CROP PROTECTION CONFERENCE 1970

CROP PROTECTION

IN

MALAYSIA

Infrared photograph of young oil palms

(Courtesy of Chemara Research Station)

CROP PROTECTION IN MALAYSIA

The proceedings of the Conference
held in
Kuala Lumpur
15 – 17 November 1970

Edited
by
R.L. Wastie & B.J. Wood

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The Society wishes to express its gratitude to the many persons who helped this Conference to succeed. The names of those who served on the working committees are recorded on the next page. Particular thanks are due to the Director of the Rubber Research Institute of Malaya, the Director of Agriculture, West Malaysia, the Dean of the Faculty of Agriculture, University of Malaya, the Director of the Commonwealth Institute of Biological Control, Sabah, and the Director of the PNP Marihat Research Station, Sumatra.

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EDITORIAL NOTE

The discussion which follows each paper is an edited version of that recorded at the Conference. The comments made by each speaker have been paraphrased and only the salient points of the topic under discussion have been included.

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INTRODUCTORY ADDRESS

by

G. C. McCulloch

Chairman, Incorporated Society of Planters

The Honourable the Prime Minister, the Honourable the Minister of Agriculture, Tungku Mansor (chairman of the conference committee), honoured guests and participants, on behalf of the Incorporated Society of Planters I welcome you all to the opening ceremony of the Malaysian Crop Protection Conference.

Previous conferences in the I.S.P. series have dealt with a wide range of aspects affecting tropical agriculture, and while plant protection was by no means overlooked it did become apparent that this important subject deserved a conference of its own. Hence we are gathered here today.

Without adequate crop protection the advances made from plant breeding to processing would be of much more limited value. Indeed, without adequate plant protection, agriculture as we know it would become considerably more hazardous than it is today.

Yesterday, those of you who were fortunate enough to attend, witnessed a most successful field day sponsored by I.C.I. Agriculture. Later today and during the following two days we will consider some 24 papers ranging from plant quarantine regulations to the large scale detection of diseased palms by the use of infra red aerial photography.

We will not only consider new approaches to plant protection but we will re-examine present approaches in the light of the availability of new chemicals, and I hope that there will be some discussion on the changing pattern in respect of both availability and cost of the increasing range of herbicides now being manufactured in Malaysia.

This is an I.S.P. conference only in so much that the Society has sponsored it and organised it. The conference in fact embraces all sectors of Malaysian agriculture concerned with rubber, oil palm, coconuts and cocoa. The Society through its wide membership acts as a catalyst for all such interests in both the private and public sectors.

We are again grateful to the Honourable Tun Haji Abdul Razak bin Dato' Hussein, S.M.N., F.I.S.P. for agreeing to open this conference today. Although the Society has been very well aware of his tremendous interest in everything connected with development in Malaysia we had thought it rather too much to hope that he would find time to continue to open our conferences. We are, Sir, doubly honoured to have this conference opened by a Prime Minister, and a Prime Minister who is also a Fellow of our Society.

We also take this opportunity to thank the Director of the R.R.I.M., the Director of Agriculture and the many other organisations in both the private and public sectors for the tremendous support they have given to this conference.

On behalf of the Society I will call upon the Hon'ble Prime Minister of Malaysia, Tun Haji Abdul Razak bin Dato Hussain, S.M.N., Fellow of the Incorporated Society of Planters, to open the conference.

OPENING ADDRESS

by

Yang Amat Berhormat Perdana Menteri

Tun Haji Abdul Razak bin Dato' Hussain

I am very glad to be with you this morning, being the fifth occasion on which I have been privileged to open an Incorporated Society of Planters' Conference. My pleasure at being invited to this Conference is even greater now that you have elected me a Fellow of your Society, and I have now come to look on these gatherings with a proprietary interest.

Following your kind invitation, I am told that my office has been inundated with a varied collection of beautiful multi-coloured brochures, which turned out to be preprints of the working papers prepared for the purpose of this Conference. I have only been able to look at a few of them and I must sincerely commend the prolific activities of your members whose contributions to this Conference bring together fruits of their research under Malaysian conditions, and this in turn will stimulate discussion gained by Malaysian experience as well as that of other countries. Now this Conference, therefore, will benefit not only members of your Society but Malaysian agriculture as a whole, and particularly, the smallholders' sector which forms the major part of our agricultural community.

I had occasion a few months ago to officially open a modern chemical factory in Batu Tiga and I was then informed that in ten years time Malaysia will be the foremost weedicide producer in this region. This, in itself, is a very significant progress because I can foresee, with the accelerated activities of your Society on the one hand, and the related industries on the other, the future of agriculture now in our country will be both strong and well-assured.

Now as you all are aware, we have embarked on a massive agricultural development plan fully conscious that agriculture will continue to be the backbone of our economy. On my visit to Pahang, a few days ago, I launched the first of the "integrated development" projects—the Jengka Development Corporation—which is designed to undertake the overall development of an area of approximately 165 000 acres, embracing the agriculture sector, industrialisation, as well as the planning and growth of new townships of the future. Now we can very well envisage similar projects taking place in the not-too-distant future in the vast tracts where feasibility studies are now being undertaken in the Pahang Tenggara area and in the Penggerang area in the State of Johore.

Our policy of agricultural diversification is, by all indications, a sound one, both in guaranteeing economic stability as well as opening new horizons for rapid expansion of the agricultural sector. We still maintain a lead as the biggest producers of rubber and oil palm and, as I said only recently, we are well on target to achieve the optimum production of rice for our own needs. At the same time, we are making rapid progress in the pineapple industry and recent findings indicate a very bright future for cocoa and coconut and there has been considerable interest in the growing of coffee and tea as well as patchouli.

Now your conference will essentially deal with the protection of crops from animal and insect pests, from diseases and from the incursion of undesirable weed growths. As a layman, I do not have the competence to comment on the impressive list of papers which you will be discussing throughout the next three days. We all know that the art and science of crop protection have made enormous strides in recent years. As the value per acre of our plantation crops increases with the development of higher yielding and more productive trees, so does the need for protecting these crops against weeds and pests. Thus, the use of more sophisticated, and often more expensive techniques of crop protection, becomes more and more necessary.

Today, industry is producing a new flow of chemicals which are more powerful, more effective and more selective for crop protection. New information is also being developed about biological and non-chemical means for control of diseases and pests. This new knowledge and the new materials must necessarily be adapted to our conditions here in Malaysia—to fit our soils, our climate and cropping system. We must determine the most economical and efficient materials and methods for pest control.

An important aspect of the art and science of crop protection is to know when action is needed. In many instances a too hasty or ill-considered use of chemicals may not be the best solution—in other words, the use of biological methods such as natural enemies to control insect pests, and careful cultivation practices to suppress weeds, may be the better answer. I am happy to note that we are increasingly aware of the potential damage to our environment and of the hazards to human health if agricultural chemicals are not used properly and wisely.

This preservation of an ecological balance, involving the conservation of both plant and animal life, is of vital importance in the world today, and the contributors to this Conference are to be commended for drawing our attention to it. Nevertheless, one can with advantage interfere with nature without upsetting the ecological balance; indeed, chemical intervention is frequently essential to save a valuable crop from the ravages of pests and diseases.

Over the many years during which I was the Minister responsible for rural development, it was only natural that I should become aware of the need for research, discussion and good husbandry in this country whose economy is based primarily on agriculture. It was this awareness which prompted our Government to establish the Malaysian Agricultural Research and Development Institute or MARDI.

Research on these problems falls within the responsibility of MARDI, in which we have increasing numbers of well-trained young research workers who are anxious to apply their skills to these and many other problems in agricultural development. MARDI will provide the organisational structure and support for this important work and I am watching the progress of MARDI with personal interest.

It is our intention to become more self-reliant in the future—and to depend less and less upon external sources for science and technology to guide agricultural development in the years ahead. In this respect, the Government is indeed very appreciative of the efforts undertaken by non-governmental organisations like yours which further add to our knowledge and experience.

As you all know, I am particularly concerned with agricultural progress and the well-being in particular of the smallholders' sector, and conferences of this kind have an essential part to play in achieving this objective. I congratulate the Incorporated Society of Planters on their initiative in organising such a useful series of discussions, and hope that information made available at this Conference will be of use to all planters, whatever the size of their holding or the nature of the crops they grow.

It gives me great pleasure to declare open the 1970 Crop Protection Conference and to wish you all success in your deliberations.

HERBICIDE SPRAYING TECHNIQUES

by

R. Shepherd, C.H. Teoh and K.M. Khoo

There is a growing trend to replace sodium arsenite by safer, more sophisticated herbicides to provide more lasting and economic control of competitive weed growths in plantation crops. These new herbicides differ in the range of weeds they control; accordingly, they should be selected carefully on their merit and applied intelligently to secure best results.

Herbicide spraying is now a science. Efficient weed control demands that personnel in charge of spraying programmes correctly identify the major weed species and possess a sound knowledge of the latest advances in herbicide usage.

The purpose of this paper is to assemble information on herbicides and spraying techniques suitable for use in plantation tree crops in Malaysia. Free use is made of information in various publications and weed control handbooks.

CLASSIFICATION AND MODE OF ACTION OF HERBICIDES

Application techniques and plant responses depend on the site of uptake and activity of the herbicide within plant tissues.

Herbicides may be placed in two broad groupings according to the way in which they primarily exert their effects on plants.

Contact herbicides—By and large these destroy only tissues with which they come in contact. They are most effective against young weeds and weed species with poorly developed root systems, especially under shaded situations when leaf tissues are more tender. Contact foliar sprays are mostly quick acting and their effectiveness is not greatly impaired by rain falling an hour or so after application.

Almost any chemical applied in sufficient concentration will destroy plant tissues on contact. Sodium arsenite and paraquat are examples of common, primarily contact, herbicides in use on estates.

Translocated herbicides—These are also known as systemic herbicides because after absorption they travel through the plant, affecting tissues remote from the point of initial contact. They are thus more effective than contact herbicides against weeds with well developed root systems or storage organs, but are slower acting and some time may elapse before their full effects become apparent.

Translocated herbicides may be grouped according to whether they are taken up primarily by foliage (*e.g.* 2,4-D, dalapon, MSMA) or by the plant root system (*e.g.* diuron, bromacil, TCA). The former move principally through living phloem tissues and accordingly tend to be more selective than the latter which are transported mainly in the transpiration stream through lignified xylem vessels. These root absorbed herbicides are sometimes termed residual herbicides because they are relatively persistent, their residual activity in the soil being dependent on resistance to biological breakdown and leaching which in turn are related to such factors as the amount of herbicide applied, soil type, rainfall and temperature. They may be applied directly to the soil but in the tropics are more commonly incorporated in mixed herbicide sprays to enhance their activity and prolong the duration of weed control.

Differential responses of plant species to translocated herbicides may be associated mainly with differences in their physiology, susceptibility being associated with inability to adapt biochemical processes to prevent accumulation of the active ingredient in susceptible vital organs (Rochecouste, 1967).

The diverse activities of selected contact and translocated herbicides available in this country are broadly as indicated in *Table 1*.

