods such as the native oaks and beech, as well as introduced trees such as sycamore, sweet chestnut, and various hybrid poplars. But a large proportion of the land available for afforestation is in exposed uplands with poor soils, and often badly drained. These areas are suitable only for a fairly small range of conifers, which are also the trees that produce the kind of wood mainly demanded by industry for the manufacture for example of paper, plywood and particle board. Hence large upland areas are planted with Sitka and Norway spruce, and Scots, Lodgepole and Corsican pines, with smaller areas of larch, Douglas fir, and a few other commercially valuable coniferous trees. All these conifers except Scots pine are introduced, some from the nearby Continental Europe, others from North America and the Far East.

In Forestry, many years elapse after the establishment of the crop before the forester receives the return on his capital. Because the crop is on the ground for many years, a great deal of money could be spent on protective measures over a long rotation. As forestry is an extensive form of land use, however, the expected return is relatively low, and typically of the order of 3 per cent. This limits the resources worth investing in a given area. The forester therefore has to keep a careful watch on costs.

Hence one of the jobs of the forest pathologist and entomologist is to assess the likely damage done by various diseases and pests so that money is not needlessly spent on the control of those that may appear spectacular but in fact cause minimal loss. Thus rusts on poplar leaves in this country cause premature leaf fall of many clones, but they appear too late in the season to reduce increment. Similarly the sawfly Anoplonyx destructor causes dramatic defoliation of larch, but only an insignificant loss of wood production. In such cases money spent in spraying would give no compensating return.

Control of pests and diseases in this country has been largely by the use of resistant species or varieties of tree, or by various silvicultural measures. Thus damage to Douglas fir by the leaf cast fungus Rhabdocline pseudotsugae is largely avoided by growing the relatively resistant Green Douglas fir (Pseudotsuga menziesii var. menziesii) instead of the very susceptible Colorado or Blue variety (P. menziesii var. glauca) (Anon 1956 a). The Blue Douglas fir, on the other hand, is more resistant than the Green to attack by the aphid-like Adelges cooleyi. Fortunately this adelgid does little more than make the trees unsightly (Crooke, 1960).

Again, in the case of the larches, larch canker caused by Trichoscyphella wilkommii (and also of the dieback associated with Adelges laricis) may be avoided by growing a resistant Sudetan provenance of European larch (Larix decidua), if available, or growing Japanese larch (L. kaempferi) or hybrid larch (L. x eurolepis) instead (Young, 1969). Similarly, control of poplar canker, caused by the bacterium Aplanobacter populi is by the use of resistant clones.

Among silvicultural control measures may be included the opening up of crops to admit air and reduce humidity eg to control dieback of Corsican pine caused by Brunchorstia pinea (stat. conid. of Scleroderris lagerbergii) (Read, 1967). On the other hand, such opening up may increase some pests, such as Ash scale (Fonscolombia fraxini) and there are some indications that it may do the same for the bark disease of beech. Steps taken to improve growth, eg by drainage or the application of fertilisers may also increase resistance to secondary pests that attack debilitated trees.

Sanitation fellings may be made to reduce the spread of some diseases and pests. Thus at present sanitation fellings of elm are being extensively carried out in areas badly affected by Dutch elm disease, in order to reduce the spread of elm bark beetles and so of the Dutch elm disease fungus (Ceratocystis ulmi). In the same way, in European larch crops affected by canker, the cankered stems are removed as far as possible in thinning, and the same is done in Scots pine crops affected by the Resin top rust (Peridermium pini). Similar sanitation fellings are carried out in pine crops defoliated by the Pine looper moth (Bupalus piniarius), to avoid subsequent infestation by the Pine shoot beetle (Tomicus piniperda).

Infestation of felled logs by this beetle is avoided during the breeding season by ensuring that the produce is removed from the forest within six weeks of felling: the application of the so-called "six week rule" (Anon, 1962). Too little time is then left for the insect to complete its breeding cycle, and so enter the shoots of surrounding trees, and later renew their attack on further logs or standing trees.

In a few cases a more direct form of biological control is used. Populations of insects, like those of other animals, are affected by disease, or preyed upon by predators and parasites. The chalcid parasite Dahlbominus (Microplectron) fuscipennis was once bred and released to control the larch sawfly Anoplonyx destructor (Hanson 1951) but inadequate control resulted. Recently, the wasp-like Dendrosoter protuberans, a parasite of the Elm bark beetle, has been released in relatively small numbers in Basildon New Town in the hope of controlling Dutch elm disease.

Very successful control of the Pine saw fly (Neodiprion sertifer) has long been obtained by the use of a naturally occurring virus (Anon 1961). The possibility of using a virus in the same way to control the European spruce sawfly (Gilpinia hercyniae) is now being explored. The major advantage of these viruses is their highly specific nature.

One serious disease, killing and butt rot caused by Fomes annosus, is in part controlled by biological means. The fungus enters the crop mainly through tree stumps produced in felling operations. Colonisation of pine stumps can be largely prevented by painting the fresh stumps with a suspension of oidia of the competing fungus Peniophora gigantea (Anon, 1970). Preparations of the oidia are now on sale.

Fomes annosus also, in fact, is the only fungus against which routine chemical control measures are in use in the established forest. On species other than pine the fungus causes a butt rot. On these as yet no competing fungus can be used, and the routine control method is to paint the stumps with a solution of either sodium nitrite, urea, or disodium octoborate.

The few other diseases against which chemicals are used so far are those of nursery stock. If damping off is a persistant problem in a nursery, soil fumigation (mostly with formaldehyde) may be carried out. If damping off appears in nursery beds, emergency drenches with captan are used.

For the remaining nursery diseases, captan is also used to control Grey mould (Botrytis cinerea) and Bordeaux mixture and thiram are used for the same purpose. Zineb and maneb are both used occasionally against Pine needle cast caused by Lophodermium pinastri (Pawsey, 1964). Colloidal and wettable sulphur preparations are used to control needle cast of larch caused by Meria laricis (Phillips, 1963) and to deal with Oak mildew (Microsphaera alphitoides) (Anon, 1956 b). Finally, cycloheximide provides control of Needle blight of Western red cedar (Thuja plicata), (Anon 1967) and is now sold for that purpose here. These fungicides are used only on a small scale, as necessary, and not as a routine.

The same applies to most pest control with insecticides. Here, in the case of felled produce, infestations by ambrosia beetle (Trypodendron lineatum) are controlled by spraying the produce with gamma BHC (Bletchly & Bevan, 1963). This is also used to prevent infestation by the Pine shoot beetle (Tomicus piniperda) when the "six week rule" referred to above cannot be applied, or when bluestain, which may be carried by these fungi, is to be avoided.

Newly planted conifers set out to replant an area previously and recently under a conifer crop are liable to severe damage by the Large pine weevil (Hylobius abietis) and the Black pine beetles (Hylastes spp). To prevent losses, in the past, the tops of the plants have been treated with DDT which is highly effective (Anon, 1964). Because DDT may be phytotoxic, and also damaging to wild life, alternatives have been sought, and gamma BHC has given good results, though not always consistent ones. Nevertheless, because the whole plant, including the roots, can be dipped in gamma BHC, control of Hylastes spp, which operates at the root collar, may be better than that from DDT (Bevan & Davies, 1970).

The search for alternatives to DDT has become an urgent matter now that the dangers inherent in the use of this material have been realised.

No other routine spray applications of insecticides are made in the forest. On rare occasions, however, a build-up of populations of the Pine looper moth (Bupalus piniarius) in established plantations has made aerial spraying necessary. DDT was used for this purpose until 1970, when an infestation at Wykeham Forest (Yorkshire) was successfully sprayed with tetrachlorvinphos (Bevan & Davies, 1971).

Occasionally there is a need to control pests in nursery stock (Bevan, 1969). Here for example in the soil, gamma BHC dust may be used to control cockchafers or Pine root aphis (Prociphilus pini). Liquid formulations of the same chemical may be used to control cutworms. Aphids on the aerial parts such as the Woolly beech aphis (Phyllaphis fagi), Spruce shoot aphis (Cinara pinicola) and the Green spruce aphis (Elatobium abietinum) are controlled by spraying with malathion, which is also used to deal with springtails (Collembola). Most remaining nursery pests, including various sawflies and weevils, have so far been controlled by the use of either DDT or gamma BHC. Tetrachlorvinphos appears to be a promising alternative for some of these pests. Finally, the Conifer spinning mite (Paratetranychus ununguis) is controlled by the acaricide dicofol.

Christmas tree plantings are a rather special case, and on these a routine spray programme may be justified, for example to control aphid infestations that lead to growths of sooty mould. For these, malathion is used, while gamma BHC or tar oil winter wash may be used to prevent the formation of the "pineapple galls" caused by adelgids.

To summarise, routine chemical treatments are little used in forestry, though sodium nitrite, urea and disodium octoborate are used for routine control of Fomes annosus and DDT and gamma BHC to protect newly planted conifer stock against Hylobius abietis and Hylastes spp. These two insecticides are also used when necessary to control a few nursery pests. Gamma BHC is also employed to prevent the infestation of felled timber by ambrosia beetles. Apart from this, about half a dozen other fungicides are used on a small scale against nursery diseases, and one or two other insecticides and acaricides against nursery pests, and in Christmas tree plantations.

In the immediate future, as far as forestry in its conventional sense as a wood producer is concerned, there is unlikely to be any major change in the philosophy of disease and pest control. Forest entomologists and pathologists, like those in other spheres, will continue to seek less toxic and less persistent chemicals as alternatives to some of those now in use, and to look for more systemic insecticides and fungicides. The quantities of chemicals used will probably remain relatively low, however.

If forests become more and more involved in matters of recreation and amenity, they may need to consider the control of the diseases and pests of a greater range of species than in the past. They have long, of course, dealt with such problems for example in elm, and are seeking systemic insecticides and fungicides to control Dutch elm disease. The elm is an important timber tree, but if the forest pathologist and entomologist are asked to extend into the field of the town tree and the motorway planting, they may find themselves in a milieu in which the individual tree is of such value that chemical control, given suitable materials, is much more often possible than it is in true forestry.

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TESTING INSECTICIDES AGAINST THE PINE WEEVIL (HYLOBIUS ABIETIS)

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Summary In investigations to find a substitute for D.D.T. against Pine weevil (*Hylobius abietis*), spruce plants treated with a number of insecticides were tested in the laboratory after being kept for varying periods in out-door conditions. A systemic granulate, phorate, gave satisfactory protection for at least two growing seasons, whereas four emulsifiable formulations of bromophos, gamma-B.H.C., tetrachlorvinphos and trichloronate, proved effective for one growing season only.

INTRODUCTION

The Pine weevil (*Hylobius abietis*) has become a serious pest in most palaearctic conifer forests where clear felling systems have been introduced. The practice of clear-felling generally improves breeding conditions for the larvae which develop in roots of fresh conifer stumps (Bakke, *et al* 1965). The inner bark of small conifer plants is a suitable food for the adult weevils and nursery plants are therefore usually dipped in a D.D.T. suspension (1% a.i.) to protect them against such damage before being planted out in reforestation areas. In Norway, no further insecticide treatment of the plants is given since the D.D.T.-film retains its protective effect for at least 2 years (Bakke 1964). As from 1970 the use of D.D.T. has been restricted in the Nordic Countries to this single purpose. However, forestry has to face a future total abolition. The present paper reports the screening of several insecticides in a search for a D.D.T. substitute for eventual use against the Pine weevil.

METHOD AND MATERIALS

A total of 10 insecticides were tested in three series during 1969 and 1970 (Table). The experiments included two concentrations or more of each compound and D.D.T. was used as a standard for comparison purposes. The compounds were applied to four year old plants of Norway spruce. Two of the series were planted out in spring (1969 and 1970), in clayey arable soil, the third in autumn 1969 in a sandy, podzolic forest soil. After different periods under out-door conditions, test plants were brought into the laboratory and the protective effect of the insecticides was then tested.

Table

Insecticides tested against Hylobius abietis

Time of treatment	Common name of insecticide	Formulation	Amount of active ingredients in test
May, 1969*	Aldicarb	gran, 10% a.i.	0.025 and 0.1 g/ plant hole
	Bromophos	e.c., 400 g/l	1 and 3%
	D.D.T.	e.c., 150 g/l	1%
	Diazinon	e.c., 183 g/l	1 and 3%
	Gamma-B.H.C.	e.c., 200 g/l	1 and 3%
	Methomyl	gran, 5% a.i.	0.025 and 0.1 g/ plant hole
	Phorate	gran, 10% a.i.	0.25 and 0.5 g/ plant hole
	Trichloronate	e.c., 50% a.i.	1 and 3%
September, 1969**	D.D.T.	e.c., 150 g/l	1%
	Gamma-B.H.C.	e.c., 200 g/l	1 and 3%
	Phorate	gran, 10% a.i.	0.1, 0.25, 0.5 and 0.75 g/plant hole
May, 1970*	Methoxychlor	w.p., 50% a.i.	1 and 2%
	Phorate	gran, 10% a.i.	0.1, 0.2, and 0.4 g/plant hole
	Promecarb + Gamma-B.H.C.	e.c., 45+23 g/l	2.25+1.15, 4.5+2.3, and 9.0+4.6 g/l
	Tetrachlorvinphos	e.c., 24% a.i.	3 and 5%

* Planted out in clayey, arable soil at Ås (County of Akershus).