Table 1. Mode of uptake and action of selected contact and translocated herbicides

Chemical/ common name	*Commercial products*	*Principal uptake sites*	*Contact or translocated*	*Mode of action*
Na_3AsO_2	Sodium arsenite	Foliage	Mainly contact	Destruction of plant cells.
$NaClO_3$	Sodium chlorate	Foliage	Contact/ translocated	Converted to toxic derivatives by plant enzymes.
M.S.M.A.	Ansar 529	Foliage	Contact/ translocated	Disruption of plant enzyme systems.
2,4-D	Amine salts of 2,4-D	Foliage	Translocated	Affects respiration, cell division and exhausts food reserves.
2,2 DPA	Dalapon	Foliage/ roots	Translocated	Protein precipitation and disruption of plant enzyme systems.
T.C.A.	Lallicide	Roots	Translocated	Action similar to dalapon.
Paraquat	Gramoxone	Foliage	Mainly contact	Cell destruction and tissue dessication.
Amino-triazole	Amitrole, Weedazol	Foliage/ roots	Translocated	Inhibits chlorophyll formation and re-growth from buds.
Diuron	Karmex	Roots/ foliage	Translocated	Retards photosynthesis.
Simazine	Simazine	Roots	Translocated	Interferes with photosynthesis.

TOXICITY HAZARDS OF HERBICIDES TO USERS

Personnel handling herbicides, particularly commercial formulations, should be conscious of their potential hazards and must take precautions to ensure that they are used with the care they deserve.

The degree of hazard of a particular herbicide to operators can be estimated by reference to published toxicological information. This is normally recorded in terms of their acute oral and dermal LD_{50} values which indicate the dosage in milligrams of test substance per kilogram body weight which on administration in a single dose to a group of animals (usually albino female rats) will be lethal to 50% of the group.

LD_{50} values of herbicide chemicals most extensively used in this country have been obtained from several publications (Anon., 1958, 1964, 1967; Edson *et al.*, 1966; Thomson, 1967) and are recorded in *Table 2* which also lists commercial formulations and their concentrations. As recorded LD_{50} values very considerably between different laboratories, the most frequently reported range of LD_{50} values for a particular herbicide is recorded in the table. Such variation may be attributed to difference in experimental techniques and concentrations of formulations tested. Considered in relation to the concentration of herbicide chemical being handled, these LD_{50} values provide a most useful indication of their potential hazards to users. As a guide, toxicity hazards of chemicals to humans are indicated below.

Oral LD_{50} value	<50	50–500	500–5000	5000–15000	>15000
Toxicity rating	extreme	high	moderate	slight	very low

To express toxicity in practical terms, the acute oral LD_{50} value multiplied by 0.002 gives the approximate weight of chemical (in ounces) which will prove lethal to one out of every two 120 pound men or other warm blooded animals of similar weight.

It will be noted that dermal LD_{50} values are lower than acute oral LD_{50} values. Operators generally appreciate the risks involved when handling commercial concentrations but do not appear sufficiently aware of the fact that dermal absorption of seemingly insignificant amounts of diluted herbicide over a prolonged period can pose a very significant health hazard because some chemicals gradually accumulate to harmful amounts in body tissues.

Spray operators should therefore be taught to regard all herbicides as hazardous and take strict precautions to prevent accidental ingestion or absorption through the skin. Readers should refer to Planters' Bulletin No. 89* for particulars of precautions which should be taken when handling herbicides.

* Of the Rubber Research Institute of Malaya

Table 2. LD_{50} values of most extensively used herbicide chemicals, commercial formulations and their concentration

Chemical or technical name	LD_{50} values		Commercial formulations	
	Oral	Dermal*	Trade name	Concentration†
Ametryne	1110	1280	Gesapax	80% W.P.
Amiben	3500–5620	3136 (Rb)	Amiben	2.4 lb a.e./gal.
Amitrole	14 700–25 000		Aminotriazole	2.4 lb a.i./gal.
			Weedazol TL	3.0 lb a.i./gal.
Atrazine	2000–3080		Gesaprim	50% & 80% W.P.
Bromacil	5200		Hyvar X	80% W.P.
Dalapon	3680–9300		Basfapon,	85% Na salt
			Monopon, Gramevin	85% Na salt
Dicamba	1100	1000	Banvel D	4.8 lb a.e./gal. E.C.
Cacodylic acid	1350–3200		Phytar 560	3.0 lb a.e./gal. E.C.
			Silvisar 510	6.8 lb a.e./gal. E.C.
Diquat	400–440		Reglone	2 lb a.i./gal.
Diuron	3400		Karmex, Diran 950	80% W.P.
D.S.M.A.	1800		Ansar 184	63%
2,4-D (acid)	375–500	1500	Fernoxone	.75 lb a.e./lb.
2,4-D (ester)	375–500	1500	Weedone LV 4	4.8 lb a.e./gal.
2,4-D (amine)	375–500	1500	HC-72 Amine	7.2 lb a.e./gal.
			Weedar Amine 96	7.2 " "
			U 46-D	7.2 " "
			Amine 80	7.2 " "
M.C.P.A.	700–800	1000	Agroxone; HC–40	4 lb a.e./gal.
Monuron	3500	2500 (Rb)	Telvar	80% W.P.
M.S.M.A.	1300		Ansar 529	4.0 lb/gal.
			Ansar 529m	6.6 lb/gal.
Paraquat	112–157	236 (Rb)	Gramoxone	2 lb a.i./gal.
Picloram	8200	4000 (Rb)	Tordon	2 lb a.i./gal.
Propanil	1380		Rogue	4 lb a.i./gal.
Simazine	5000		Simazine	50% W.P.
Sodium arsenite	10–50		Sodium arsenite liquid	10 lb/gal.
Sodium chlorate	5000		Sodium chlorate	100%
2,4,5-T	300–800		Esteron, Trifen	4.8 lb a.e./gal.
T.C.A.	3200–5000		Lallicide	90% W.P.

* Assessed on rats or rabbits (Rb). † a.i. = active ingredient; a.e. = acid equivalent

STORAGE AND ISSUE OF HERBICIDES

To avoid theft and possible misuse, herbicide containers must be clearly labelled and stored in identified bays within a secure building to which only authorised personnel have access. This is particularly important in mixed plantations because certain herbicides are extremely hazardous to one or other crop and mistakes in their identity can be disastrous. It is strongly recommended that herbicides be stored in a separate building from other estate chemicals and that those involving greatest risk to economic crops are kept well apart from safer herbicides.

Issue of herbicides should be entrusted to a senior staff member who must dispense estimated daily requirements in clearly identified containers and ensure that all containers and apparatus used in spraying are returned to the store when the day's work has been completed. Under no circumstances should spray operators be given overnight custody of herbicide concentrate containers.

Whenever possible, herbicides should be issued in their original containers. If these are too large to be taken to the field, they may be measured into clean polythene containers on which the herbicide identity and recommended dilution rate are clearly and permanently marked. *Herbicides must never be issued in domestic containers.* Containers no longer required should be completely emptied, rendered useless for domestic or other purposes and buried at depth, remote from water catchments, or destroyed by burning.

CHOICE AND CONCENTRATION OF HERBICIDE

Herbicides are expensive chemicals and the economics of weed control depend largely on the choice of herbicide and efficient application at the right concentration. It is thus essential that, in addition to being thoroughly familiar with spraying techniques, personnel in charge of herbicide work on estates should be aware of factors which influence the choice of herbicide and the concentration at which it should be applied.

Weed species—No single herbicide applied at economic rates will kill all weed species. In recent years a wide variety of herbicides has been screened against weeds in plantation crops in this country and some highly efficient herbicides are now available.

Many of these new herbicides are derived by mixing compatible chemicals of complementary action to improve herbicidal activity and increase the range of weeds controlled by a single spray application. It must be stressed that development of herbicide mixtures is a highly technical operation which should be left to suitably qualified personnel possessing the necessary understanding of the mode of action of individual herbicide chemicals and their physical and chemical compatibilities. This note of caution is sounded because indiscriminate mixing of herbicides may lead to interactions between constituents which reduce their herbicidal activity. As recommended herbicides differ in their effectiveness against different weed species, it is important that dominant weeds are correctly identified (it is not good enough to group grasses of similar appearance as bamboo grasses!) and herbicides are selected which are known to provide economic control of the dominant competitive growths. It is outside the scope of this paper to discuss the choice of herbicide for specific weed situations, nevertheless, for convenient reference, the comparative efficacies of the more popular herbicides in current use against major weeds in this country are indicated in *Table 3*.

Main crop—The selected herbicide should preferably be non-toxic to the main crop; however, weed situations sometimes require that herbicides involving some risk to the main crop be used. Such risks must be minimised by spraying at the correct concentration using the correct technique.

By virtue of the fact that they may be transferred in the plants' conductive systems to sensitive tissues remote from the point of spray contact, translocated herbicides are potentially more dangerous than contact herbicides. The risk of damage is greatest in young plantings, especially of palms which have a single growing point and are extremely susceptible to hormone sprays. Unless spray operators are completely trustworthy and aware of risks, potentially dangerous chemicals should not be used in susceptible plantings. Alternative safe herbicides may be more costly and provide less effective weed control, but careless spraying with dangerous chemicals can have very serious consequences.

The susceptibility of selected plantation tree crops to damage by the more commonly used herbicides applied at normal concentrations is recorded in *Table 4*.

Environmental factors—The choice and concentration of herbicide spray solution can be influenced by the environmental factors, in particular:

Light intensity. In open situations weeds tend to grow more vigorously and have tougher foliage than in shaded situations. As the light intensity also affects herbicidal activity, it is usually necessary to increase the concentration and/or alter herbicide ingredients to effect comparable control in light and shaded situations. For instance, the activity of paraquat is greatest when weed photosynthetic rate is reduced, as in shaded situations. However, in open situations the degree of control of certain weeds (especially *Paspalum conjugatum*) with paraquat is poor unless photosynthetic inhibitors such as substituted ureas (*e.g.* diuron) are added at low rates to the herbicide solution (Wessels *et al.*, 1956).

Temperature. The rapidity and duration of herbicide activity may be affected by temperature. Hormone-type chemicals tend to be most active when temperatures fall within the range 70–90°F. At lower temperatures their action is retarded while at temperatures above 90°F the effectiveness of these chemicals tends to be reduced (Helgeson, 1957).

Table 3. *Susceptibility of major weed species to herbicide sprays*

	Herbicide sprays	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*Notes*
Grasses	*Axonopus compressus*	***	**	***	**	****	****	***	****	***		Wet foliage thoroughly
	Brachiaria mutica	*	*	*	*	**	***	**	**	*		
	Centotheca lappacea	**	*	**	***	***	***	***	****	***		
	Cynodon dactylon	*	*	*	*	*	***	*	**	**	**	
	Digitaria adscescens	**	***		**	***	***	***	****	***	*	
	Digitaria longiflora	**	*	*	*	**	***	***	****	**	*	
	Echinochloa colona	*	**	**	**	***	***	***			***	
	Eleusine indica	*	*	*	**	*	***	***	****	*	*	
	Eragrostis spp.	*	*	*	**	**	***	***	***	*		
	Imperata cylindrica	**	*	*	*	*	**	*	*	**		
	Ischaemum aristatum	*	*		*	***	***	***	****	**		Several rounds required
	„ muticum	**	***	***	***	****	***	***	****	**		
	„ timorense	**	***	***	***	****	***	***	****	**		
	Leersia hexandra	*	*	**	**	**	***	***	****			
	Ottochloa nodosa	**	**	***	***	***	****	***	****	***	**	
	Panicum pilipes	***	**	**	***	***	***	***	****	***		
	„ repens	*	*	*	*	*	***	*	***	*		
	„ trigonum	***	***	***	****	****	***	****	****	***		
	„ sarmentosum	*	*	*	***	***	***	***	***		***	
	Paspalum conjugatum	***	***	****	***	****	****	****	****	*	***	
	„ commersonii	*	*	*	***	***	***	***	***	*	**	
	„ „ var. longifolium			**		***	***					
	Tricholaena rosea	**	*	**	***	***	***	***	****			
	Sprobolus indicus	*	*	*	*	*	***	***	***	*		
Sedges	*Cyperus rotundus*	*	**	***	**	**		**	***	*	**	
	Fimbristylis spp.	*	**	**	**	***	***	***	***	***	**	
	Scleria spp.	*	**	**	**	***	***	***	****	***	**	
Ferns	*Cyclosorus* spp.	*	**	**	***	***	***	***	***			Very susceptible in shade
	Gleichenia linearis	****	**	*	***	***	***	***	***			Add more wetting agent
	Lygodium spp.	*	*	**	***	***	***	***	***			
	Nephrolepis bisserata	**	*	**	***	****	****	***	****			
	Pityrogramma sp.	*	*	***	***	****	***	****	****	***	***	
	Stenochlaena palustris	*	*	**	**	***	***	***	****			
Dicotyledons	*Ageratum conyzoides*	**	**	***	****	****	***	***	****	**		3 pint/ac 2,4-D amine most effective
	Borreria latifolia	*	*	**	**	***	**	**	***			
	Erechthites sp.	***		***	***	***	**		****	***		
	Eupatorium odoratum	**	*	**	****	***	**	***	***	***	***	Young plants only
	Melastoma malabathricum	**	*	**	****	**	**	**	**			Young plants only
	Mikania cordata	*	**	***	****	***	**	***	***	***	**	1 pint/ac 2,4-D amine also effective
	Scorparia dulcis	*	*	**	**	***	**	***	***			
Others	*Commelina nudiflora*	*	*	**	**	**	**	**	**			
	Aroids			*	**	*	*	*	**			

KEY

* = Resistant to herbicide
** = Moderately resistant to herbicide
*** = Susceptible to herbicide
**** = Highly susceptible to herbicide

Table 3 (contd.) Ingredients of herbicide sprays

Code	Commercial formulation*	Amount formulation per sprayed acre/hectare (a) Shaded situation /ac	(a) Shaded situation /ha	(b) Open situation /ac	(b) Open situation /ha
A	Sodium arsenite liquid	12 pints	16.8 litres	20 pints	28.0 litres
B	MSMA (4 lb a.i./gal)	3½ "	4.9 "	5 "	7.0 "
	repeated 3 w later at	3 "	4.2 "	4 "	5.6 "
C	MSMA (4 lb a.i./gal)	3½ "	4.9 "	5 "	7.0 "
	+ 2,4-D amine (7.2 lb a.e./gal)	1 "	1.4 "	1 "	1.4 "
D	2,4-D amine (7.2 lb a.e./gal)	1 "	1.4 "	1 "	1.4 "
	+ Sodium chlorate	15 pounds	16.8 kg	25 pounds	28.0 kg
E	MSMA (4 lb a.i./gal)	3½ pints	4.9 litres	4 pints	5.6 litres
	+ 2,4-D amine (7.2 lb a.e./gal)	1 "	1.4 "	1 "	1.4 "
	+ Sodium chlorate	5 pounds	5.6 kg	8 pounds	9.0 kg
F	MSMA (4 lb a.i./gal)	3½ pints	4.9 litres	4 pints	5.6 litres
	+ 2,4-D amine (7.2 lb a.e./gal)	1 "	1.4 "	1 "	1.4 "
	+ Dalapon	2 pounds	2.2 kg	3–4 pounds	3.4–4.5 kg
G	MSMA (4 lb a.i./gal)	3½ pints	4.9 litres	?	
	+ Diuron (80% W.P.)	5 ounces	0.35 kg	?	
	+ Paraquat 2 lb a.i./gal)	1 pint	1.4 litres	?	
H	Sordox L 33	3 pints	4.2 "	4 pints	5.6 litres
	2,4-D amine	½ "	0.7 "	1 "	1.4 "
	Sodium chlorate	5 pounds	5.6 kg	5 pounds	5.6 kg
I	Paraquat (2 lb a.i./gal)	2 pints	2.8 litres	3 pints	4.2 "
J	Aminotriazole (3 lb a.i./gal)	1 pint	1.4 "	1 pint	1.4 "
	followed 2 w later with				
	Sodium chlorate	5 pounds	5.6 kg	10 pounds	11.2 kg

* a.e. = acid equivalent; a.i. = active ingredient

Table 4. Susceptibility of plantation crops to herbicides

Herbicide	*Rate per sprayed acre**	*Crop*	*Spraying precautions*
Sodium arsenite	10–15 lb	Rubber and cocoa	Avoid contact with foliage and bark. Green bark particularly susceptible.
Sodium chlorate	5–15 lb	Oil palms and coconuts	Avoid contact with fronds and growing point.
Paraquat	4–8 oz a.i.	Rubber and cocoa	Avoid contact with foliage and green bark. Safe in mature plantings.
MSMA	1½–3 lb a.e.	Oil palms and coconuts	Avoid contact with fronds. Relatively safe at all stages of development.
Diuron Amitrol	4 oz–16 oz a.i. 6–12 oz a.i.	Rubber and cocoa	Relatively safe unless foliage thoroughly wetted.
Dalapon	2–15 lb a.i.	Oil palms and coconuts	Relatively safe, but less tolerant than rubber or cocoa.
Amine salt of 2,4-D	8–16 oz a.e.	Rubber and cocoa	Avoid contact with foliage and green bark. Safe in mature plantings.
		Oil palms and coconuts	Lethal to very young seedlings. Diminishing susceptibility with age. Safe in mature palms.
2,4-D Esters 2,4,5-T		All crops	Highly volatile and potentially very damaging. Amine salt of 2,4-D should be used instead.

* a.e. = acid equivalent; a.i. = active ingredient

Temperature also influences the persistence of residual translocated herbicides such as the triazines (*e.g.* simazine) which provide lasting pre-emergence weed control in temperate climates but have been relatively ineffective as pre-emergence herbicides in this country.

Rainfall. In high rainfall areas or rainy weather, greater emphasis ought to be placed on rapid acting contact herbicides (*e.g.* paraquat) as there is a risk of only partial success with predominantly foliage translocated herbicides if heavy rain falls within four hours of application. In dry weather, the emphasis should be switched to use of more effective translocated herbicides.

Relative humidity. The relative humidity also affects herbicidal sprays as it increases or decreases evaporation of the liquid from leaf surfaces. High relative humidity also improves penetration of herbicides into foliage.

Soil. The effectiveness of contact and foliage translocated herbicides is independent of soil type. In contrast, the effectiveness and persistence of root translocated herbicides depends largely on the physical characteristics of the soil and its microflora. When soils have a high organic status or heavy texture, higher rates of root translocated herbicides must be applied because much of the chemical is absorbed by organic and clay colloids and eventually decomposed by soil micro-organisms.

Duration of weed control required. With strip or circle spraying, the duration of weed control is determined to a large extent by the degree of control of vegetation within the sprayed area and rate of encroachment of weed growths from the surrounding area. These depend on the weed species present, herbicides used and environmental factors. In relatively open conditions where weed growth is most vigorous it is unlikely that acceptable weed control from a single application of herbicide at economic rates will be obtained over periods in excess of 3–4 months. To achieve more lasting weed control in these circumstances the herbicide would have to be put down at very high uneconomic concentration which could conceivably affect the main crop and soil microflora.

Cost effectiveness of available herbicides. As costs of herbicides differ considerably, it is obvious that, all other things being equal, the cheapest treatment should be selected.

TIMING OF SPRAY APPLICATIONS

Spraying rounds should be regulated according to the economics and need for weed suppression or eradication rather than to a fixed time scale. This aspect of herbicide usage is inadequately appreciated on estates and can profoundly affect results.

The following points should be considered when determining when herbicides should be applied:

Weather. Spraying should preferably not be undertaken in notoriously wet seasons when there is a real risk of herbicides being leached before they have penetrated weed tissues in sufficient quantities to provide the desired level of control. Immediate retreatment is probably necessary in the event of severe rain interference in normal spraying periods.

Stage of weed growth. Spray applications can be made more effective if they are timed to coincide with the stage of growth when dominant weeds are most vulnerable to herbicide activity. Unfortunately weeds differ in their tolerance to herbicide activity at different stages of growth and such information is available for only a limited number of weed species. Generally weeds are most susceptible either when they are very young or when they are approaching maturity but before appreciable reserves are accumulated in storage organs. In the case of highly competitive weeds, spraying should therefore be undertaken when they are young; on the other hand, spraying of less competitive weeds may be delayed until they approach maturity.

Follow-up treatments are usually necessary for complete eradication of tenacious weeds. If the initial treatment severely damages foliage, the follow-up spray application ought to be delayed until sufficient green leaf is available to absorb enough herbicides to be lethal to the entire plant.

Nature of herbicide treatment. Sequential herbicide treatments requiring two spray applications in rapid sequence are still popular on some estates. The time interval between initial application of a sub-lethal amount of translocated herbicide and the second application of contact herbicide varies between two and four weeks and requires a high level of supervision to ensure that full advantage is taken of the activity of the translocated herbicide and that weeds show no signs of recovery before the second application.

Fertiliser applications. To minimise losses through poaching, competitive weed growths should be sprayed out from land surface to which fertilisers will be applied. In mature rubber plantings, one of the annual spraying rounds should therefore be timed to coincide with the onset of defoliation so that trees gain maximum benefit from the annual application of fertilisers, normally made when defoliation is well advanced, and the heavy shade after refoliation discourages regeneration.

VOLUME OF SPRAY APPLICATION

The effectiveness of contact and foliage translocated herbicide sprays depends primarily on the uniformity of coverage and amount of chemical retained by the plant. It is clearly of economic importance to determine the minimum volume of spray solution required for maximum response to a given amount of herbicide. This differs according to the characteristics of the herbicide used and the identity and vigour of weeds in the field under consideration.