** Planted out in sandy, podzolic, forest soil at Kongsberg (County of Buskerud).

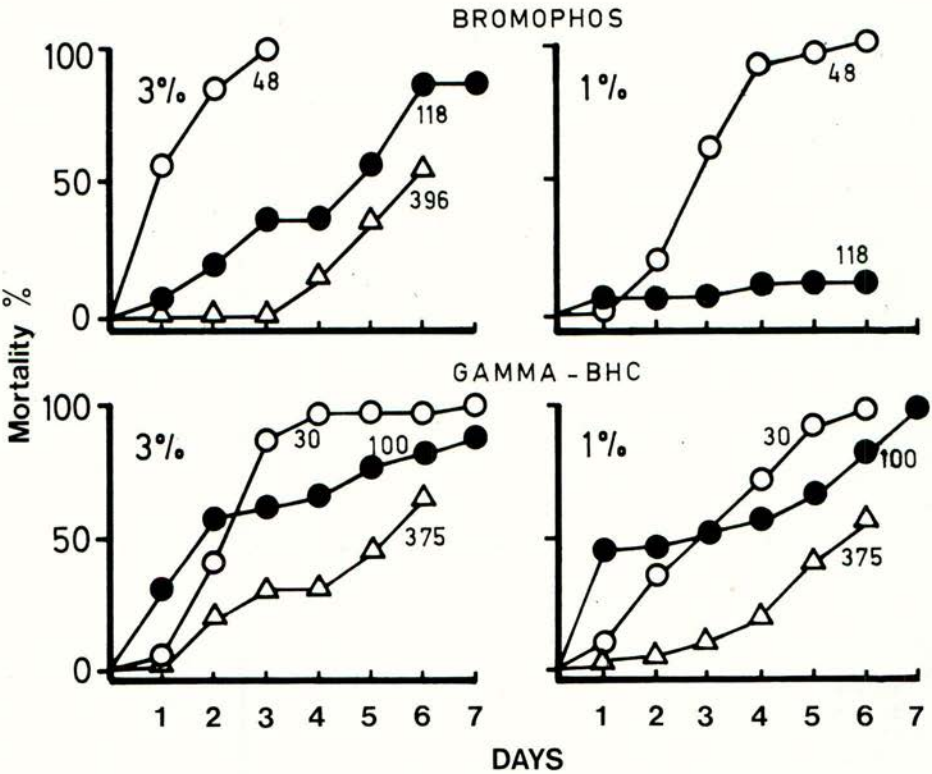
In most cases, the shoots and stems of the plants were dipped in an aqueous suspension of the chemical. The three systemic granular compounds were introduced by mixing them into the soil of the planting holes. Part of the group planted in September 1969, viz a number of phorate-treated plants, were transferred the following June to soil of the same type near by where no phorate was present in the ground. At specified times, four plants of each treatment plus four untreated controls were transplanted into flower pots in the laboratory. Each plant was covered with a plexi-glass cylinder equipped with screen-covered ventilation openings in top and bottom. Five pine weevils were then released into each cylinder.

The weevils had been collected from saw-dust heaps in South Norway during the swarming period in early June and had been stored in moist sawdust at 3°C. During the test period (7 days), the laboratory temperature was 22 to 24°C. A daily record of progressive weevil mortality was kept, a specimen being recorded as "dead" when it was lying on the back and no longer able to cling to a finger tip. A total of 1200 weevils was used in the whole test programme.

RESULTS

In the series planted in May 1969, four compounds, bromophos, gamma-B.H.C., phorate, and trichloronate, proved sufficiently toxic to the weevils for one growing season, at least in the highest concentration (Fig. 1). Only phorate remained satisfactory for two seasons.

Fig 1.



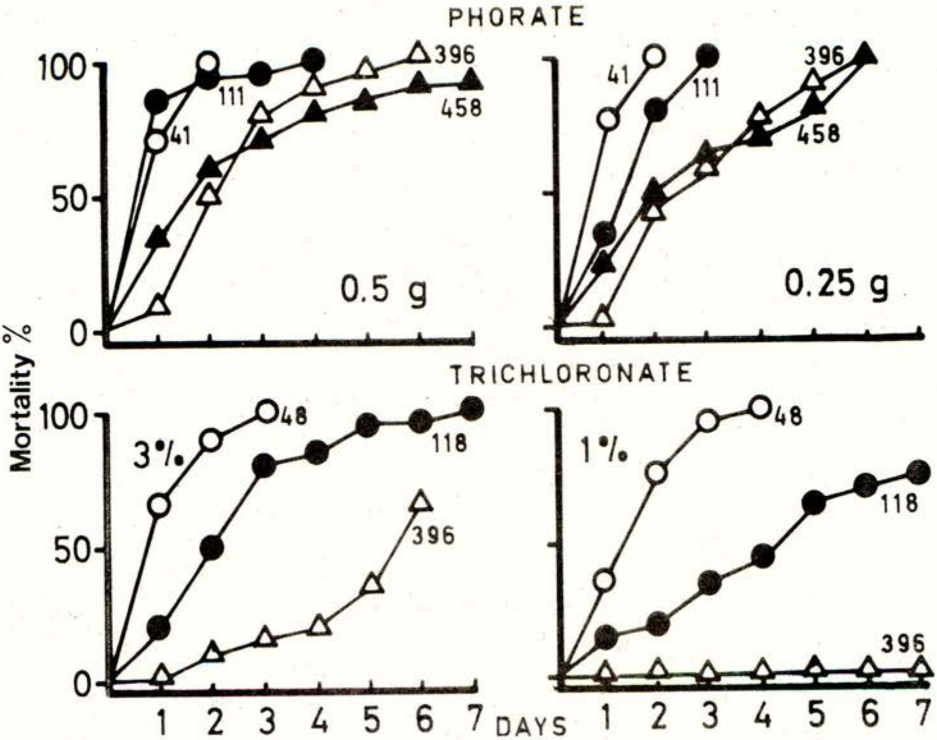


Figure 1. Cumulative mortality in *Hylobius abietis* during the first days after release on plants treated with different insecticides/concentrations (a.i.). The number at each curve denotes the time in days from application of insecticide (May 1969) to release of weevils.

The series planted in May 1970, also revealed a good long-term effect for phorate (Fig. 2). This application's delay in taking effect was probably due to a drought period in early summer preventing the uptake of the systemic. The graph shows the fall in effect of tetrachlorvinphos towards the end of the growing season.

Fig 2.

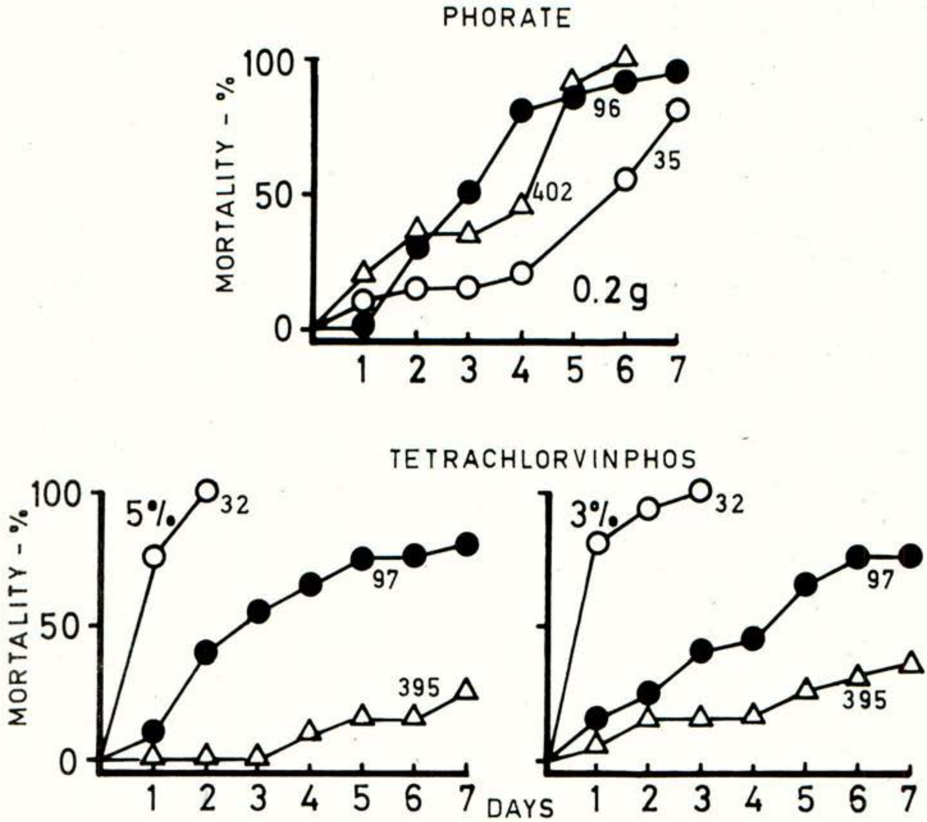


Figure 2. Cumulative mortality in Hylobius abietis during the first days after release on plants treated with different insecticides/concentrations (a.i.). The number at each curve denotes the time in days from application of insecticides (May 1970) to release of weevils.

Plants treated with gamma-B.H.C. and phorate in September 1969 were sufficiently toxic to the weevils next spring (Fig. 3). With respect to phorate, this test-series shows, apart from the pronounced long-term effect the results of transferring plants to fresh soil (Fig. 4). The compound retained its effect in the plants one year after transplanting, although a slightly higher mortality was recorded in weevils on plants remaining in treated soil.

Fig 3.

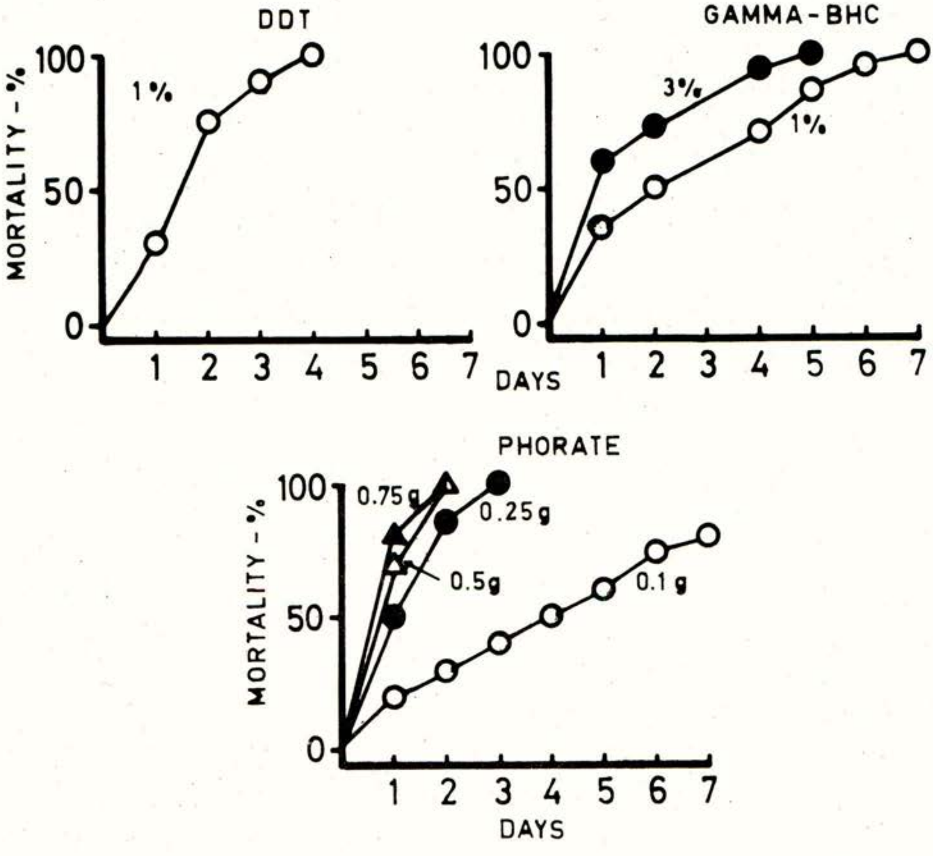
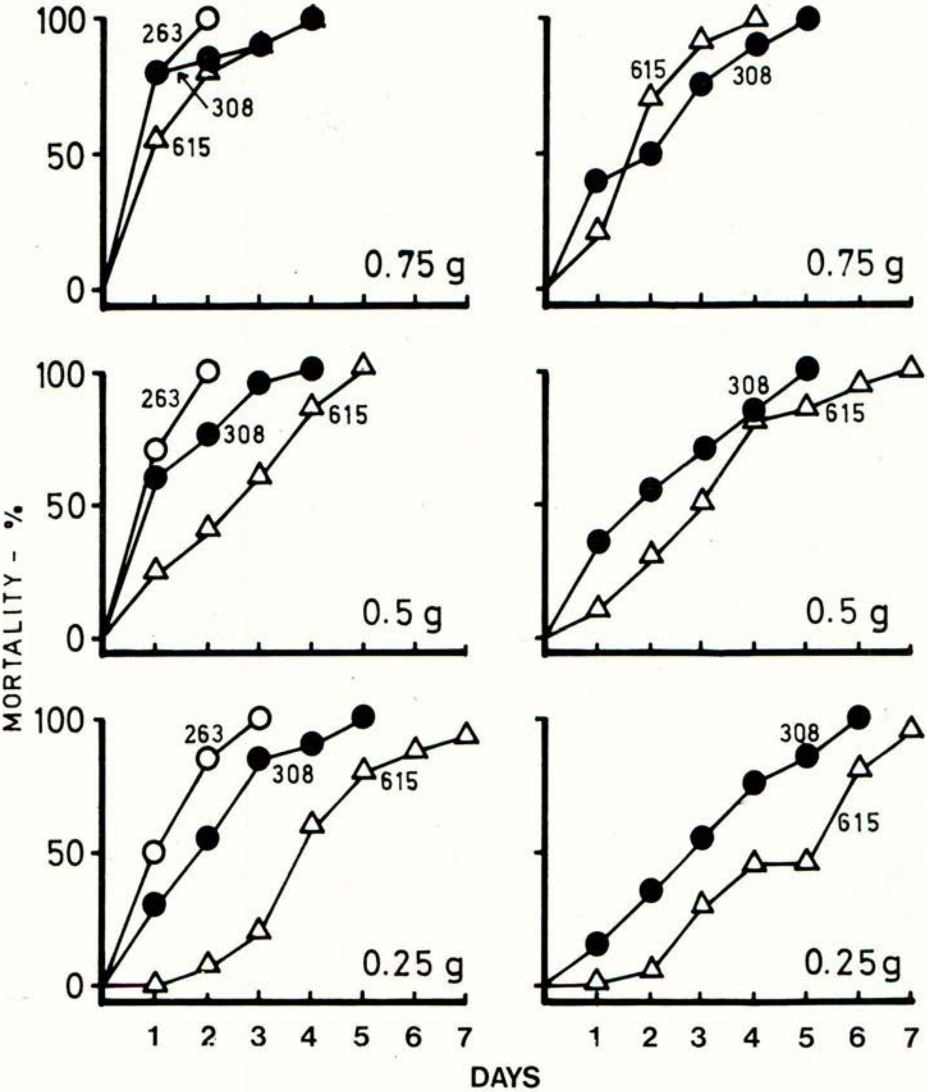