Three volume rates may be distinguished:

High volume	60–100	gallons	per	sprayed	acre	(650–1100	litres/ha)
Medium volume	20– 60	,,	,,	,,	,,	(200– 650	,,)
Low volume	5– 20	,,	,,	,,	,,	(50– 200	,,)

High volume spraying has been essential in the past when using herbicides of relatively low solubility. However, with improved formulations and spraying equipment, most herbicides in current use can be applied at medium volume rates, with considerable saving in labour costs. As a general rule, high volume spraying is now recommended only when primarily contact or root translocated herbicides are to be applied to a mat of vegetation which is so dense that the effectiveness of the spray is liable to be impaired if less than 60 gallons are applied. When high volume rates must be applied, it should be borne in mind that to spray beyond run-off point is wasteful because less herbicide remains on the foliage than if spraying is stopped just before that point is reached (Amsden, *c.* 1960).

Low volume spraying necessitates increasing the concentration of herbicide ingredients and reducing droplet size to achieve reasonable weed coverage. The extent to which the volume of spray may be lowered depends on several factors:

(a) Fine nozzles required for low volume spraying can readily be clogged when wettable powders and dirty water are used.

(b) Reduction in droplet size increases the risk of crop damage by spray drift. This is a real danger with hormone-type herbicides which can be very effective at low volume rates.

(c) Penetration of dense vegetation by fine sprays is unsatisfactory.

(d) The effectiveness of certain translocated herbicides (*e.g.* dalapon) may be reduced because they act as contact herbicides at high concentrations, destroying tissues before appreciable translocation can occur.

(e) Accurate application becomes more difficult at very low volumes and small errors in spraying become magnified.

In choosing volume rate for a particular herbicide and weed situation one should take these points into consideration and be guided by experience.

PREPARATION OF FIELD STRENGTH SPRAY SOLUTION

Mixing precautions. Having determined the optimum quantity of herbicide concentrate and volume rate of application for a specific weed situation, care should be taken to ensure that field-strength spray solutions are correctly prepared.

It is obviously important not to contaminate water supplies. Preparation of spray solutions should therefore be done some distance from streams and other source of water.

The water used should be as clean as possible because dirt particles will abrade pumps and cause erosion and blockage of nozzles. Clean water is especially important when paraquat is used, as this herbicide may be partially inactivated by soil particles held in suspension, especially if the solution is allowed to stand for some time (Anon., undated).

If herbicides are not liable to settle out after a time and individual operators cannot be relied upon to dispense herbicide concentrates accurately into knapsack tanks, bulk preparation of field-strength solutions is preferred.

Table 5. Formulae for calculation of commercial herbicide dilution rates

PART 1. *To determine the amount of commercial herbicide required for preparation of a given volume of field strength solution.*

A. *Recommendation based on application of commercial herbicide per acre (or hectare)*

$$\text{Herbicide reqd. (fl oz)} = \frac{20 \times \text{S (gal)} \times \text{H (pint)}}{\text{V (gal)}}$$

$$\text{Herbicide reqd. (oz)} = \frac{16 \times \text{S (gal)} \times \text{H (lb)}}{\text{V (gal)}}$$

$$\text{Herbicide reqd. (grams)} = \frac{1000 \times \text{S (lit. or gal)} \times \text{H (kg)}}{\text{V (lit. or gal)}}$$

$$\text{Herbicide reqd. (cc)} = \frac{1000 \times \text{S (lit. or gal)} \times \text{H (lit.)}}{\text{V (lit. or gal)}}$$

B. *Recommendation based on application rate of active ingredient (a.i.) per acre (or hectare)*

$$\text{Herbicide reqd. (fl oz or oz)} = \frac{1600 \times \text{S (gal)} \times \text{lb a.i. per ac (or ha)}}{\text{V (gal)} \times \text{\% a.i. in herbicide}}$$

C. *Recommendation based on % active ingredient (a.i.) in spray solution.*

$$\text{Herbicide reqd. (fl oz)} = \frac{160 \times \text{S (gal)} \times \text{reqd. \% a.i.}}{\text{\% a.i. in herbicide}}$$

$$\text{Herbicide reqd. (grams or ccs)} = \frac{1000 \times \text{S (lit.)} \times \text{reqd. \% a.i.}}{\text{\% a.i. in herbicide}}$$

PART 2. *To determine the percentage active ingredient (a.i.) in a spray solution.*

$$\text{\% a.i.} = \frac{\text{herbicide used (lb)} \times \text{\% a.i. in herbicide}}{\text{S (gal)} \times 10}$$

$$\textit{or } \text{\% a.i.} = \frac{\text{herbicide (fl oz or oz)} \times \text{\% a.i. in herbicide}}{\text{S (gal)} \times 160}$$

$$\textit{or } \text{\% a.i.} = \frac{\text{herbicide used (c.c. or g)} \times \text{\% a.i. in herbicide}}{\text{S (lit.)} \times 1000}$$

Notes: S = Volume of spray solution being prepared.
V = Volume of spray solution to be applied per acre or hectare.
H = Amount of herbicide concentrate to be applied per acre or hectare.

Before herbicide concentrates are measured out, instructions and container *labels should be read carefully and completely.* Useful formulae for calculation of dilution rates according to whether recommendations are based on the quantity of active ingredient or concentrate per acre or on the percentage active ingredient in the field-strength solution are presented in *Table 5*. In instances where the recommendation is based on the rate of application of commercial concentrate per acre, dilution rates per gallon for varying volume rates of spray application per acre can be determined more readily by reference to *Table 6*.

Personnel responsible for diluting herbicides to field strength should be thoroughly familiar with weights and measurements. As recommendations may be quoted in imperial or metric units, useful conversion factors are listed in the appendix.

Vessels for dispensing herbicide concentrates should be accurately graduated, or hold only as much herbicide as is required for mixing in the fixed volume of water held in bulk containers or sprayer tank. Accurate dispensing is particularly critical when small volumes of expensive herbicides have to be measured because seemingly small errors will adversely affect the cost effectiveness of the spray and may place the main crop in jeopardy. More precise volumetric measurement can be made if dispensing vessels are tall and narrow instead of short and broad.

The special precautions necessary when preparing field strength solutions comprising mixtures of herbicides should be strictly followed, otherwise the action of one or all constituents is likely to be impaired. As a general rule, herbicide concentrates should never be mixed, and each constituent should be completely dissolved or dispersed by vigorous stirring in the final volume of water before the next is added. This is particularly important when 2,4-D amine is one of the components of the spray mixture (Anon., 1967).

Wettable powders (*e.g.* diuron) should be added to the knapsack tank just before spraying and the solution continuously agitated to maintain uniform dispersion.

Choice and rate of incorporation of wetting agents/stickers.

The adjuvants popularly known as wetting agents are more correctly termed surfactants (surface active agents) because their action involves more than reducing the surface tension to increase the area of contact between spray droplets and the leaf surface.

Other properties of surfactants may include:—

(i) Increased water solubility of herbicides.

(ii) Modification of herbicidal properties *e.g.* diuron is normally root translocated but if adequate surfactant is added to the spray solution, this herbicide becomes translocated into the leaf and retards photosynthesis (Rochecouste, 1967).

Table 6. Herbicide dilution rates per gallon

Commercial formulation application rates/acre	Approximate quantity of herbicide per gallon field strength solution when the volume rate of spray application per acre is:															
	10 gal		20 gal		30 gal		40 gal		50 gal		60 gal		70 gal		80 gal	
	oz	gm	oz	gm	oz	gm	oz	gm	oz	gm	oz	gm	oz	gm	oz	gm
1 pound	1.6	45	0.8	23	0.5	15	0.4	11	0.3	9	0.3	8	0.2	6	0.2	6
2 pounds	3.2	91	1.6	45	1.1	30	0.8	23	0.6	18	0.5	15	0.5	13	0.4	11
3 "	4.8	136	2.4	68	1.6	45	1.2	34	1.0	27	0.8	21	0.7	19	0.6	17
4 "	6.4	181	3.2	91	2.1	60	1.6	45	1.3	36	1.0	30	0.9	26	0.8	23
5 "	8.0	227	4.0	113	2.7	76	2.0	57	1.6	45	1.3	38	1.1	32	1.0	28
6 "	9.6	272	4.8	136	3.2	91	2.4	68	1.9	54	1.6	45	1.4	39	1.2	34
7 "	11.2	317	5.6	159	3.7	106	2.8	79	2.2	64	1.8	52	1.6	45	1.4	39
8 "	12.8	362	6.4	181	4.3	121	3.2	91	2.6	75	2.0	60	1.8	52	1.6	45
9 "	14.4	408	7.2	204	4.8	136	3.6	102	2.9	82	2.3	68	2.1	58	1.8	51
10 "	16.0	454	8.0	227	5.3	151	4.0	113	3.2	91	2.5	76	2.3	65	2.0	57
	fl. oz	cc	fl. oz	cc	fl. oz	cc	fl. oz	cc	fl. oz	cc	fl. oz	cc	fl. oz	cc	fl. oz	cc
1 pint	2.0	57	1.0	28	0.7	19	0.5	14	0.4	11	0.3	9	0.3	8	0.3	7
2 pints	4.0	114	2.0	57	1.3	38	1.0	28	0.8	23	0.7	19	0.6	16	0.5	14
3 "	6.0	170	3.0	85	2.0	57	1.5	43	1.2	34	1.0	28	0.9	24	0.8	21
4 "	8.0	227	4.0	114	2.7	76	2.0	57	1.6	45	1.3	38	1.1	32	1.0	28
5 "	10.0	284	5.0	142	3.3	95	2.5	71	2.0	57	1.7	47	1.4	41	1.3	36
6 "	12.0	341	6.0	170	4.0	114	3.0	85	2.4	68	2.0	57	1.7	49	1.5	43
7 "	14.0	398	7.0	199	4.7	133	3.5	99	2.8	80	2.3	66	2.0	57	1.8	50
8 "	16.0	455	8.0	227	5.3	152	4.0	114	3.2	91	2.7	76	2.3	65	2.0	57
9 "	18.0	511	9.0	256	6.0	170	4.5	128	3.6	102	3.0	85	2.6	73	2.3	64
10 "	20.0	568	10.0	284	6.7	189	5.0	142	4.0	114	3.3	95	2.9	81	2.5	71

(iii) Solubilisation of cuticle.

(iv) Better penetration of herbicides into foliage.

(v) Enhanced herbicidal action.

Herbicides and surfactants may be non-ionic, anionic or cationic in nature. Whereas non-ionic surfactants can be incorporated safely in any herbicide solution, anionic surfactants are incompatible when mixed with cationic herbicides and cationic surfactants are incompatible with anionic herbicides. Fortunately, much of the guess-work of selecting the correct surfactant is removed by some manufacturers who incorporate compatible surfactants in their herbicide formulations. Most herbicides used in this country have either non-ionic or anionic charges and are accordingly compatible with both non-ionic (*e.g.* Lissapol N, Citowett) and anionic (*e.g.* Teepol, Megapol) surfactants. Cationic paraquat is a notable exception and its herbicidal activity can be reduced if anionic surfactants are included in the spray solution.