Figure 3. Cumulative mortality in Hylobius abietis during the first days after release on plants treated with different insecticides/concentrations (a.i.). The test started 263 days after the insecticide application in September 1969.

Fig 4.



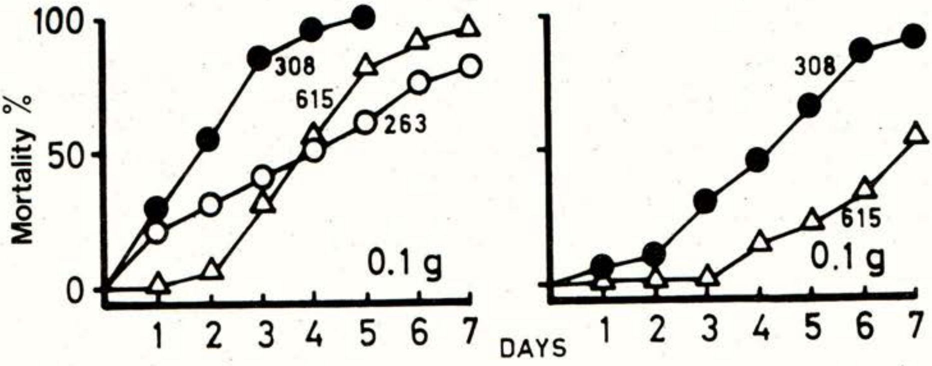


Figure 4. Cumulative mortality in *Hylobius abietis* during the first days after release on plants treated with different concentrations (a.i.) of phorate. The number at each curve denotes the time in days from application of insecticide (September 1970) to release of weevils. The left hand four graphs refer to plants which remained in treated soil until testing took place; the right hand four to plants transferred to untreated soil 250 days after application.

The five compounds aldicarb, methomyl, diazinon, methoxychlor and promecarb + gamma-B.H.C. did not give satisfactory effects in the concentrations used, as less than 50% of the weevils were killed within 4 days. It should, however, be noted that the dosages, particularly of the two systemics, may have been too low (Table).

DISCUSSION

A granular formulation of the systemic phorate retained its strongly toxic effect against *Hylobius abietis* for at least two growing seasons. This compares with the results obtained in North Carolina, U.S.A., where Werner *et al* (1969) studied the absorption of phorate in loblolly pine seedlings. The compound has, however, two major disadvantages: (1) It is highly toxic to mammals. (2) Uptake in plants is likely to take some days or weeks before a satisfactory insecticidal level is reached. Before systemics of this type are accepted into practice, comprehensive information should be made available upon the fate of residues in different soil types. In our experiments the soil still smelled strongly of phorate two years after application.

Bromophos, gamma-B.H.C., tetrachlorvinphos and trichloronate appeared sufficiently effective when applied in an appropriate dosage for the protection of plants for one growing season only. More work is needed on questions of dosage since an insecticide against *Hylobius abietis* should preferably retain its effect for more than two growing seasons.

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'NEGATIVE' EFFECTS OF FUNGICIDES IN COFFEE

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Summary - Even in the absence of noticeable disease, application of fungicides to *arabica* coffee in Kenya produces substantial (100 per cent approx.) increases in yield. The benefits of this 'tonic' effect are, however, offset to a considerable degree because fungicides exacerbate both leaf rust (*Hemileia vastatrix*) and particularly coffee berry disease (*Colletotrichum coffeanum*). Effective control of these diseases now requires the use of an extended and accurately timed spray programme which is thus relatively expensive.

INTRODUCTION

It is now widely appreciated that the use of insecticides for control of crop pests is not without attendant risks. Quite apart from any consideration of environmental pollution, insecticides may actually aggravate pest problems; new races of pests, resistant to insecticides may develop and destruction of predatory or parasitic insects may not only increase the severity of existing pest problems but result in the emergence of new ones. These deleterious or 'negative' effects of insecticides are now well recognised and as a consequence there is active concern with the development of integrated control programmes which aim to optimise the effects of both insecticidal and biological control.

By comparison with insecticides, the use of fungicides does not appear to have produced comparable problems. It is true that in recent years a few fungi, notably *Pyrenophora avenae* and *Sphaerotheca fuliginea* have produced mutant forms resistant to specific fungicides (Nobel, et al, 1966; Schroeder & Provvidenti, 1969) but on the whole fungicides appear to have been either beneficial or at worst neutral in their effects. Is this, however, a true state of affairs? Are fungicides really such inocuous substances or is it that deleterious side-effects have been undetected or ignored? Certainly experience with fungicides on *arabica* coffee in Kenya during the past decade or so has revealed numerous 'negative' effects and unless coffee is unique amongst crop plants these effects must be of more common occurrence.

'TONIC' EFFECTS

One of the most striking features of fungicide use on coffee in Kenya is its remarkable 'tonic' effect. In the absence of any significant observable disease a single spray of Bordeaux mixture applied in March/April can approximately double yields (Table 1). The most obvious visual effects of spraying are that leaves are usually darker green in colour and leaf fall is retarded so that trees are well foliated throughout the season; in the absence of the 'tonic' spray heavy leaf fall occurs in the dry seasons. Moreover, although copper fungicides have been widely used as 'tonic' sprays other fungicides achieve the same effect i.e. it is an effect of fungicide action and not due to copper *per se* (Rayner, 1957).

Table 1. Effect of copper fungicides on yield of coffee (Gillett, 1942) Values shown are means for all years from 1934-1941.

Treatment	Mean yield cwt/ac	Increase over control (%)
One spray 1% Bordeaux in March	9.7	102
Two sprays 1% Bordeaux in March & June	10.4	117
Control	4.8	-

Not surprisingly 'tonic' spraying became a normal practice in the post-war period and few growers can now afford to forego the benefits which it gives. However, once 'tonic' spraying is used there is little doubt that both leaf rust (Hemileia vastatrix) and coffee berry disease (Colletotrichum coffeanum) become more serious problems and further action has to be taken to control them.

LEAF RUST

Leaf rust has been studied in Kenya for over 50 years and these studies have recently been reviewed by Nutman (1970). Two factors, other than rainfall and temperature, strongly influence the severity of rust epidemics. The first of these is the amount of primary inoculum, the second the degree of foliation (Bock, 1962a).

In Kenya leaf rust infection is normally at its lowest point prior to the short rains in November and it has been shown that there is a close relationship between the amount of infection at this time and the severity of subsequent outbreaks (Table 2). For this reason control of leaf rust at the time of the short rains is particularly important and even

Table 2. Relationship between residual inoculum and ultimate degree of severity of outbreaks (Bock, 1962a)

	Site no.	Level of infection in trough phase (no. pustules/leaf)	Maximum level of infection in ensuing outbreak (no. pustules/leaf)
5000-5500 ft.	1	0.50	7.00
	2	0.60	8.50
	3	2.60	15.10
5600-5800 ft.	4	0.20	1.60
	5	0.25	2.70
	6	0.90	5.50
	7	1.50	8.90

one well timed spray can reduce disease to negligible proportions for many months. When short rains sprays are augmented by sprays at the beginning of the long rains (March - May) excellent control throughout the year can be achieved (Fig 1) as demonstrated by Bock (1962b).

However, when the long rains sprays are omitted disease incidence in the months May - October often exceeds that in unsprayed coffee and, as a consequence, the amount of inoculum available at the next short rains is increased (Fig. 2). This state of affairs

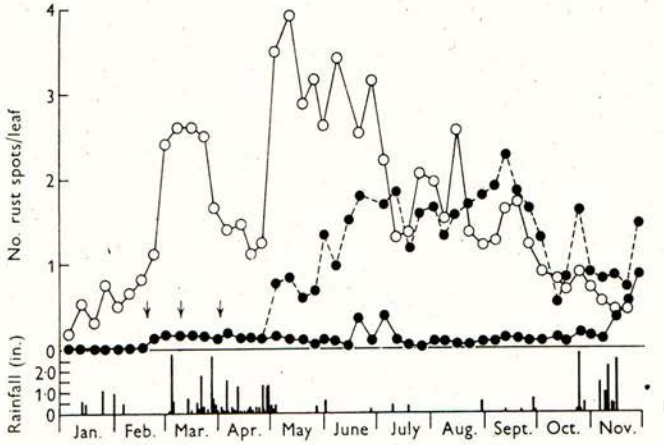


Fig. 1. East Rift districts. -O-O-O-, Unsprayed control; -●-●-●-, copper-sprays applied as indicated by arrow (in addition to two sprays in preceding October/November). Broken line illustrates course of disease after two sprays only, applied in October/November of preceding year. Bock, 1962b.

can be attributed mainly to the changed pattern of foliation as a result of spraying. By virtue of their 'tonic' effect and rust control sprays in the short rains period result in trees which are more heavily foliated and on which rust can develop more rapidly (Fig. 3, Bock 1962a).

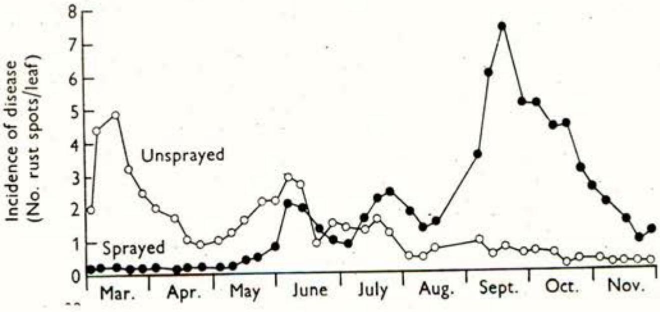


Fig. 2. Incidence of rust on unsprayed trees and on trees sprayed the previous November (Bock, 1962b).

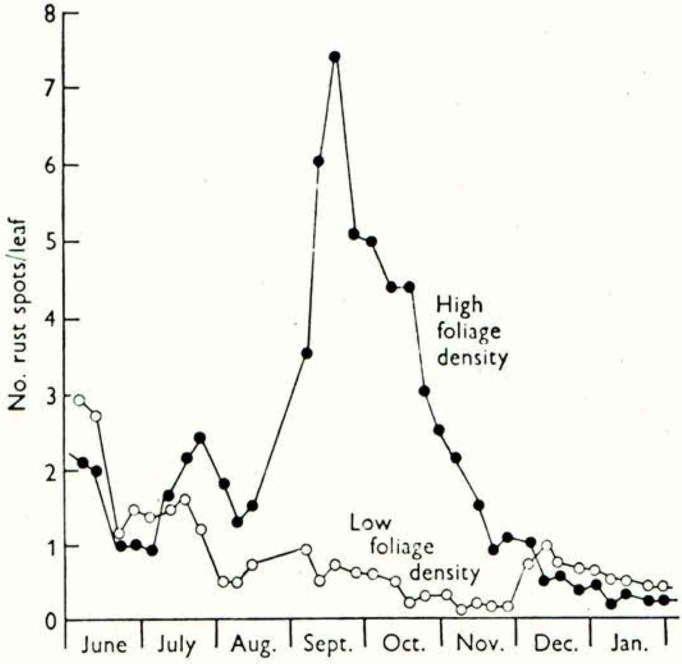


Fig. 3. Course of leaf rust development on trees of high and low foliage density, respectively. Bock 1962a.

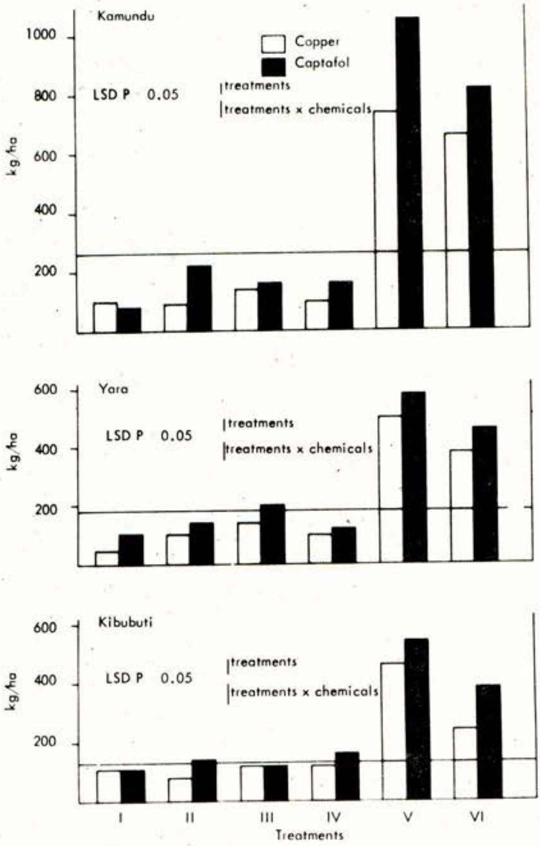
Effective rust control can evidently be achieved in Kenya by a small number of well timed sprays but, as pointed out by Bock (1960) "mistimed or inadequate sprays, even though they may give short-period control, will increase the severity of the following epidemic two - or three-fold or more .... There is equally conclusive evidence that spraying during an epidemic will increase the severity of the next outbreak."

Although the effects of fungicides on foliation probably account for most of the 'negative' effects produced it should not be overlooked that fungicides may directly increase disease incidence by stimulating spore germination. Nutman and Roberts (1962) have shown that, on coffee leaves, germination of rust uredospores is very considerably stimulated (150 times) by low (1 ppm) concentrations of copper. Residual fungicide on coffee leaves may thus, in effect, increase their susceptibility to infection.

COFFEE BERRY DISEASE

Fungicidal control of coffee berry disease (CBD) in Kenya was the subject of a detailed study between 1956 and 1960 (Bock, 1963; Nutman and Roberts, 1960 a, b, 1961). This indicated that in the main coffee growing areas good control of the disease could be achieved by a short programme of sprays applied early in the season (February to April).

The efficacy of this programme was believed to be due to a reduction in the inoculum derived from the bark and not to the protection of the developing crop. Since 1961, however, this programme has given erratic and generally unsatisfactory results (Wallis and Firman, 1965, 1967; Griffiths and Vine, 1968; Griffiths and Gibbs, 1969) and various views have been advanced to explain its failure (Nutman and Roberts, 1969 a, b; Griffiths and Gibbs, 1969). These need not be discussed here but it is necessary to point that spray programmes designed to give protection of berries during susceptible growth stages have, over the past four years given satisfactory economic control of the disease. However, of greater interest in the present context is the fact that early season sprays may not merely fail to control CBD but that they can result in crop loss. This is clearly evident



Treatment	Spraying dates
I	15 Jan., 6Feb., 28 Feb.
II	15 Jan., 6Feb., 28 Feb., 20 Mar., 10 Apr.
III	20 Mar., 10 Apr.
IV	6 Feb., 28 Feb., 20 Mar., 10 Apr.
V	6 Feb., 28 Feb., 20 Mar., 10 Apr., 6 May, 4 Jun., 2 Jul.
VI	20 Mar., 10 Apr., 6 May, 4Jun., 2 Jul.

[Treatments V and VI also received sprays on 4 Oct. and 4 Nov. but these were shown in a separate experiment on the same site to have no significant effect on yield].

Fig. 4 Yield of clean coffee (kg/ha) at three sites in 1968. The horizontal line represents the yield of the unsprayed control. Griffiths et al 1971.

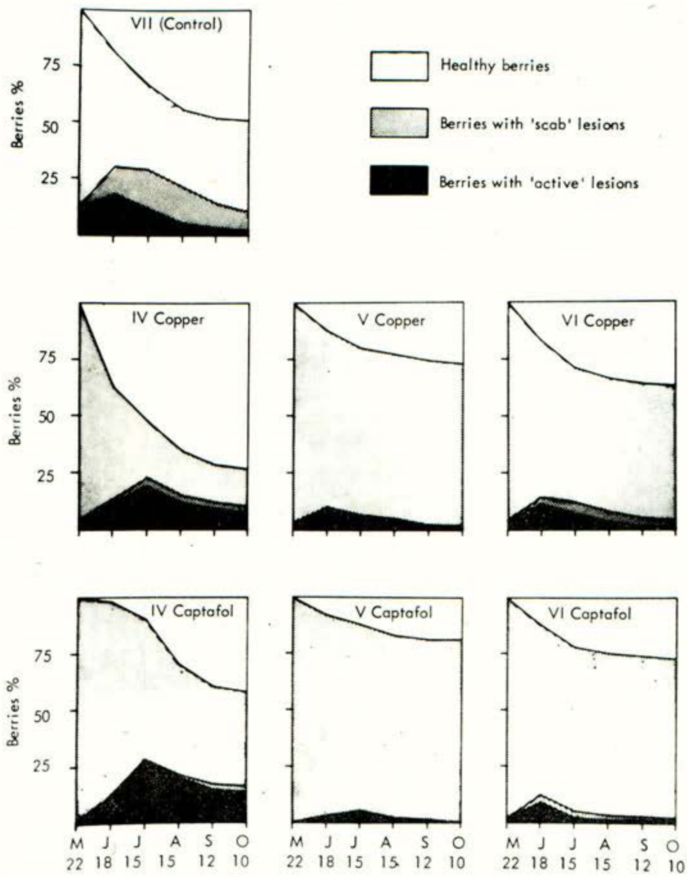


Fig. 5 Effect of spray treatments (IV, V, VI and VII, see Fig. 4) on crop loss and disease incidence, May - October - Kamundu estate, 1968. Griffiths et al 1971.

from the data collected in 1968 from three field experiments designed to examine various spray programmes from fig. 4. it can be seen that all four early season programmes (I - IV) failed to produce yields in excess of the unsprayed control and that in many instances yields were significantly reduced.

The reasons for this somewhat unusual state of affairs is now in part understood. The patterns of disease incidence and crop loss of treatments IV - VII are summarized in fig. 5. It will be noted that diseased berries are divided into two groups viz. those with 'active' and 'scab' lesions respectively. The distinction is important epidemiologically because 'active' lesions sporulate freely and result in berry shedding or formation of mummified fruits still capable of producing spores under favourable weather conditions; 'scab' lesions, by contrast, sporulate sparsely if at all and may even be sloughed off.

Comparing first the unsprayed control (VII) with the early season programme (IV) it is evident that, though there is substantial crop loss in both, the pattern of disease development differs in two important respects: (1) by October 10, the proportion of berries capable of producing spores (i.e. those classified as having 'active' lesions but actually mainly mummified fruits at this time) was small in the control but large in the sprayed. As a consequence much larger amounts of inoculum were available when the crop was ripening and also highly susceptible. This coincided with the November rains; heavy infection occurred and more crop was lost in the sprayed plots: (2) the second distinction between these two treatments is in the proportion of infected berries with 'scab' lesions. These would have contributed little to the progress of the epidemic and the relative infection rate for the control during the period June 18 to July 15 was substantially and significantly lower in the control than treatment IV. The puzzling feature, however, is why unsprayed berries should behave so differently. If, as seems possible, 'scab' lesion formation is the expression of an active natural defence mechanism, than it must be concluded (a) that unsprayed coffee berries are more resistant than those sprayed earlier in the season and (b) that two quite different fungicides can effectively block the resistance mechanism. It has been suggested (Griffiths, Gibbs, and Waller, 1971) that exposure of berries to infection in the immediate post flowering period may induce a phytoalexin whose effects become most apparent when the berries begin to swell and susceptibility increases (Mulinge 1970). The high proportion of 'scab' lesions in treatment VI, unsprayed until two weeks after flowering, lends some support to this view.

Whatever the precise explanation for these effects it is clear that fungicides, even in the short run, have actions which are to some degree deleterious.

Fungicides, however, have another and more serious effect on coffee berry disease. The pathogenic or CBD strain of C. coffeanum (Gibbs, 1969) exists saprophytically in the maturing bark of coffee shoots and during the hot dry season (Jan. - Feb.) when infected berries are scarce or absent, the bark is the primary source of inoculum. Onset of rain results in spore formation and dispersal, and in situations where susceptible crop (e.g. from a November flowering) is present, it can be shown (Gibbs, in press) that there is a direct relationship between the sporulating capacity of the fungus in the bark and percentage infection of berries. Moreover, very low sporulating capacities (Spores/cm^2 bark/hr incubation at 20°C) are capable of giving substantial levels of primary infection. Once infected berries appear on the tree these become the main inoculum source (Gibbs, 1969) but clearly the bark, as a permanent reservoir of infection, is a critical factor in the epidemiology of coffee berry disease.

Table 3 Residual effects of early season sprays applied in 1968 on the sporulating capacity (spores/cm^2/h) of the CBD strain of C. coffeanum on Feb. 24, 1969. [Kamundu estate]. (Gibbs in press).

Fungicide	Sporulating capacity
Copper	18.9
Captafol	23.2
Control	3.2

Numerous factors influence the abundance of the CBD strain of C. coffeanum in the bark (Mulinge, 1971 a,b) but in commercial cultivars none is more important than fungicide application. The immediate effect of spraying a fungicide is, not surprisingly, a substantial reduction in sporulating capacity (Nutman & Roberts, 1969; Gibbs, 1971; Furtado, 1970) but this effect is relatively short-lived. Some 9 - 12 months after spraying has ceased the sporulating capacity of the CBD strain is found to be many times that found in unsprayed trees as shown in Tables 3 and 4 (Furtado, 1969, 1970; Gibbs,

Table 4 Assessment of the CBD strain of C. coffeanum on sprayed and unsprayed farms. Values shown are percentage infections in test berries obtained with standard spore suspensions washed from the bark (Furtado, 1970)

Site	Unsprayed[1]	Sprayed[2]
I	6.01	5.68
II	2.48	5.68
III	1.76	16.30
IV	5.10	21.46
V	0.75	11.63
VI	7.13	44.20
VII	4.88	33.30
Mean	4.02	19.75

1. Unsprayed - farms which have never used fungicides.

2. Sprayed - the last spray (copper fungicide) had been applied at least 14 months before sampling commenced on 15 Jun. 1968. [Values shown are means for samples collected 15.VI.68, 14.VIII.68, 13.IX.68, 10.X.68 and 3.III.69].

in press) and consequently the net result of spraying is a potentially much more serious disease situation. Thus where inadequate spray schedules are used (Griffiths & Gibbs, 1969) disastrous epidemics may occur, this being particularly evident in 1967 and 1968 when climatic conditions were highly favourable for the development of CBD (Griffiths, Gibbs, & Waller, 1971).

DISCUSSION

With hindsight it now seems that Kenyan coffee growers, in order to reap the substantial benefits of 'tonic' spraying, have aggravated, if not actually induced, serious disease situations. The two major diseases of coffee in Kenya - leaf rust and coffee berry disease - can certainly be effectively and economically controlled by fungicides but this should not be allowed to obscure the fact that fungicides have also brought about effects which are deleterious.

There is now urgent need to know a great deal more about the interactions between fungicides, the coffee tree and its pathogens for these have obvious relevance not only to plant pathologists but to crop physiologists, agronomists and plant breeders. This is particularly important at a time when the world's major coffee producing country, faced with the problem of leaf rust control, is beginning to use fungicides on coffee on a large scale for the first time. In the light of experience in Kenya any programme of fungicidal control should be undertaken with extreme caution and the possibility of undesirable side-effects continually checked.

The complex effects of fungicides on coffee may well be unusual but they are hardly likely to be unique and it is a reasonable expectation that the extended application of more exact methods of epidemiological analysis will bring to light many more examples in other crops.

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THE EFFECTS OF COCOA CAPSIDS ON GROWTH AND YIELD IN GHANA

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Summary
At the present time damage by the capsids *Sahlbergella singularis* Hagl. and *Distantiella theobroma* (Dist) is considered to be the greatest single cause of cocoa crop limitation in Ghana. The trend of published national annual crop totals follows the trend of capsid infestation levels on regularly sampled farm plots during the preceding year. Results from spray trials on capsid degraded cocoa in 1968-1971, using a range of more or less effective capsicides, demonstrate a clear negative relationship between capsid infestation levels in the treatment year and crop performance measured by pod counts and foliage recovery in the subsequent year. Successful treatment doubles the crop in the following year but this is still substantially less than that of undamaged cocoa on comparable plots of equivalent age and site conditions. Difficulties associated with plot trial work in a variable farm tree crop in the tropics are briefly discussed.