Rates of incorporation of surfactants depend upon their concentration, nature of herbicide, volume rate of spray application and characteristics of the vegetation to be sprayed. The optimum amount of surfactant to be added to the spray solution is therefore difficult to define, particularly as some herbicide formulations contain sufficient surfactant for spraying at normal concentrations. For general purpose medium volume spraying, the field solution should contain approximately 0.1% surfactant, unless the surfactant is particularly concentrated (*e.g.* Citowett—0.025% v/v). The concentration of surfactant in low volume sprays should be approximately 0.15%. At these rates, uniform wetting of leaf surfaces will be obtained in most situations. Benefit may be derived from increasing the surfactant concentration further under the following circumstances: —

(i) When spraying very dense, resistant grasses.

(ii) When spraying weeds such as aroids which have very waxy cuticles and are difficult to wet uniformly.

(iii) When spraying diuron and dalapon.

Where it is found necessary to incorporate relatively high concentrations of surfactant, it should be added to the knapsack tank, not earlier, as excessive foaming can be troublesome when decanting from one container to another.

Sticking agents are less important than surfactants in herbicide sprays. It is generally unnecessary to add stickers to sprays in which the active ingredient is highly soluble and acts largely as a contact herbicide. Addition of 0.03% sticker may however have some value if incorporated in less soluble translocated herbicide sprays, especially when the weeds concerned have erect or waxy foliage.

CHOICE OF SPRAYING EQUIPMENT

Sprayers. Knapsack sprayers are very suitable for strip, circle and spot spraying of weeds in plantation crops. Because of simplicity of operation, continuous pumping type sprayers are most popular on estates. These sprayers have tanks of 3–4 gallon capacity and spray output is determined by the length and frequency of pumping strokes.

As there are several brands of knapsack sprayers, the following points should be considered when selecting sprayers.

(i) *Simplicity of design.* The fewer parts the better. Tanks should be easily filled and cleaned.

(ii) *Fabrication.* Sprayers may be constructed from stainless steel, mild steel, brass or plastics. Brass sprayers are very popular and reasonably priced. Stainless steel sprayers are costly and difficult to repair. Mild steel sprayers are less satisfactory as they tend to corrode rapidly, especially when used for spraying herbicides such as dalapon, paraquat and TCA. Plastic sprayers are light but are liable to crack after a limited period of use.

(iii) *Pump.* Piston pumps are more dependable than diaphragm pumps. If machines are likely to be roughly treated, the pump and fittings should preferably be located within the sprayer body.

(iv) *Reliability and robustness.* Locally constructed knapsack sprayers of reputable make have proved very reliable and robust. In selecting a sprayer, particular attention should be paid to components which are most liable to give trouble.

(v) *Availability of spare parts.* Spares should be readily available. Parts most frequently requiring repair and replacement are the trigger assembly, washers, air cylinder and piston components.

(vi) *Comfort and ease of operation.* This is an import aspect as operator discomfort and fatigue can markedly influence spraying results. The sprayer must not be too heavy and must fit comfortably on the operator's back. It should preferably be equipped with a drip guard which prevents spray solution from dripping down the tank sides. The pumping lever must be conveniently sited and the spray lance well balanced. An agitator should be fitted on sprayers to maintain suspension of sprays of poor dispersibility. Fittings should be leak-proof and the tap or trigger control of good quality and easily operated.

(vii) *Costs.* The sprayer should be reasonably priced. Cheap sprayers made of thin gauge metal which is liable to corrode are a poor investment.

Nozzles. Nozzles are very important as, together with pump pressure, they determine the pump output and quality of spray.

The characteristics of basic types of nozzles and their uses are indicated in *Table 7*.

Table 7. Spray-cone characteristics

Type	*Spray characteristics*	*General use*
Hollow cone	Cone-shaped with little deposit in the centre.	Blanket spraying, mounted on booms.
Solid cone	Cone-shaped with greatest deposit in the centre.	Blanket spraying, mounted on booms. Spot spraying.
Flat fan	V-shaped at fixed angle (65–95°); spray distribution elliptical. Droplet size varies with jet orifice and pump pressure.	Blanket spraying, mounted on booms.
Flat-even fan	V-shaped spray at fixed angle (65–95°); spray distribution uniform across swathe. Droplet size varies with jet orifice and pump pressure.	Narrow band and spot spraying.
Flood jet	V-shaped spray. Angle varies from 125–155° with jet orifice and pump pressure. Rather coarse droplets.	Wide band spraying.

Nozzles may be made from brass, stainless steel, aluminium, ceramics or plastics and are available complete with screw thread or as cheaper interchangeable tips. Brass and plastic nozzles are reasonably priced and reputable brands give good service if not abused.

Although cone nozzles are widely used on estates for application of herbicides, they are more suitable for applying fungicides and insecticides.

Flat-even fan and flood jets are better suited for precision spraying of circles and tree rows, the choice depending on the volume of spray to be applied, density of vegetation and desired swathe width. Flat-even fan jets are particularly well suited for spraying swathes of less than 4 ft width and, delivering a more forceful spray, are more suitable than flood jets for spraying dense vegetation. Although flood jets are especially sensitive to variation in pump pressure, they are very useful for spraying wide (4–6 ft) swathes.

As flat-even and flood jets are not designed for blanket spraying from booms, only one nozzle should be fitted to the knapsack lance.

When ordering nozzles it is important to specify the brand and full particulars of the types of nozzles required. The specifications of some jets can be determined by reference to numbers marked on the nozzle tip. For instance, on fan jets the first two numbers refer to the spray angle at 40 psi and subsequent numbers to the output in US gallons per 10 minutes at 40 psi, the letter E printed after the last figure indicates that the nozzle produces a flat-even spray. Thus 8 002 E on a fan nozzle indicates that it produces a flat-even spray of 80° angle and 2 US gallons per 10 minutes at 40 psi. Specifications markings on flood jets are less consistent, numbers may relate to output in US gallons per minute at 10 psi or 40 psi pressure; catalogues should therefore be consulted before initial orders are made.

Useful accessories

(i) *Strainers.* Virtually all knapsack sprayers are equipped with strainers at their inlets. These are generally not sufficiently fine to remove particles capable of blocking jets of less than 0.072″ (1.8 mm) diameter. To obviate nozzle blockage, 50-mesh stainless steel screen strainers should be fitted at a convenient point on the lance, preferably immediately to the tank side of the trigger control mechanism or pressure regulator.

(ii) *Pressure gauges.* For calibrating sprayers and accurate maintenance of spray pressure, pressure gauges should be fitted to the lance in full view of the operator. Reliable gauges should be purchased because cheap ones are notoriously untrustworthy. Even the better makes of gauges suffer distortion after some time, so personnel responsible for servicing sprayers should be equipped with means to check the accuracy of gauges.

(iii) *Pressure regulator valves.* As pressure gauges tend to be delicate and the operator has to watch both placement of spray and dial reading when a pressure gauge is used, they may be dispensed with if a pressure regulator valve is fitted to the lance.

Regulator valves are spring loaded, pressure being regulated by choice of spring or adjustment of spring tension. Ideally the pressure regulator valve should maintain spray within specified narrow limits. In practice, regulators available in this country maintain a constant maximum pressure and, with experience, operators can maintain the required pressure.

(iv) *Elbow joints.* These are fitted to the end of the lance to give the desired angle of forward projection of spray.

(v) *Spray guards.* Special guards which match the spray pattern should be fitted whenever hazardous sprays have to be applied in close proximity to the main crop. Guards which intercept spray and create large droplets must not be used as they are wasteful.

MAINTENANCE OF SPRAYING EQUIPMENT

Efficient spraying is possible only if equipment is maintained in good working condition by giving close attention to the following points: —

(i) Equipment must not be abused by operators who should be made responsible for care and routine maintenance of their sprayers. Operators must therefore be trained how to handle sprayers and have at least a rudimentary knowledge of the working parts.

(ii) Immediately after the day's spraying has been completed, sprayers should be washed out with clean water. This is necessary to prevent corrosion or blockage of vulnerable parts by herbicide residues. Sprayers should be left overnight filled with water.

(iii) Sprayers should be checked daily for leakages.

(iv) The condition of strainers and nozzles should be checked. Operators should be trained to clear blockages using a nylon toothbrush. Harder materials must never be used as they are liable to affect efficiency.

(v) All moving parts must be lubricated weekly and the condition of washers checked.

(vi) Major overhauls should be undertaken by experienced mechanics.

CALIBRATION AND OPERATION OF SPRAYERS

To ensure economical and effective use of expensive herbicides, the output of individual sprayers must be checked at regular intervals. Attention should be paid to these four variables which determine the volume of spray applied to a given area:

Swathe width
Walking speed of operator
Spray pressure
Nozzle jet orifice

These will be dealt with in turn.

Swathe width—Normally herbicide spraying necessitates uniform spray application to a 4–6 ft wide strip of weeds in a single pass. The width of strip actually treated depends on the angle of spray discharge from the nozzle, the angle of forward projection of spray to the ground and the height at which the nozzle is held.

Nozzles with discharge angles exceeding 80° at 40 psi should be selected for spraying wide swathes. The angle of spray discharge decreases with operating pressure (*Table 8*), so the actual angle of spray output at 15–20 psi pressure will be less than the 40 psi rated value which is normally recorded in fan jet nozzle specifications.

Table 8. Effect of pump pressure on angle of spray discharge from fan jet nozzles

Orifice diameter (inches)		Spray angle at 40 psi: 80°		95°		110°	
		Spray angle at pressure (degrees)					
		20 psi	80 psi	20 psi	80 psi	20 psi	80 psi
1/32	.031	68	89	82	105	97	121
	.036	69	88	82	105	98	120
	.043	70	87	83	104	99	120
	.052	71	86	84	103	100	119
1/16	.062	72	85	86	101	101	117
	.072	72	84	87	100	102	117
5/64	.078	73	84	89	100		
3/32	.094	74	83	90	100		

Forward projection of the spray at 45° to the ground is recommended to increase the swathe width and minimise 'spray shadow' which arises from obstructions such as tree trunks (Anon., 1966). This can be achieved by fitting an elbow joint to the lance.

For a particular combination of nozzle, spray pressure and angle of forward projection of spray, the width of sprayed strip can be adjusted as required by varying the height at which the nozzle is held.

Walking speed of operator—This will vary according to the nature of terrain, density of vegetation, volume rate required in relation to pump output—these should be matched be judicious choice of nozzle, and individual endeavour.

Operators can maintain 2 mph (3.2 kph) walking speed in most estate situations. A rough check on the walking speed of an operator can be obtained by measuring the distance sprayed in 10 seconds and relating it to the following conversions:

Distance in 10 seconds	*Av. speed*	*Distance in 10 seconds*	*Av. speed*
15 feet	1 mph	5½ metres	2 kph
22 ,,	1½ ,,	8 ,,	3 ,,
29 ,,	2 ,,	11 ,,	4 ,,
36 ,,	2½ ,,	14 ,,	5 ,,
44 ,,	3 ,,		

As far as practicable, operators should be trained to walk at the desired speed.

Spray pressure and nozzle jet orifice—These are considered together as the output of a pump depends on both. To increase output, one has the choice of increasing the spray pressure and/or size of jet orifice.