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INTRODUCTION

Stapley and Hammond 1964 showed that plots sprayed with gamma BHC against capsids resulted in two-fold and three-fold crop increases in the second and third year respectively from the start of their spray trials, as compared with untreated plots. However, no record of levels of capsid damage were published. In a number of other similar spray trials comparing insecticide performance including those reported by Entwistle, Youdeowei and Eguagie, 1964, Peterson and Bond, 1965, only information on capsid numbers before and after treatment was given. Johnson, Burge and Gibbs, 1970, extended their data to include records of capsid damage during the succeeding months after spraying. However, none of these authors recorded subsequent cropping performance.

In the present work a number of comparisons on insecticide treated and untreated cocoa plots showed that pod counts or harvest yields closely reflected the degree of capsid infestation during the peak population period of the previous season. This gave a good measure of comparative insecticide treatment success. Some of these results have already been reported in part (Collingwood, 1971, Collingwood and Marchart, 1971). In this paper, the relationship between capsid damage in the first year and cropping performance in the following season is examined further.

METHODS

Counts of capsids to hand height, numbers of trees infested and in later plot work numbers of trees showing fresh capsid damage were recorded each month.

Collingwood, 1970, 1971, showed that numbers of visibly infested trees gave as good criteria as actual capsid counts, with a highly significant correlation between them ($r = .655$, $n = 63$, $p = 0.001$). Moreover infested trees were found to be easier to record than trees showing fresh damage which had been used by Johnson, Burge and Gibbs 1970, 1971 in assessing the results of comparative insecticide spray trials. In this paper capsid infestation refers to numbers of trees visibly infested per unit area or per 100 trees.

In addition to plot records on insecticide trials, similar records taken each month from each of 25 farmers' plots in the eastern region over a period of 7 years (Collingwood, Marchart and Manteaw, in press) have been used to obtain an index of annual capsid damage. This is given as the logarithm of the average capsid population times duration of infestation levels above 45 capsids per acre. This level of 45 capsids per acre during the period of population increase to December has been found empirically to be about the level above which serious capsid damage becomes noticeable. The published national yields for Ghana during the period 1965-1971 have been used to compare yield loss relative to capsid infestation expressed as an index of annual capsid damage.

Complete cropping records were obtained on a young cocoa establishment trial, but on the out of station spray trials on mature cocoa crop was assessed by pod counting on whole plots, or on samples of 100 trees at two periods of the year, April-May and August-September, to represent the small mid-season crop and the main crop respectively. On mature cocoa the pods counted included all those of 6 cm length or over.

NATIONAL YIELD LOSS IN GHANA

Precise data are not available on either the total acreage of bearing cocoa, or the proportion of this which is more or less severely damaged by cocoa capsids. Yield records from the Cocoa Research Institute plots at Tafo and Bunso over a 7 year period averaged 472 lb per acre. This represents well maintained cocoa grown under plantation conditions and regularly sprayed against capsids and the recorded crop can be assumed to be above the average for the country as a whole for those farms where there is little or no capsid damage. Estimating the cropping area at 4 million acres and the average crop potential in the absence of capsids, but allowing for other disease losses, at 400 lb per acre, the annual crop expectation would be 700,000 tons. Figure 1 shows the difference between this total and the actual recorded total as the assumed loss due to capsid damage and it is seen that the curve of crop loss closely follows that for the national capsid damage index during the previous season. On this graph the logarithm of the annual capsid population peaks and troughs per acre from the 25 farmer plots in the eastern region are also shown. It will be seen that the populations for 1970/1971 are very low and the expectation of loss due to capsids for the 1971/1972 crop is, therefore, correspondingly low. Table 1 gives the peak capsid counts per acre for each of 7 years and the national crop figures as means of adjacent years.

TABLE 1 CAPSID POPULATION YEAR 1 AND NATIONAL YIELD YEAR 2 GHANA 1964-1971

Year	Peak Capsid Population/25 Farms	Crop (Running Mean) in 1,000 Tons
1964	72	476
1965	83	483
1966	98	393
1967	126	395
1968	140	374
1969	106	368
1970	42	406
		(471)

These figures show a significant negative correlation, r = -0.843 with a regression of yield year 2 = 520,000 tons - 11.55 x the mean capsid population at peak in year 1.

CROP YIELDS AND CAPSID DAMAGE ON MATURE COCOA

During the period 1946-1949, individual trees were scored for severity of capsid damage and the numbers of harvested pods were recorded (Voelcker, 1950). The results expressed as pods per 100 trees are shown in table 2.

TABLE 2 PODS PER 100 TREES AT DIFFERENT LEVELS OF CAPSID DAMAGE SEVERITY

Year	Severe	Slight	Healthy
1946	2107	2910	1963
1947	401	1060	1778
1948	130	1150	2900
1949	570	2067	3160
Mean ratio 1947-49	14	54	100

On the severely damaged trees, the crop decline after the first year of recording was very marked. At 600 cropping trees per acre and 12 pods to 1 lb dried cocoa the mean yield for each of the years 1947-1949 would be approximately 183 lb per acre, compared with 1,306 lb per acre on the healthy trees.

In the trials reported by Stapley and Hammond, 1959, the yields from sprayed plots starting at an initially high level of capsid damage showed considerable increases in the year following spraying, compared with untreated plots. A further analysis of these and other data by Vernon, 1964, gave the following comparisons.

TABLE 3 ANNUAL YIELDS LBS DRY COCOA PER ACRE (VERNON, 1964)

Treatment	1956	1957	1958	1959	Total	Ratio
Sprayed	615	640	690	885	2830	100
Control	380	400	320	425	1525	54

The average crop for the 4 years shows an approximate doubling of yield on treated plots compared with control. Similar results were reported by Collingwood and Marchart, 1971, for spray trials in 1968 and for the best treatment in spray trials in 1969 by Collingwood, Marchart, Owusu Manu and Manteaw, 1971, using plots already severely degraded by capsid. In the 1969 spray trial series sample pod counts in 1970 were also taken on undamaged cocoa representing similar tree age and growing conditions at each site in May with the following results.

TABLE 4 1969 SPRAY TRIAL - POD COUNTS MAY 1970 (PODS/ha)

Site	Untreated Control	Best Insecticide Treatment	Undamaged Cocoa
1	1,200	4,070	17,140
2	2,810	7,100	9,790
3	280	6,310	9,920
4	3,390	460	14,960
5	6,770	17,800	35,620
6	2,400	3,980	8,560
7	2,760	3,160	12,050
8	1,590	5,370	15,680
Mean	2,650	6,031	15,465
Mean ratio	16	40	100
Mean % trees infested at peak	4.03	1.05	"0.00"

These figures show clearly that although on average spray treatment more than doubled the crop compared with no treatment, previously undamaged cocoa of similar age and growing conditions was yielding at a much higher rate and that a programme of spraying extending over more than one season would be necessary to restore full cropping potential. In fact the mean yield ratios from the above table for control, treated and undamaged plots correspond closely with those from the 1946-1949 observations quoted earlier for severely, slightly and not damaged trees respectively. The percentage trees recorded as infested at the time of peak capsid population (November-January) is very low according to the normal visual counting method employed. However, as with actual capsid counts, pyrethrum knockdown samples on the same plots show that the true number of trees infested is underestimated by a factor of about 12.

Using data for 90 plots of the 1968 spray trial and from 64 plots of the 1969 spray trial the following regressions were calculated, as shown in Table 5. In figure 2 the regression curves for 1968/1969 and 1969/1970 have been combined for the April/May pod counts since the regression lines come very close together. There was insufficient data recorded for the main crop count in 1970 and only that for the 1968/1969 trials are shown in the figure. When these results are converted to actual percentage crop loss a very steep decline in crop potential is evident with every unit of progressive capsid damage and this is more or less in accord with the actual data already shown in table 3, ie just over 1% visible capsid infestation gives 60% crop loss and 4% infestation is associated with 84% crop loss.

TABLE 5 REGRESSION EQUATIONS: POD COUNTS AND CAPSID INFESTATION
A MATURE COCOA: POD COUNTS YEAR 2 AND CAPSID INFESTATION YEAR 1
SPRAY TRIAL PLOTS 1968-1970; LOG TRANSFORMATION

Pods/ha April 1969 $r = -0.5846$, $n = 90$, $p = 0.001$
Capsid infested trees/ha $y = 4.38 - 0.674x$
November-January 1968 (mean)

Pods/ha September 1969 $r = -0.5048$, $n = 90$, $p = 0.001$
Capsid trees, 1968 $y = 4.526 - 0.4336x$

Pods/ha April and September 1969 $r = -0.6506$, $n = 90$, $p = 0.001$
Capsid trees, 1968 $y = 4.722 - 0.517x$

Pods/ha May 1970 $r = -0.4995$, $n = 63$, $p = 0.001$
Capsid trees, 1969 $y = 4.295 - 0.5437x$

B YOUNG COCOA: FIRST CROPPING YEAR, SYSTEMIC INSECTICIDE PLOTS, 1967-1969

Total pods harvested 1968 $r = -0.78$, $n-2 = 10$, $p = 0.01$
Peak capsid infestation 1967 $y = 3.838 - 0.2418x$

SECOND CROPPING YEAR

Total pods harvested 1969 $r = -0.83$, $n-2 = 10$, $p = 0.001$
Peak capsid infestation 1968 $y = 4.375 - 0.428x$

Pods 1968 + 1969 $r = -0.851$, $n-2 = 10$, $p = 0.001$
Capsids 1967 + 1968

Pods 1968 $r = -0.761$, $n-2 = 10$, $p = 0.01$
Capsids 1968

Pods 1969 $r = -0.326$, $n-2 = 10$, n.s.
Capsids 1969

DAMAGE ASSESSMENT ON YOUNG COCOA

Twelve plots of young cocoa each subdivided into 36 tree units of 5 varieties were studied during a period of 3 years to include the first and second cropping year from establishment. Individual tree records of capsid infestation were taken monthly and each plot was harvested at appropriate intervals throughout each cropping season. The regression calculations shown in table 5 for young cocoa show that when pods and capsids are compared for the same year the negative correlation is lower and less significant than when pods in year 2 are compared with capsids year 1. In these plots individual trees were scored monthly for all pests seen including capsids, but the data recorded clearly show that only capsids were of importance in affecting yield and growth (Collingwood and Marchart, 1971). Moreover the yield results are clearly attributable to decline in numbers of pods harvested rather than to rejected pods at harvest as Marchart, 1971, has already shown that direct capsid feeding on the pod has a negligible effect on bean weight. Other data from this trial have been quoted elsewhere to show that the number of establishing cocoa trees actually dying as a result of capsid injury were much higher on the untreated plots than on the treated. Apart from yield data, however, no special measurements were taken to show the extent of foliage and tree injury, since this was so obvious visually.

Limited observations on pollination and pod setting suggested that even where tree recovery in the season following capsid damage was sufficient to allow for flower production, the setting was about 50% less on the untreated plots than on the treated. In other words the vigour of the already damaged tree was insufficient to carry a normal crop.

TABLE 6 TREE MORTALITY AND CAPSID INFESTATION AT PEAK

Year of Treatment	Mean per cent trees infested at peak over 3 years	Per cent tree mortality
Treated each year	2.5	0.9
Treated year 1 only	7.25	1.72
Untreated	48.9	3.64

CAPSID DAMAGE, FOLIAGE, GROWTH AND CROPPING

In some of the trials trees were scored for foliage or canopy rating and mean results compared with capsid infestation as shown in table 7.

TABLE 7 CAPSIDS AND CANOPY SCORES PER 100 TREES

Capsid Infestation at Peak (Jan) Range	Mean	Mean Canopy Rating (May)
1-1.7	1.4	8.6
2.2-3.3	2.6	7.5
4.1-5.5	4.7	7.0
Above 6%	10.9	6.5

Tree canopy at the time of maximum capsid damage is compared with subsequent crop in table 8.

TABLE 8 CANOPY AND CROP

Number of samples	% trees with good canopy (Jan) Range	Mean Rating	Numbers of pods/100 acres Sept-Oct
11	Below 45	-	67
6	45-54	50	87
11	55-64	61	201
27	65-74	69	349
9	75-84	80	365
27	85-94	90	526
23	95-100	97	539

These tables show clearly that on average there is a fairly clear relationship between capsid incidence on the one hand and tree growth as measured by canopy and pod production. Individual variation, however, is very considerable especially with the better canopied trees, while sometimes individual trees will produce very few pods for reasons unrelated to capsid injury.

DISCUSSION

The data supports the view that capsids are of over-riding importance in relation to tree growth and cropping performance and that yield will reflect the cumulative effects of capsid damage over several years. However, actual records show very great variability so that mean results only achieve high significance when many plot records are taken together, especially in farmers cocoa where much of the spray trial type of work was done.

Plot sizes were kept small i.e. to one acre for all the main critical trials because of the difficulty in finding even blocks of cocoa. In fact plots were selected for evenness of poor condition and high capsid infestation level both because the effects on capsids could be more readily observed and also because such evenly bad degraded trees with often two-thirds of their top growth destroyed by capsids were easier to assess visually for record purposes. Other difficulties were attempting to ensure similarity of site criteria for each block in the trial and it will be seen from table 4 how cropping means varied from site to site on both treated, untreated and on undamaged plots, so that at one site for example, the treated plot gave substantially lower pod counts than the untreated.

Because of the need to use plots away from the Research Institute through lack of availability of suitable sites on or near the Institute grounds, there were the usual difficulties to be expected in arranging transport of men and equipment, delays in obtaining spares and sometimes test insecticides and uncertainty of weather and road conditions. Indeed the success of the outstation 1968-1970 spray trial operations depended entirely on the enthusiasm and resourcefulness of the spray trials team under the energetic leadership of F K Manteaw.

Acknowledgments are due to the Director and Staff of the Cocoa Research Institute, Ghana, where this work was carried out.

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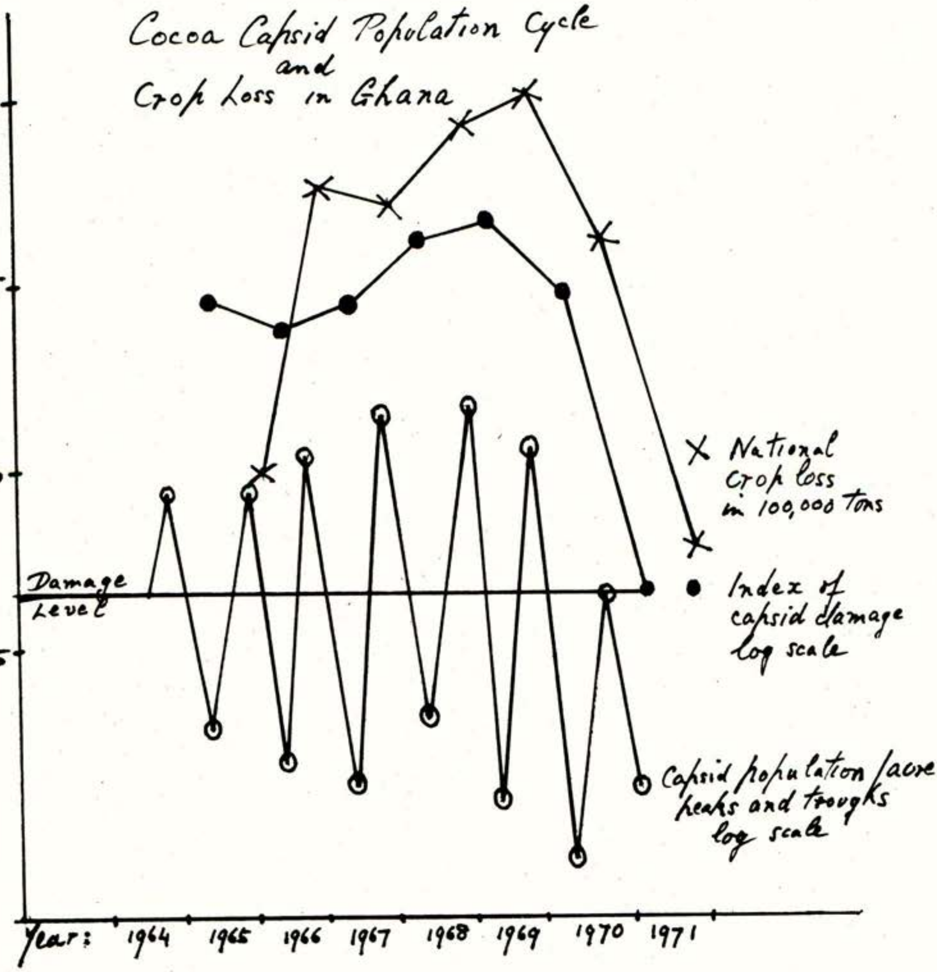
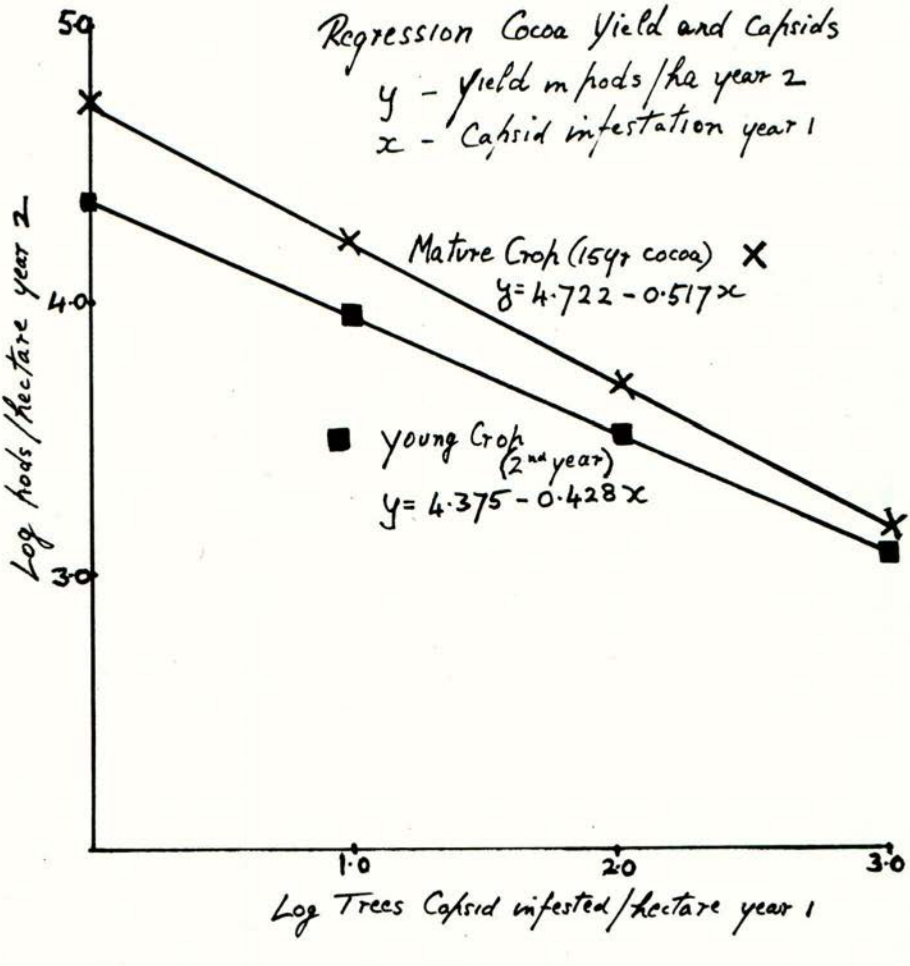
Fig. 1



Cocoa Capsid Population Cycle and Crop Loss in Ghana
3.0
2.5
2.0
1.5
Damage Level
Year: 1964 1965 1966 1967 1968 1969 1970 1971
X National crop loss in 100,000 tons
● Index of capsid damage log scale
Capsid population/acre peaks and troughs log scale

FIG. 2



Regression Cocoa Yield and Capsids
y - yield in pods/ha year 2
x - Capsid infestation year 1
Mature Crop (15yr cocoa) X
y = 4.722 - 0.517x
young Crop (2nd year)
y = 4.375 - 0.428x
5.0
4.0
3.0
1.0
2.0
3.0
Log pods/hectare year 2
Log Trees Capsid infested/hectare year 1

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PEST AND DISEASE PROBLEMS IN THE SEYCHELLES

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Summary. Some aspects of recent work in this small Crown Colony are considered. Particular attention is given to the types of problem associated with experimental programmes in the humid tropics. Much of this work was concerned with the coconut trunk borer (Melittomma insulare, Coleoptera : Lymexylidae) an almost intractable problem under Seychelles conditions; whilst some references to the coconut beetle (Oryctes monoceros), rats, ticks, stored products pests, molluscs, nematodes and vegetable pests are made. Difficulties were encountered involving the supply of equipment and chemicals; personnel; transport and water supply. Unwanted side-effects, in this case, hazards to children, domestic animals and wildlife are more acute than is normally found in UK. It proved impossible to obtain residue data. Without a resident entomologist other problems emerged rapidly following requests emanating from H.E. The Governor downwards. The principal one involved biting midges on the beaches with their potential tourists and the alien "Crazy Ant".

INTRODUCTION

In 1969-70, for a period of 18 months I had the privilege of serving as Entomologist to the Government of Seychelles. This very small Crown Colony, in terms of land area (100 square miles) and population (55,100 people) provided an interesting range of problems, some almost intractable, on which to work. The archipelago consists of 77 islands and islets of which 38 are granitic and 39 coral in origin. The granitic islands lie between latitude 4° and 5°S and longitude 55° and 56°E, they occupy 87 square miles of a shallow bank (above the 40 fathom line) about 16,000 square miles in total area. They are the only granitic oceanic islands in the world, and were uninhabited until about 200 years ago when French settlers and slaves arrived from Mauritius. At the northern edge of the Seychelles bank are 2 coral islands (sand-cays), Bird and Denis with similar islands eg Amirantes lying between Seychelles and the Malagasy Republic, a distance of 650 miles S.W. Astove and Cosmoledo Atolls and Assumption Island are relatively flat, elevated coral reefs (now limestone). In November 1965 the British Indian Ocean Territory was created with Aldabra, Farquhar, Desroches (previously administered by Seychelles) and the Chagos Archipelago (previously run from Mauritius). The new laws follow Seychelles for criminal, land, income tax, postal and wild life protection. They have an Administrator and a Commissioner (H.E. The Governor of Seychelles). The territory is scattered over a vast area of ocean. The sea is almost completely open in all directions from the granitic islands of Seychelles for upwards of 1000 miles.

Mahe, Praslin, Silhouette and La Digue are the largest islands of the granitic group. Mahe the main island is 17 miles long and up to 7 miles wide. It consists of a ridge of mountains rising to about 3,000 ft, fringed with coral reefs and flat, coral sand 'plateau' (rendzinas) with some granite islets offshore. It carries upwards of 40,000 of the total population of 52,100 (55% under 21 years old), as well as the only town Port Victoria. Silhouette is extremely rugged (nearly 2,600 ft a half-mile from the sea), has 600 inhabitants and is relatively undisturbed compared with Mahe. Praslin and La Digue (5,000 and 2,500 population respectively) possess extensive 'plateau' areas under cultivation, both are well under 1,500 ft.

The climate of the Seychelles is humid tropical being only 300 miles south of the equator. The mean daily temperature varies from 75-85°F, highest daily temperatures rarely exceed 95°F. The mean annual rainfall on Mahe is 94 in. falling mainly in November-February during the N.W. Monsoon. In March to mid-May both temperature and humidity (which never falls below 75%) are high, which is somewhat enervating. Some of the southermost coral islands receive only 20 in. of rainfall per year. The S.E. Trades blow from June to October, bringing cooler, drier conditions. On the granitic islands no month is without rainfall of about 2-3 in. The weather during my stay was atypical, in that much drier conditions prevailed than usual, this may have affected experimental and survey data, in particular a nematode survey.

There are 4 soil series derived from coral, Seychelles Red Earth (largest area), River Valley, Marsh, Mangrove Swamp and Rocky and Bouldery land recognised. The Red Earth has been divided into 3 phases, having different degrees of erosion. The coral sands (open, highly calcareous and low in nutrients and organic matter) occur as coastal flats on the granitic islands and on the outlying coral islands. The crops grown are mainly coconut, fodder, vegetables and vanilla. The red earth which is found on the gentler slopes is derived from granite (lateritic). (When uneroded it can form a fairly fertile, free-drainage loam bearing coconuts, semi-wild cinnamon (Cinnamomum zeylanicum), patchouli (Pogostemon cablin) and vanilla (Vanilla planifolia).

The economy is based on agriculture with coconuts (copra and coir products), cinnamon (bark and leaf oil), vanilla pods and patchouli (dry leaves and oil) being exported. Tourism is destined to be a very important feature in the next decade. Government wishes to diversify agriculture/horticulture so that lime and tea enterprises are underway, with experimental work on ylang ylang (Cananga odorata), annatto (Bixa orellana), groundnut, nutmeg (Myristica fragrans), quinine and pineapples in progress. Crops produced for local consumption are tea, coffee, tobacco, bananas, breadfruit, sugar cane (for 'bacca', an alcoholic beverage), coconut toddy ('calou') and the usual range of tropical and sub-tropical and, to a small extent, temperate crops, particularly vegetables. Large imports of rice, flour and sugar are necessary, together with smaller quantities of other foodstuffs. Timber has now to be imported.

The Seychellois are mainly descendants of freed slaves, with Indian and Chinese traders, the planters ('grands blancs') with some UK expatriot administrators. The predominant racial strain is African, miscegenation has been advanced so that almost every type and feature of colouring is represented. They are mainly R.C. (> 90%) speaking Creole (a French patois) with some French, whilst English has been the official language since 1954. They have developed their own culture and distinctive way of doing things.