The output of a nozzle is proportional to the square root of the pressure. Thus a four-fold increase in pressure is required to double spray output from a particular nozzle (Amsden, *c.* 1960). It follows that only limited changes in spray output may be achieved by small variations in pump pressure.

In practice, operating pressures between 15 and 25 psi are recommended for application of herbicides by means of knapsack sprayers. Pressures in excess of 25 psi are difficult to maintain, impose excessive strain on the pump, increase nozzle erosion and, when combined with small jets, may lead to formation of too fine droplets which are liable to drift and damage the main crop.

Nozzle jet outputs at different operating pressures are listed in *Table 9*. Nozzles should be discarded when they give an uneven spray pattern and their outputs differ significantly from rated outputs of new nozzles.

The actual volume rate of spray application by individual sprayers may be checked by either of the following methods:

Method 1

1. Measure in feet or metres the average width of strip sprayed.
2. Measure (average of several checks) the distance in feet or metres walked by the sprayer in 10 seconds at normal operating speed.
3. Measure spray output in cc per minute at operating pressure (average of several checks).
4. The volume of spray applied per acre can now be calculated:

$$\text{Gallons/acre} = \frac{8 \times \text{output (cc) per min.}}{5 \times \text{distance (ft) per 10 sec.} \times \text{swathe width (ft)}}$$

$$\text{Litres/hectare} = \frac{5 \times \text{output (cc) per min.}}{3 \times \text{distance (m) per 10 sec.} \times \text{swathe width (ft)}}$$

Table 9. *Nozzle types and specifications*

Nozzle types	Nozzle identity	Orifice diameter (inches)	Pressure in pounds/sq. inch — Approx. water output (cc/min) 5	10	15	20	30	40
Fan jets	– – 01	≡ .026	130	190	230	270*	340*	380*
	– – 015	≡ .031	210	300	360	420*	490*	570*
	– – 02	≡ .036	260	370	450	530*	640*	760*
	– – 03	≡ .043	400	570	690	800*	980*	1140*
	– – 04	≡ .052	530	750	920	1060*	1330*	1510*
	– – 05		660	940	1150	1330*	1630*	1890*
	– – 06	≡ .062	790	1120	1380	1590*	1970*	2270*
	– – 08	≡ .072	1080	1530	1870	2160*	2610*	3030*
	– – 10	≡ .078	1340	1900	2330	2690*	3290*	3790*
	– – 15	≡ .094	2000	2840	3470	4010*	4920*	5680*
	A – – *B*							
Flood jets	– – 1	1/32 .031	270	380*	450*	530*	640*	760*
	– – 1.5	1/25 .040	400	570*	680*	800*	980*	1140*
	AF 40 – – 2	3/64 .047	540	760*	920*	1060*	1330*	1510*
	AF 50 – – 2.5	.051	680*	950*	1170*	1320*	1630*	1890*
	AF 60 – – 3	1/16 .063	800*	1140*	1400*	1590*	1970*	2270*
	AF 100 – – 5	5/64 .078	1320*	1890*	2310*	2690*	3290*	3790*
	– – 7.5	3/32 .094	2010*	2840*	3480*	4160*	4920*	5679
	Yellow polijet	.040	270*	410*	500*	580	710	820
	Blue ”	.062	640*	910*	1100*	1270	1560	1800
	Red ”	.078	1230*	2000*	2410*	2780	3410	3930

* Figures from catalogues, other figures calculated.

Notes: Some variation may occur in discharge rates of nozzles from different sources with similar orifice diameter.

Column A flood jet nozzle numbers = output at 40 psi × 100.
Column B flood jet nozzle numbers = output at 10 psi × 10.

Flow rate conversion factors for liquids of varying specific gravity

Specific gravity	Conversion factor
.84	1.09
.90	1.05
.96	1.02
1.00	1.00
1.02	.99
1.08	.96
1.14	.94
1.20	.91
1.26	.89
1.32	.87
1.38	.85
1.44	.83
1.50	.81

Method II

1. Fill the knapsack to capacity.

2. Spray a specified number of feet/metres or circles at customary speed and operating pressure.

3. Measure in feet/metres the average width of strip or diameter of circle sprayed.

4. After spraying, refill the tank, measuring the volume required (gallons/litres).

5. The volume of spray applied per acre/hectare can now be calculated as follows:

(i) *Strip spraying*

$$\text{Gallons/acre} = \frac{43\,560 \times \text{gallons delivered}}{\text{swathe width (ft)} \times \text{swathe length (ft)}}$$

$$\text{Litres/hectare} = \frac{10\,000 \times \text{litres delivered}}{\text{swathe width (m)} \times \text{swathe length (m)}}$$

(ii) *Full circle spraying*

$$\text{Gallons/acre} = \frac{55\,462 \times \text{gallons delivered}}{D^2 \text{ (ft)} \times \text{no. circles sprayed}}$$

$$\text{Litres/hectare} = \frac{12\,732 \times \text{litres delivered}}{D^2 \text{ (m)} \times \text{no. circles sprayed}}$$

(iii) *Ring spraying*

$$\text{Gallons/acre} = \frac{55\,462 \times \text{gallons delivered}}{D^2\text{-}d^2 \text{ (ft)} \times \text{no. circles sprayed}}$$

$$\text{Litres/hectare} = \frac{12\,732 \times \text{litres delivered}}{D^2\text{-}d^2 \text{ (m)} \times \text{no. circles sprayed}}$$

Note: D = diameter of circle (circle spraying) or diameter of outer circle (ring spraying)

d = diameter of inner circle (ring spraying)

These formulae may also be used for calculation of the length of strip/number of circles/number of rings which can be sprayed when volume rates of spray application per acre/hectare are known.

Tables 10–12 should be consulted when a rapid estimate is required of the volume of spray application per acre/hectare.

If the calculated volume rate of application differs significantly from that desired, each of the four variables which determine the volume of application should be critically examined and necessary alterations made. In the event that the width of sprayed strip, pressure and operator speed are acceptable, the volume should be varied by changing the nozzle. The approximate output (cc per minute) of the replacement nozzle at operating pressure can be determined by substituting data in the following formulae:—

cc/min. = 5/8 × gal/ac × distance (ft) per 10 sec. × swathe width (ft)

or

cc/min. = 3/5 × lit/ha × distance (ft) per 10 sec. × swathe width (m)

Table 9 should be consulted when the output rating (cc per minute) of the replacement nozzle has been determined. After the replacement nozzle has been fitted, repeat checks to ensure that the desire application rate is achieved.

The efficiency and cost of herbicide usage can also be checked by comparing the amount of commercial concentrate actually used in a given area with the calculated amount required. The amount of commercial concentrate which should have been used can be determined by means of the following formulae:

Strip spraying

$$\text{Amount reqd.} = \frac{R \times A \times W}{S}$$

Full circle spraying

$$\text{Amount reqd.} = \frac{R \times A \times T \times D^2}{55\,462 \text{ (ac) or } 12\,732 \text{ (ha)}}$$

Ring spraying

$$\text{Amount reqd.} = \frac{R \times A \times T \times (D^2 - d^2)}{55\,462 \text{ (ac) or } 12\,732 \text{ (ha)}}$$

Notes: R = Intended rate per sprayed acre or hectare
A = Planted area in acres or hectares
W = Swathe width in feet or metres
S = Average spacing between rows in feet or metres
T = Stand per acre or hectare
D = Diameter (in feet or metres) of circle (circle spraying) or outer circle (ring spraying)
d = Diameter (in feet or metres) of inner circle (ring spraying)

Table 10a. Spraying distance per gallon in relation to application rate and width of sprayed strip

Width sprayed strip	Volume rate per acre (gallons)												
	5	10	15	20	25	30	35	40	50	60	70	80	90	100
feet	yards	yards	yards	yards	yards	yards	yards	yards	yards	yards	yards	yards	yards	yards
2	1452	726	484	363	290	242	207	182	145	121	104	91	81	73
2½	1162	581	387	290	232	194	166	145	116	97	83	73	65	58
3	968	484	323	242	194	161	138	121	97	81	69	61	54	48
3½	830	415	277	207	166	138	119	104	83	69	59	52	46	41
4	726	363	242	182	145	121	104	91	73	61	52	45	40	36
4½	645	323	215	161	129	108	92	81	65	54	46	40	36	32
5	581	290	194	145	116	97	83	73	58	48	41	36	32	29
5½	528	264	176	132	106	88	75	66	53	44	38	33	29	26
6	484	242	161	121	97	81	69	61	48	40	35	30	27	24

Table 10b. Spraying distance per litre in relation to application rate and width of sprayed strip

Width sprayed strip	Volume rate per hectare (litres)												
	50	100	150	200	250	300	350	400	500	600	700	800	900	1000
cm	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres
50	400	200	133	100	80	67	57	50	40	33	29	25	22	20
75	267	133	89	67	53	44	38	33	27	22	19	17	14	13
100	200	100	67	50	40	33	29	25	20	17	14	13	11	10
125	160	80	53	40	32	27	23	20	16	13	11	10	9	8
150	133	67	44	33	27	22	19	17	13	11	10	8	7	6.7
175	114	57	38	29	23	19	16	14	11	10	8	7	6	5.7
200	100	50	33	20	20	17	14	13	10	8	7	6	5.5	5

Table 11a. Number of circles sprayed per gallon in relation to application rate and radius of sprayed circle

Radius sprayed circle	Volume rate per acre (gallons)													
	5	10	15	20	25	30	35	40	50	60	70	80	90	100
feet	*Number of circles sprayed per gallon*													
2	693	347	231	173	139	116	99	87	69	58	50	43	39	35
2½	443	222	148	111	89	74	63	55	44	37	32	28	25	22
3	308	154	102	77	62	51	44	39	31	26	22	19	17	15
3½	226	113	75	57	45	38	32	28	23	19	16	14	13	11
4	173	87	58	43	35	29	25	22	17	14	12	11	10	9
4½	137	68	46	34	27	23	20	17	14	11	10	9	8	7
5	111	55	37	28	22	18	16	14	11	9	8	7	6	5
5½	91	46	30	23	18	15	13	11	9	8	7	6	5	
6	77	38	26	19	15	13	11	10	8	6	5			

Table 11b. Number of circles sprayed per litre in relation to application rate and radius of sprayed circle

Radius sprayed circle	Volume rate per hectare (litres)													
	50	100	150	200	250	300	350	400	500	600	700	800	900	1000
cm	*Number of circles sprayed per litre*													
50	255	127	85	64	51	42	36	32	25	21	18	16	14	13
75	113	57	38	28	23	19	16	14	11	9.4	8.1	7.1	6.3	5.7
100	63	32	21	16	13	11	9.1	80	6.4	5.3	4.5	4.0	3.5	3.2
125	40	20	14	10	8.1	6.8	5.8	5.1	4.1	3.4	2.9	2.5	2.3	2.0
150	29	14	9.5	7.1	5.7	4.8	4.1	3.6	2.9	2.4	2.0	1.8	1.6	1.4
175	21	10	6.9	5.2	4.1	3.5	3.0	2.6	2.1	1.7	1.5	1.3	1.2	1.0
200	16	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.6	1.3	1.1	1.0		