The fauna and flora is typical of an oceanic island group, the number of species being small, but with a very high proportion of endemic forms, especially the unique avifauna. It is, however, richer than might be expected from its small size and isolated position and this is probably due to its extreme age (granite, argon dated = 660 million years old) and previously larger area.

From a biogeographical point of view Seychelles, together with Madagascar, the Comoros, and the Mascarenes are now included in the Madagascan Region. The flora and fauna is a mixture of extant African and Asian species and endemic taxa, the affinity being greatest towards the Asian component, ie Seychelles seems to represent the western limit of the Oriental Region, rather than the eastern limit of the Ethiopean Region. In general the majority of the pests and diseases from the adjacent continents and Madagascar are absent in Seychelles, possibly due to their previous isolation. They do however, have their own pest and disease complexes; the major ones will be dealt with together with a mention of the extraneous difficulties associated with investigational work in the tropics.

PESTS

The Colony appeared initially to be very receptive towards biological control of its pests (isolation enhancing the effect), as shown by the scale/ladybird spectacular of Vesey-Fitzgerald (1936-39). Many introductions have been made since then, the results however have been far less satisfactory. There is now a bounty of Rs. 30 on the South African Barn Owl and one of 10 cents on rat-tails, from the pest it was intended to control.

Control of the citrus blackfly (*Aleurocanthus woglumi*) by the Eddy wasp (*Eretmoceros serius*) sometimes lapses warranting chemical control on citrus and coffee. The control of the coconut beetle (*Oryctes monoceros*) by the scoliid wasp (*Scolia ruficornis*) has not materialised. The wasp breeds very slowly and may exert control in 20-30 years time! There is no evidence that the predacious snails (*Goniaxis quadrilateralis* and *Euglandina rosea*) have significantly reduced populations of the giant snails, *Achatina panthera* on the coast or *A. fulica* on the slopes.

The major pest of the coconut palm is the coconut trunk borer (*Melittomma insulare*) which attacks palms which have just formed a trunk (5-7 years old). The pest is particularly acute on Praslin Island where the large area of marshy land produces very sappy palms which are ideal for rapid borer development. The paradichlorbenzene (PDCB) fumigation technique devised by Brown (1954) was not successful. The fermentation process associated with the borer progressed more rapidly in the closed, humid chambers formed. Nye (1961) proposed a more thorough excision of the necrotic tissues and larvae followed by a liberal application of creosote-tar to the cut surface. The expected decline of *Melittomma* populations has not occurred. Trials involving 10,300 palms were conducted, preventative organochlorine sprays using water, kerosene or diesel oil as carrier were applied to the base of the palm to prevent infestation and reinfestation by killing ovipositing females, eggs or first instar larvae prior to penetration. Certain sprays were successful, others (using kerosene and diesel) proved very phytotoxic. Further detailed studies were made on the associated microflora which occurs in advance of (up to 15 cm) and surrounding (0·5 - 1 cm) each tunnel. The Nye treatment when properly carried out, is the only approach possible with infected palms. There is no alternative to the skilled gouging needed. Chemical methods alone would be useless against an active tissue fermentation process. There was no evidence of behavioural avoidance associated with the sprays (Mathias, 1970).

It is difficult to visualise any scheme which could lead to an increase in copra production on Praslin and reduce *Melittomma* populations significantly at the same time. In general when favourable conditions are created for palms it will automatically favour *Melittomma* development and *vice-versa*.

There is no known predator or parasite in Seychelles; except casual predators of adults or accidentally exposed larvae eg by the ant *Odontomachus haematoda*, this position also applied in Madagascar. Simmonds (1956) considered that because of its life-cycle the possibilities of biological control against larvae were not promising. However, after reviewing the world literature and searching Mauritius, E Africa and Trinidad for beneficial insects he thought that egg predation offered most hope. Consignments of *Rhizophagus dispar* a Nitidulid beetle feeding on the eggs of another Lymexylid, Hylecoetus dermestoides occurring in UK were liberated on Mahe and Cerf during 1955. They did not become established, presumably the climatic change was too great. No further work on this aspect of control was done.

The coconut beetle (O. monoceros) is a major obstacle to replanting coconuts on Praslin (but is less severe on Mahe) where palms have fallen after Melittomma attack. Seedling palms are killed soon after planting out or suffer damage for the first 5-7 years of their life before Melittomma takes over. The beetles bore down the 'spout' to the growing point or reach it by burrowing through the soil (similar behaviour to O. pyrrhus in Madagascar). Plantation hygiene was poor, with a large backlog of fallen palms needing to be burnt. Large-scale trials were carried out, sawdust poisoned with BHC or chlorfenvinphos and granules of dieldrin and chlorfenvinphos suitably placed gave good control if applied at monthly intervals. The dry conditions no doubt aided control by reducing beetle activity with minimal leaching of the insecticides. The use of Rhabdionvirus oryctes in Mauritius against O. rhinoceros is worth trying in Seychelles.

Rats are a major pest of coconuts, yams and sweet potatoes. Populations rose rapidly following the epidemic of feline enteritis in 1966 and lack of interest by the Barn Owl. Blocks of paraffin/maize/warfarin are used but were ineffective, a change to coumatetralyl, chlorophacinone or alpha-chloralose was advised in case resistance was developing.

A tick problem existed on Long Island (quarantine station) with Boophilus microplus (transmitting anaplasmosis) infesting recent cattle imports intended to upgrade the beef and milk enterprises. A change from toxaphene (after 10-12 years use) to dioxathion or a dioxathion / chlorfenvinphos mixture was recommended).

Problems existed on stored products (copra for export; rice from Rangoon; animal feeds from S. Africa). A survey showed that at least 15 pest species were involved. These were most acute on animal feeds where Tribolium castaneum, Tenebroides mauritanicus and Alphitobius diaperinus were rife. Storage facilities were very limited and the problem was largely one of hygiene. Fenitrothion, bromophos and propoxur sprays were most impressive, the use of pirimiphos-methyl for in-sack storage should be investigated.

Two other public health problems were studied during my stay. A biting midge (Leptoconops spinosifrons) on certain beaches was studied in some depth. An entomological investigation before tourist development was desirable since these insects can be very formidable enemies. An alien ant species, the "Crazy Ant" (Anoplolepis longipes) was a problem in a village 600 ft up on the middle slopes of N. Mahe. Ecological and baiting studies were made, but no simple solution such as chemical control presented itself because of the large area involved, difficult terrain and the possibility of unwanted side-effects.

Dieldrin and chlorfenvinphos are used against the banana weevil (Cosmopolites sordidus) which is an important pest in the Colony on many of the 25 cultivars grown. A campaign to grow more Dwarf Cavendish was made as this is fairly resistant to attack. The scale, Icerya sechellarum colonises a wide range of plants. Citrus (particularly lime) is attacked by scale, mealy bug, aphid (Toxoptera citricidus) and fruit-flies, mainly Ceratitis capitata. Other fruit trees suffer from the Indian Mynah bird and fruit-bats. Cinnamon has no major pest (or disease). Local insects do not appear to have become adapted to attack sugar cane. Maize grows poorly, but stalk-borers are not to blame. Forestry pests (and diseases) are unimportant, but timber-borers and termites rapidly attack buildings.

The cultivation of European vegetables in small mixed lots is likely to increase (if imports are controlled), raised mainly as cash crops for the tourist industry. Many crops are not grown sufficiently well or intensively to allow much expenditure on crop protection. However, high vegetable prices allow some scope for this. With the expansion of vegetable production, and the possible switch to all-year cropping (under protection against rain in N.W. Monsoon) and hydroponics there is likely to be an increasing awareness of pest and disease problems. The production of uniform crops will necessitate some forecast of the likelihood of such damage (surveillance programme), so that suitable, safe chemicals can be imported well in advance. Diamond-back moth is a limiting factor in brassica production, but both monocrotophos and tetrachlorvinphos are effective if used every 5 days. In 1970, American Land Cress (Barbarea praecox) seedlings were badly stunted by the thrip (Copidothrips formosus).

Beans (Phaseolus spp.) suffer badly from red spider mite (Tetranychus lombardinii), bean fly (Melanoagromyza phaseoli) and the pod borer (Etiella zinckinella). The rose beetle (Adoretus versutus) is a voracious feeder on a wide range of plants under Seychelles conditions. Methiocarb pellets gave good control of the giant snail (Achatina panthera) under the dry conditions of 1969-70. Great care had to be taken on Frigate Island to be certain that the Seychelles Magpie Robin (Copsychus sechellarum) possibly the rarest bird in the world, was not pellet orientated!

The nematodes, Meloidogyne javanica and M. incognita caused severe damage on tomato, tobacco, egg plant, patchouli, carrots and red beet. Numbers of migratory nematodes per l soil were low (a possible result of the dry conditions) compared with UK arable soils. Prominent were Xiphinema spp., but Longidorus and Trichodorus spp. were not detected. The Hoplolaimidae were very well represented in all soils, beneath most crops.

DISEASES

No comprehensive plant disease survey has been carried out in the Seychelles but fungal and bacterial problems were well in evidence and may become important for future vegetable - growing enterprises. Diagnosis is complicated by non-parasitic troubles, such as sulphur (minimal burning of fossil fuels compared with UK) and potassium deficiencies. Severe chlorosis and leaf damage encourage the growth of saprophytic fungi which mask symptoms due to viruses or mycoplasmas.

1 Viruses

A mosaic disease of cassava was widespread, whilst sweet peppers suffered from a seed-borne disease which appeared to be due to a virus. If stricter selection of planting material and more rigid quarantine on seed imports respectively were used, control could be achieved. There was no evidence of citrus viruses, although one vector of Tristeza virus, Toxoptera citricidus was common on citrus and tea.

2 Bacteria

Pseudomonas solanacearum - causing a wilt of tomato, egg plant, patchouli and Granville wilt of tobacco is a serious problem in Seychelles particularly during wetter periods. Some protection is given when egg plants are grafted on wild, partially resistant rootstocks.

Xanthomonas citri - is well established causing cankers on various Rutaceae.

Xanthomonas vesicatoria - causes leaf spotting on tomato, again emphasising the need for seed quarantine.

Agrobacterium tumefasciens - causes root galling on a wide range of plants but no aerial symptoms were noticed.

3 Fungi

Fusarium oxysporum f. sp. vanillae on vanilla roots has caused the recent decline in importance of this crop. Previously anthracnose symptoms due to *Gleosporium*, *Colletotrichum* and *Marssonia* species had been limiting.

Fusarium solani - frequently wilts tomato on Mahe and Praslin. *Cladosporium fulvum* and *Corynespora cassiicola* are also found on this crop but are less important.

Fusarium oxysporum f. sp. phaseoli - has caused frequent heavy losses, due to a collar rot of beans. *Botryodiplodia theobromae* and a *Pestalotiopsis* sp. have been isolated at the same time.

Phomopsis vexans - (new record - det. Booth, CMI Kew) blights both tomato and egg plant, this was serious on Praslin in 1970.

Cercospora nicotianae - causing frog-eye of tobacco was prevalent on Praslin in 1970. Other *Cercospora* spp. were found on papaw (*C. papayae*) on cassava (*C. henningsii* - det. Deighton, CMI Kew) and runner bean (*C. canescens* ?).

Leptosphaera sacchari - (det. Punithalingam, CMI Kew) was widespread in sugar plantations.

Curvularia senegalensis - (det. Ellis, CMI Kew) was present on the few crops of sorghum grown on Mahe.

Deightoniella torulosa (new record - det. Deighton, CMI Kew) was recorded on the banana cv Dwarf Cavendish in 1970, producing leaf blotches and black end of the fruit. The variety seemed very susceptible.

Glomerella cingulata - caused brown blight in the recently established tea plantations. It is not a vigorous pathogen and is usually associated with some other factor, eg S or K deficiency, sun scorch or nematodes.

PROBLEMS

Various problems were encountered during the investigational work, they were of the following nature :-

a) Co-ordination of arrival of equipment and chemicals to coincide with the period of secondment

b) Suggestions to work on extra pests were made that had not been included in the original request for technical aid.

c) Difficulties in obtaining suitable support staff and transport

d) Spraying trials on Praslin were hindered by water shortage

e) It was difficult to convince the Seychellois that no chemical existed which could clean up a *Melittomma* infested palm without gouging. Planters are reluctant to remove or treat palms and the powers of the Plant Pests and Diseases Ordinance are rarely invoked

f) Great care was necessary when applying insecticides near homes or waterways containing *Tilapia* spp.

g) There were no offers to do residue determinations for organochlorine deposits under Seychelles conditions so that extrapolation had to be used in devising a spray regime

h) Biological problems were not appreciated by the administration in their requests for frequent progress reports

Acknowledgements

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RESULTS OF TRIALS WITH TRIDEMORPH ON THE CONTROL OF MYCOSPHAERELLA MUSICOLA ON BANANAS

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Summary Tridemorph, a fungicide designed for the control of ascomycetes, is transported acropetally in bananas and can thus be termed a local systemic fungicide. Both in small scale trials and on aerial application, tridemorph had a better fungicidal effect and gave longer protection in the control of *Mycosphaerella musicola* than the conventional dithiocarbamate and oil mixtures. The addition of oil to tridemorph effected very little improvement in the results.

INTRODUCTION

Sigatoka disease (*Mycosphaerella musicola*) is economically the most important fungus disease attacking bananas today, and regular control measures are necessary in most banana-growing areas. In many places banana-growing could not be made into a paying proposition until the introduction of Bordeaux mixture in the thirties. Since the end of the fifties the use of spray oils has not only increased the degree of control but also reduced the cost of treatment (Meredith 1970). Dithiocarbamates, which have been in use for a few years now, and the recently tested systemic fungicides are applied solely in combination with oil. The main advantage of oil sprays over the older fungicides is their considerably better curative action. They also prevent to a large extent yellow streaks developing into spots (Calpouzos 1966). Although the admixture of oil with fungicides is so widely practised, it is a well known fact that paraffin and naphthene can under certain conditions cause phytotoxicity, the results being fewer fruits and a reduction in the weight of the bunches.

This paper discusses the results of field trials with tridemorph on the control of Sigatoka in bananas.

METHOD AND MATERIALS

Tridemorph (N-tridecyl-2,6-dimethyl-morpholine) is already used for the control of powdery mildew of cereals in various European countries. Tridemorph has a prophylactic and curative action against *Erysiphe graminis* (Pommer et al., 1969). After completing successful laboratory tests, field experiments for the control of *Mycosphaerella musicola* were started in Costa Rica, Central America. The area of banana cultivation in Costa Rica is situated along the 10th latitude north and is marked by high rainfall (approx. 5,000 mm, or 200 inches), a yearly mean temperature of 26°C and a relatively high incidence of Sigatoka disease.

In small scale trials, two replications were made to 6 banana plants per treatment. The fungicides were applied in a total of 400 l/ha spray solution. The plot size of the aerial trials was 12 ha, the spray solution 25 l/ha.

The small scale experiments described here were evaluated by three different methods: a) recording of the primary infection on the 3rd open leaf, b) assessment of the total infection in stages 1 (no infection) to 9 (complete infection), c) counting of the perithecia of M. musicola on the 7th leaf (Lactophenol method). The experiments with aerial application were carried out according to the method described by Stover and Dickson (1970): recording of the youngest leaf infected and estimation of the relative infection (in %) on 50 plants per treatment.

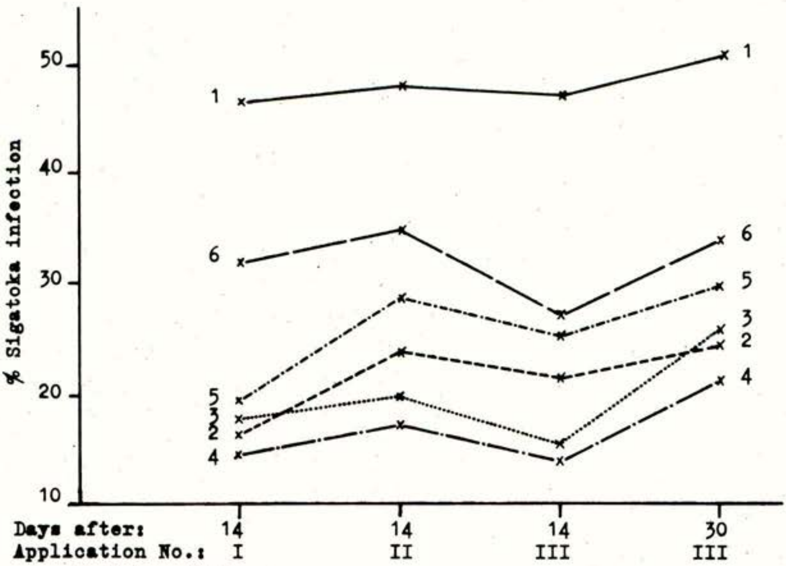
Application rates mentioned in this paper always refer to the formulated product.

RESULTS AND DISCUSSION

Experiments carried out so far indicate that tridemorph is transported upwards in banana leaves and can therefore be regarded as a locally systemic

Figure 1

Effect of tridemorph on primary Sigatoka infection on 3rd unfolded leaf (4 trials)

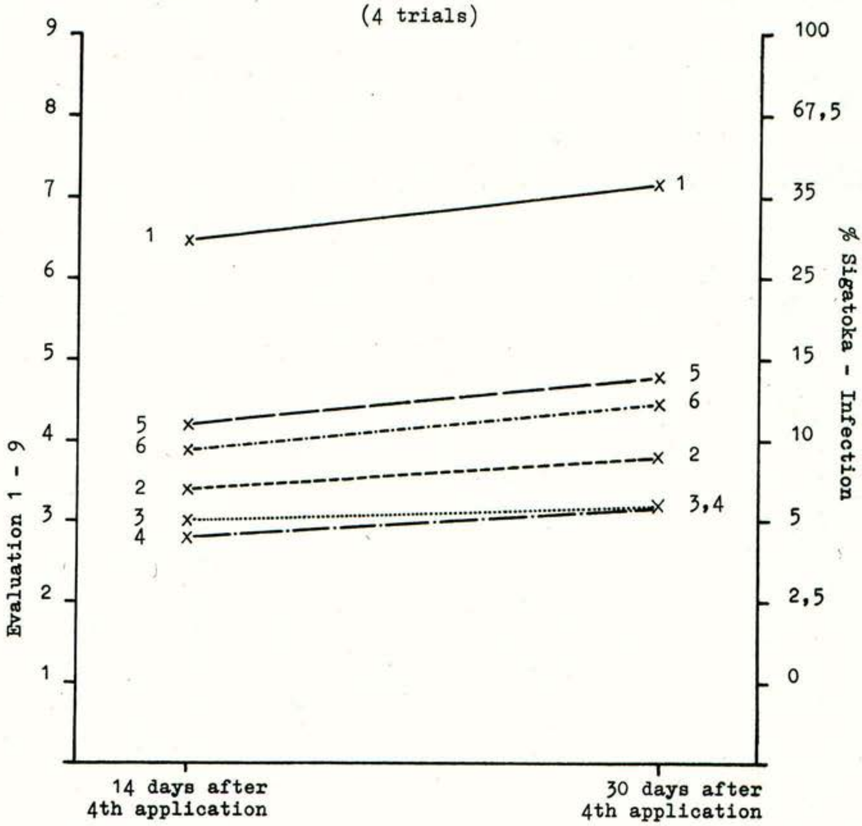


1	Untreated	
2	Tridemorph	0,3 l/ha
3	Tridemorph	0,6 l/ha
4	Tridemorph + oil	0,3 l/ha + 5,0 l/ha
5	Benomyl	0,3 kg/ha
6	Maneb + oil	2,5 kg/ha + 5,0 l/ha

Figure 2

Duration of efficacy of Tridemorph on Mycosphaerella musicola

(4 trials)



1	Untreated	
2	Tridemorph	0,3 l/ha
3	Tridemorph	0,6 l/ha
4	Tridemorph + oil	0,3 l/ha + 5,0 l/ha
5	Benomyl	0,3 kg/ha
6	Maneb + oil	2,5 kg/ha + 5,0 l/ha

fungicide. Preliminary tests have shown that the product is less effective on M. musicola in vitro than after application to the banana leaf. Presumably the reasons for this can be found in special properties of the product, which differs markedly in its mode of action from most fungicides known to date. Investigations carried out by Schlüter and Weltzien (1971) on the mode of action of various fungicides effective against powdery mildew have shown that the fungicidal action of Tridemorph is mainly through inhibition of the formation of haustoria. Most of the other products studied - irrespective of whether they act by contact or systemically - affect the germination of the spores or the formation of appressoria. The fact that tridemorph acts comparatively late against fungus already established in the host plant may give an explanation for the product's different performance in vitro and in vivo.

To what extent the findings of Schlüter and Weltzien can be applied to M. musicola has yet to be investigated.

The small scale experiments to control M. musicola included 4 applications at 14-day intervals. Figure 1 shows the effect of tridemorph and some other products on the primary infection of Sigatoka on the 3rd open banana leaf. The results indicate clearly that tridemorph, even without the addition of oil, reduces the primary infection more than Maneb + oil (2.5 kg/ha + 5 l/ha) or Benomyl (0.3 kg/ha). Infection was most effectively reduced by 0.3 l/ha tridemorph + 5.0 l/ha oil and by 0.6 l/ha neat tridemorph. Figure 1 shows that the duration of effectiveness of tridemorph is not influenced by the addition of spray oil. The fungicidal effect decreases between the 3rd and 4th evaluation (14 and 30 days after application respectively) in the neat tridemorph treatments in the same range as with the fungicide + oil combinations tested. The results are confirmed by perithecia counts and by assessment of total infection at the dates mentioned above (see figure 2).

The use of other methods of evaluation shows again the outstanding performance of tridemorph. Total infection (1st - 9th leaf) was best reduced by tridemorph. The formation of perithecia, the ascospores of which are particularly important for spreading the Sigatoka disease during the rainy season , was inhibited more by tridemorph than by the other products tested. All results indicate that the addition of oil effected very little improvement in the fungicidal effect of tridemorph. Applications of 0.6 l/ha neat were equally as effective as 0.3 l/ha + 5.0 l/ha spray oil. (Figure 3)

Figure 3
Effect of Tridemorph against Mycosphaerella musicola

	Appl. rate l/kg/ha	Infection with Sigatoka disease		
		total infection (score 1 - 9)	prim.infection of 3rd leaf (% infection)	perithecia count on 7th leaf (rel.)
Control		5.8	47	100
Tridemorph	0.3	2.9	20	41.4
Tridemorph	0.6	2.6	18	33.4
Tridemorph + oil	0.3 5.0	2.7	17	33.4
Benomyl	0.3	3.7	24	50.4
Maneb + oil + Emulsifier	2.5 5.0 0.045	3.7	33	58.5

Evaluation: 14 days after the 2nd, 3rd and 4th applications.

Encouraged by the results of the small scale experiments, testing of tridemorph was continued under plantation conditions with aerial application. The product was used with and without oil and was compared with the standard treatment of Mancozeb + oil. There were 5 applications at 3-weekly intervals. Evaluation was carried out 3 weeks after the 3rd, 4th and 5th application and, in order to measure the duration of effectiveness, 4 weeks after the 5th application. (Figure 4)

Figure 4

Effect of tridemorph against M. musicola when applied by aeroplane

Compound	l/kg/ha	Youngest leaf spotted	Area of leaf affected (%) Leaves 10 - 12
Tridemorph	0.3	5.4	1.9
Tridemorph + oil	0.3 5.0	5.8	1.9
Tridemorph	0.6	6.5	1.2
Tridemorph + oil	0.6 5.0	6.6	1.3
Mancozeb + oil	1.8 5.0	4.6	3.3

Depending on the rate of application, tridemorph protected 1 - 2 more leaves from infection than the Mancozep + oil mixture. Sigatoka infection of older leaves (Nos. 10 - 12) was also reduced better by tridemorph. Both results suggest that the fungicidal effect of tridemorph depends more on the rate of application than on the addition of spray oil.

It can be concluded from the results obtained that tridemorph controls Sigatoka disease satisfactorily without the addition of spray oil. A slight increase of fungicidal effect by addition of spray oil was found in small scale experiments, but it was barely noticeable in large scale aerial applications.

At a rate of 0.6 l/ha tridemorph proved to be a marked improvement on the fungicide + oil combinations commercially used at present. The results obtained to date are not sufficient for a full understanding of the mode of action of tridemorph against M. musicola. More work, both in the field and the laboratory, is planned to solve this problem.

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President's Closing Remarks

Ladies and Gentlemen, during the past three days you have listened to so much about pesticides of all kinds and about crop protection, that you will not wish to listen to any more from me. I need only say that, from the sessions I attended and the discussions I have had with many delegates, I am left in no doubt that the hope I expressed when opening the Conference, that it would be at least as successful as previous ones, has been fully realised. The time-keeping has been excellent, the papers well delivered and the lantern slides better prepared than ever before. Indeed, during the period I have attended these conferences, it has been a pleasure to see the steady improvement in the presentation of papers. For this, I thank the speakers, but even more the Programme Committee and the Session Organisers, whose gentle discipline has been so important in getting this improvement.

The success of our conference initiates in the immense amount of planning and work put in by the Programme Committee. I am sure you will all wish me, not only to express our great appreciation to Mr. Higgons, Chairman of the Committee, his Vice-Chairmen, Dr. Taylor and Mr. Gair, and all the members, but also to congratulate them on the quality of the programme.

This is the last occasion on which I shall have the honour to preside at one of these conferences. I have been privileged during my period of office to see the conferences increasing in importance and influence, not only because of the increased attendance, but also because of the widening range of problems discussed and of the interests of people attending the conferences. Although officially the British Crop Protection Conferences, they are truly international gatherings, and I know of no other meetings where there are representatives of so many and such diverse interests. There are, no doubt, some people who think we meet only to advocate using pesticides, but they can hold these views only by not attending the meetings or not looking at our programmes. Doing either would show them, not only that our interests extend to all methods of crop protection, but also that we are fully conscious of our social responsibilities by ensuring that pesticides are used safely.

I express my personal gratitude to all those who have contributed to the success of the conference, and to the many who have made my period of office so enjoyable and rewarding. In declaring this Conference closed, I wish the Council every success in its very important tasks.