Table 12a. Number of rings sprayed per gallon in relation to application rate, inner radius and width of sprayed ring

Inner radius of sprayed ring	Width of sprayed ring	Volume rate per acre (gallons)													
		5	10	15	20	25	30	35	40	50	60	70	80	90	100
		Number of rings sprayed per gallon													
feet	feet														
3	3	173	87	58	43	35	29	25	22	17	14	12	11	9.6	8.7
3	3	103	51	34	26	21	17	15	13	10	8.6	7.3	6.4	5.7	5.1
3	4	69	35	23	17	14	12	9.9	8.7	6.9	5.8	5.0	4.3	3.9	3.5
3	5	50	25	17	13	10	8.4	7.2	6.3	5.0	4.2	3.6	3.2	2.8	2.5
3	6	39	19	13	9.6	7.7	6.4	5.5	4.8	3.9	3.2	2.8	2.4	2.1	1.9
6	2	99	50	33	25	20	17	14	12	9.9	8.3	7.1	6.2	5.5	5.0
6	3	62	31	21	15	12	10	8.8	7.7	6.2	5.1	4.4	3.9	3.4	3.1
6	4	43	22	14	11	8.7	7.2	6.2	5.4	4.3	3.6	3.1	2.7	2.4	2.2
6	5	33	16	11	8.2	6.5	5.4	4.7	4.1	3.3	2.7	2.3	2.0	1.8	1.6
6	6	26	13	8.6	6.4	5.1	4.3	3.7	3.2	2.6	2.1	1.8	1.6	1.4	1.3

Table 12b. Number of rings sprayed per litre in relation to application rate, inner radius and width of sprayed ring

Inner radius of sprayed ring	Width of sprayed ring	Volume rate per hectare (litres)													
		50	100	150	200	250	300	350	400	500	600	700	800	900	1000
		Number of rings sprayed per ten litres													
cm	cm														
100	100	212	106	71	53	42	35	30	27	21	18	15	13	12	11
100	125	156	79	52	39	31	26	22	20	16	13	11	9.8	8.7	7.8
100	150	121	61	40	30	24	20	17	15	12	10	8.7	7.6	6.7	6.1
100	175	97	49	32	24	19	16	14	12	9.7	8.1	6.9	6.1	5.4	4.9
100	200	86	40	27	20	16	13	11	9.9	8.0	6.6	5.7	5.0	4.4	4.0
200	100	127	64	42	32	25	21	18	16	13	11	9.1	8.0	7.1	6.3
200	125	97	49	32	24	19	16	14	12	9.7	8.1	6.9	6.1	5.4	4.9
200	150	77	39	26	19	15	13	11	9.6	7.7	6.4	5.5	4.8	4.3	3.9
200	175	63	32	21	16	13	11	9.0	7.9	6.3	5.3	4.5	4.0	3.5	3.2
200	200	53	27	18	13	11	8.8	7.6	6.6	5.3	4.4	3.8	3.3	2.9	2.7

Any serious discrepancy between actual and intended usage should be rectified by adjusting the herbicide dilution (see *Table 6*) or volume of spray applied.

CONCLUSION

In recent years, many sophisticated herbicides have been evolved for controlling competitive weed growth in plantation tree crops. The selection of these herbicides and methods of preparation and application to ensure their efficient and economic usage have been discussed. Herbicides must be selected carefully for each situation because no single herbicide or mixture of herbicides applied at economic rates will provide lasting control of diverse weeds in this country, and repeated application of a particular herbicide is liable to result in dominance of resistant weed species.

Application of herbicides has thus become highly technical. Effective and economical use of herbicide chemicals now demands that personnel in charge of spraying programmes can identify the major weed species and are conversant with the properties of herbicides and developments in spraying equipment and techniques.

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APPENDIX

Conversion factors

Conversion of	*To obtain*	*Multiply by* or	*Divide by*
Acres	Hectares	0.4047	2.471
Centimetres	Inches	0.3937	2.540
Cubic centimetres	Fluid oz (Imp)	0.0352	28.41
Cubic centimetres	Fluid oz (US)	0.0338	29.57
Cubic centimetres	Pints (Imp)	1.760×10^{-3}	568.2
Cubic centimetres	Pints (US)	2.113×10^{-3}	473.2
Cubic centimetres	Gallons (Imp)	2.200×10^{-4}	4546
Cubic centimetres	Gallons (US)	2.642×10^{-4}	3786
Feet	Centimetres	30.48	0.0328
Feet	Metres	0.3048	3.281
Fluid oz (Imp)	Cubic centimetres	28.41	0.0352
Fluid oz (US)	Cubic centimetres	29.57	0.0338
Fluid oz (Imp)	Fluid oz (US)	0.9608	1.041
Fluid oz (US)	Fluid oz (Imp)	1.041	0.9608
Fluid oz (Imp)/ac	Cubic centimetres/ha	70.20	0.01425
Fluid oz (US)/ha	Cubic centimetres/ha	73.08	0.0137
Gallons (Imp)	Gallons (US)	1.201	0.8327
Gallons (US)	Gallons (Imp)	0.8327	1.201
Gallons (Imp)	Cubic centimetres	4546	2.200×10^{-4}
Gallons (US)	Cubic centimetres	3786	2.642×10^{-4}
Gallons (Imp)/ac	Litres/hectare	11.23	0.0890
Gallons (US)/ac	Litres/hectare	9.351	0.1069
Grammes	Ounces	0.03527	28.35
Grammes	Pounds	2.204×10^{3}	453.6
Grammes/litre	Ounces/gallon (Imp)	0.1604	6.236
Grammes/litre	Ounces/gallon (US)	0.1336	7.485
Grammes/litre	Parts per million (ppm)	10^{-3}	10^{-3}
Hectares	Acres	2.471	0.4047
Hectares	Square feet	1.076×10^{-5}	0.929×10^{-5}
Inches	Centimetres	2.540	0.3937
Kilogrammes	Pounds	2.204	0.4536
Kgs/hectare	Pounds/acre	0.8922	1.121
Kgs/litre	Pounds/gallon (Imp)	10.02	0.0998
Kgs/litre	Pounds/gallon (US)	8.344	0.1198
Kgs/sq. cm	Pounds/sq. inch	14.22	.07031
Kilometres	Yards	1094	0.9141×10^{-3}
Kilometres	Miles	0.6214	1.609
Kilometres/hr	Feet/Min	54.68	0.01829
Kilometres/hr	Miles/hr	0.6214	1.609
Litres	Gallons (Imp)	0.2200	4.546
Litres	Gallons (US)	0.2642	3.786
Litres	Pints (Imp)	1.760	.5683

Conversion of	*To obtain*	*Multiply by* or	*Divide by*
Litres	Pints (US)	2.113	.4732
Litres/hectare	Fluid oz (Imp)/ac	14.24	.0702
Litres/hectare	Fluid oz (US)/ac	13.68	.07308
Litres/hectare	Gallons (Imp)/ac	0.08902	11.23
Litres/hectare	Gallons (US)/ac	0.1069	9.351
Metres	Inches	39.37	.02540
Metres	Feet	3.281	.3048
Metres	Yards	1.094	.9144
Metres/min	Miles per hour	0.03728	26.82
Miles	Kilometres	1.609	.6214
Miles/hr	Feet/min	88.00	0.01136
Miles/hr	Metres/min	26.82	0.03728
Ounces	Grammes	28.35	0.03527
Ounces/gallon (Imp)	Grammes/litre	6.236	0.1604
Ounces/gallon (US)	Grammes/litre	7.489	0.1336
Ounces/acre	Grammes/hectare	70.05	0.01428
Parts per million (ppm)	Milligrams/litre	1.000	1.000
Pints (Imp)	Cubic centimetres	568.3	1.760×10^{-3}
Pints (US)	Cubic centimetres	473.2	2.113×10^{-3}
Pints (Imp)	Litres	0.5683	1.760
Pints (US)	Litres	0.4732	2.113
Pints (Imp)	Fluid oz (Imp)	20.00	0.0500
Pints (US)	Fluid oz (US)	16.00	0.0625
Pints (Imp)	Pints (US)	1.201	0.8327
Pints (US)	Pints (Imp)	0.8327	1.201
Pounds	Grammes	453.6	2.204×10^{-3}
Pounds/acre	Kilogrammes/ha	1.121	0.8921
Pounds/gallon (Imp)	Grammes/litre	99.80	0.01002
Pounds/gallon (US)	Grammes/litre	119.86	8.343×10^{-3}
Pounds/gallon (Imp)	Pounds/gallon (US)	.8327	1.201
Pounds/gallon (US)	Pounds/gallon (Imp)	1.201	.8327
Pounds/sq. inch	Kgs/sq. cm	0.07031	14.22
Square feet	Square metres	0.0929	10.764
Square kilometres	Acres	247.1	4.047×10^{3}
Square kilometres	Hectares	100.0	.01
Square metres	Square yards	1.196	.8361
Square miles	Acres	640.0	1.563×10^{-3}
Square yards	Square metres	0.8361	1.196
Yards	Metres	0.9144	1.0936

DISCUSSION

Chairman: P. R. Wycherley

Kirsch: According to which international standard did you classify the toxicity of the products?

Teoh: These values were obtained from Ansul Chemicals' publications on toxicity hazards.

Kirsch: I think that it is not in the interest of the public, who these days are very sensitive about toxicity hazards and environmental pollution, or of pesticide manufacturers, to classify a product with an LD_{50} of between fifty and five hundred as highly toxic. For example malathion, which falls into this range, should not be regarded as a highly toxic product.

Teoh: Do you therefore mean that the manufacturer of a pesticide like malathion would not like people to know that it is potentially a dangerous chemical?

Kirsch: Manufacturers of plant protection chemicals are very careful in instructing the user what dangers exist and what precautionary measures have to be taken when these chemicals are used. A manufacturer would not wish to keep the user in doubt about the toxicity of the material. I wish to make the point that, to avoid confusion, one should keep to the accepted classifications in drawing up a table of toxicity ratings, such as those already set by the US Department of Agriculture and other government organisations.

Chairman: One should bear in mind that some of the operators who use these chemicals in this country are near illiterate. Furthermore, wearing protective clothing is exceedingly uncomfortable in a tropical country. We should, if necessary, set higher and stricter standards in this country than those applying in Europe or North America.

Barnes: The table referred to is intended only as a guide. The information it contains has been gleaned from published toxicity data, some of it from the US Department of Agriculture. Any pesticide that has an LD_{50} of 500 should certainly be handled carefully, and one of only 50 is that much more dangerous. Many people using pesticides—even planters—are not aware what LD_{50} means; it is the dosage at which 50% of the test animals do not survive. It is a reproducible figure and is a measure of the chemical's toxicity. For instance, although malathion is a safe chemical to use, nevertheless it has an LD_{50} which must be observed and taken into account when handling it.

Kirsch: As well as the LD_{50}, a product's dermal toxicity is also important, especially for the operator. If a man sprays continuously it is not the LD_{50} which is endangering him, but the dermal toxicity—the spray-mist which soaks his clothing or wets his skin. For this reason LD_{50} figures may be misleading, and one should stress the dermal toxicity rating also.

Teoh: We did in fact draw attention to the dermal toxicity, but we did not list any figures because of the different values quoted by various sources. Dermal toxicity apparently varies with the method used to measure it.

Pushparajah: Besides LD_{50} values one should also consider the persistence of the chemical and its residual effect in the soil. Also, from its oral and dermal toxicities an estate manager should be aware of a chemical's handling hazards, and be able to assess the degree of field supervision which its use entails. Having seen field workers actually stirring sodium arsenite solutions with their hands I am convinced that handling safeguards are necessary.

Webb: I wish to mention toxicity hazards in relation to equipment. The drift factor should be borne in mind, for it affects the exposure of the operators to toxic substances as well as the danger of spray drift to other crops. The droplet size should be above 200 microns so that spray drift is minimised. Equipment such as mistblowers and pneumatic equipment producing fine droplets smaller than 50 microns can be dangerous to use because of the drift hazard—in fact deaths have occurred because of the use of the wrong type of equipment with highly toxic substances.

WEED CONTROL IN RUBBER CULTIVATION

by

E. Pushparajah

Cultivation of the soil and establishment of crops alter the ecological balance of the natural vegetation of any area. In the tropics, where weed growth is very rapid, competition with crops is likely to be observed very readily—an effect which usually arises when crop and weed roots compete for moisture and nutrients (Watson *et al.*, 1964a, b); further, the common weed *Mikania cordata* has been found to have a damaging effect which has been attributed by Wong (1964) to growth-inhibiting substances which retard the growth of *Hevea*.

The available data on the depression of yield of rubber by weeds is not extensive. The growth of immature rubber is depressed by *Mikania cordata*, *Eupatorium odoratum*, *Ficus* spp. and *Melastoma malabathricum*. Competition from other common weeds like *Paspalum conjugatum*, *Axonopus compressus* and *Ottochloa nodosa* is relatively less (de Jonge, 1962; Wycherley, 1964; Wycherley & Chandapillai, 1969). Indeed, during the early stages of its growth leguminous covers also compete with the rubber, and keeping the planting strips clear of legumes as well as weeds has been shown to be beneficial (Akhurst, 1940).

CLEAN VERSUS STRIP WEEDING

In the pre-war and early post-war years clean weeding was practised. Although this gave an initial growth advantage to the rubber compared with partial weed control, Haines (1932) showed that in clean-weeded plots, soil washed from terraces was about three times greater than from areas with creeping legume or grass covers. Pereira and Jones (1954) showed that clean weeding in coffee plantations encouraged sheet erosion because pore space and the rates of infiltration and percolation of rainfall were reduced. Watson *et al.* (1964c) showed that keeping the ground bare resulted in loss of organic carbon and led to a greater loss of nutrients by leaching. The effect persisted into the fourth year of maturity, where measurements showed that not only was the carbon content low (Pushparajah & Chellapah, 1969), but the stability of soil structural aggregates was reduced, resulting in compaction (Soong, pers. comm.). Currently, the main consideration in keeping clean weeding to a minimum is its cost; hence one has tended to strike a balance between weed competition and soil deterioration and to confine weeding to planting strips, where the fertilisers are applied.

COVER MANAGEMENT TODAY

In preparation for planting or replanting, weeding of existing vegetation is done with blanket sprays of chemicals or by mechanical cultivation. Where creeping legumes have been sown, hand weeding can prevent competition from emerging weeds. As the rubber grows, the canopy reduces the light reaching the ground and limits the vigour of covers. By the fifth year the legume cover is usually succeeded by a light vegetation of a variety of grasses and broad-leafed plants. These are then maintained as inter-row covers with occasional selective weeding or slashing.

Recently, as an alternative to a legume cover, it has become common practice to allow grasses and other short broad-leafed plants in the inter-rows and for the rubber to be given additional nitrogen fertiliser to compensate for that which would normally be supplied by leguminous covers (Pushparajah & Chellapah, 1969; Anon., 1967a, b). This type of cover often becomes very dense, and may be a source of persistent weed infestation of the planting strips.

Intercropping the interrow with short term crops is more popular with smallholders than on estates. The consequent weed problems are generally greater and more complex, and are of particular interest to the Rubber Research Institute because of the enormous acreage of newly-planted and re-planted smallholdings in Malaysia.

USE OF HERBICIDES

Post-emergence herbicides

In the past decade, in its search for alternatives to sodium arsenite, the Rubber Research Institute of Malaya has carried out extensive tests with many chemicals. The results of these earlier trials have been reviewed by Riepma (1968), and for ease of reference his *Table 1* is reproduced here. From these chemicals a number of combinations, generally of systemic and contact herbicides involving mixtures or sequential sprays, have been formulated for general weed control and are described in *Table 2*. An estimate of costs (*Table 3*) shows that the use of combinations of herbicides in *Table 2* on mature rubber results in a lower expenditure in weed control than when sodium arsenite is used.

Pre-emergence herbicides

In testing pre-emergence herbicides for use in rubber cultivation (Riepma 1965a, b) emphasis was placed on their selectivity, in order to avoid damage to the legume cover. Of the chemicals tested, *i.e.* simazine, atrazine, atratone, prometryne, diuron, monuron and neburon, only the last was selective to legumes; none had any adverse effect on rubber seedlings or green buddings, provided the spray was no closer than 1–2 in. from the plant. This type of herbicide gave effective weed control for about 13–16 weeks. The efficacy of these and of some other pre-emergence chemicals in controlling five common weeds is summarised in *Table 4*. The variability of the effectiveness and persistence of these chemicals according to soil conditions cannot be over-emphasised (Riepma, 1962a, b, 1965a, b), although their use effects

*Table 1. Summary of susceptibility of various weeds to herbicides**

Weed species	Conditions		lb/acre active ingredient of herbicide								
	Stage of rubber	Daylight %	Dalapon	Amino-triazole	Sodium chlorate	Par-aquat	2,4-D	2,4,5-T	Picloram	2,4,5-T	DSMA
Grasses											
Axonopus compressus	immature	100	5–10	3–5		1.0					4–8
Axonopus compressus	mature	80	5–10			1.0					2–4
Paspalum conjugatum	immature	100		3–5		1.0–2.0					6–10
Paspalum conjugatum	mature	70–80		2–3		1.0–2.0					2–4
Ischaemum muticum	immature	80			25						6–10
Digitaria longiflora	immature	100	3–5			0.5–1.0					6–10
Digitaria sanguinalis	immature	100	3–5			0.5–1.0					4–8
Ottochloa nodosa	immature	90–100	5–10		25	1.0–2.0					4–8
Ottochloa nodosa	mature	70–90	10–20		25	1.0–2.0					
Ottochloa nodosa	mature	40–50	5–10		25	1.0–2.0					
Tricholaena rosea	immature	80–100				0.5–1.0					
Leersia hexandra	immature	90–100	10–20								
Paspalum scrobiculatum	mature	70	15								12
Cynodon dactylon	immature	100	5+5+5								
Eleusine indica	immature	100	5+5+5 10+5+5								
Panicum repens	immature	100	10–20								
Imperata cylindrica		100	15–20								
Chrysopogon aciculatus	immature	100	5–10								
Panicum pilipes	mature	60	5–10			1.0–2.0					
Sedges											
Scleria multifoliata	immature					0.5–1.0					
Scleria hebecarpa						0.5–1.0					
Scleria laevis	mature					0.5–1.0					
Scleria sumatrensis	mature					0.5–1.0					

* From Riepma (1968)

Table 1. — (continuation)

Weed species	Conditions: Stage of rubber	Conditions: Daylight %	lb/acre active ingredient of herbicide: Dalapon	Amino-triazole	Sodium chlorate	Par-aquat	2,4-D	2,4,5-T	Picloram	2,4,5-T	DSMA
Ferns											
Gleichenia linearis									1.5–3.0	3.0–6.0	
Stenochlaena palustris	mature	80				1.0–2.0		4.8			8–12
	developing										
Stenochlaena palustris	developed					0.5–1.0		4.8			6–12
Nephrolepis biserrata	mature	70–80				1.0		2.4		3.0	8
Lygodium scandens	immature	100									8–12
Cyclosorus gongyloides								1.0–2.0	0.5–1.0	2–4	
Broad-leafed weeds											
Hevea brasiliensis	mature	70						1.0–2.0	0.5–1.0	1.5–3	
Eupatorium odoratum	mature	80–90						?	?	1.5–3	
Melastoma malabathricum	mature	70–100		3–5				2.0		2.0–3	
Mimosa pudica		100					2(ester)				
Musa acuminata							2(ester)				
Musa malaccensis				1.5–3.0							
Passiflora foetida							2				4–6
Cleome ciliata						0.5					
Erechthites valerianaefolia							2–4				8–12
Ageratum conyzoides						1.0–1.5	2–4			3.0	
Alternanthera triandra						0.5–1.0					8–12
Vitis hastata							2–4				
Borreria latifolia							1–2				
Mikania cordata								1–2		1–2	
Tetracera scandens								1–2		1–2	
Tetracera indica											

*Table 2. Recommendations for weed control in rubber: alternatives to sodium arsenite**

Weed situations	*Amount per sprayed acre or concentration*			
	Using sodium chlorate-based formulations	*Using paraquat-based formulations*	*Using MSMA-based formulations*	*Using other formulations*
NURSERIES AND VERY YOUNG RUBBER				
(i) General weed control		Use a 1/80 solution of paraquat concentrate. Avoid spray drift on to leaves		
(ii) Grass control			Frequent spray with 2–3 pints MSMA in 40 gallons	1% solution of dalapon formulation in water. Avoid leaves of rubber.
IMMATURE RUBBER				
(i) *Mikania cordata*	Cocktail of 20–25 lb sodium chlorate + 1 pint 2,4-D in 40–60 gallons water	2 pints paraquat + ½ pint 2,4-D amine in 20–30 gallons water	2 pints MSMA+1 pint 2,4-D amine in 40–60 gallons water	1–2 lb ai of 2,4-D
(ii) *Ottochloa nodosa*				1% solution of dalapon in water
(iii) *Paspalum conjugatum* dominant	Sequential spray with 1 pint Amitrole–T in 40 gallons water, followed 2–4 weeks later by 5–10 lb sodium chlorate in 40–60 gallons water	Sequential spray with 1 pint Amitrole–T in 20 gallons water followed 3–4 weeks later with 1–2 pints paraquat in 20 gallons water		
(iv) *Axonopus compressus Paspalum conjugatum Ottochloa nodosa Mikania cordata* dominant among weeds	Cocktail of 2 pints MSMA, 1 pint 2,4-D amine and 10 lb sodium chlorate in 40–60 gallons water		As in the sodium chlorate formulation column	
(v) Ferns *e.g. Lygodium, Nephrolepis, Gleichenia linearis*		Spray with 0.5 to 2.0 lb paraquat in 40–60 gallons water		

Table 2. — (continuation)

Weed situations	Amount per sprayed acre or concentration: Using sodium chlorate-based formulations	Using paraquat-based formulations	Using MSMA-based formulations	Using other formulations
IMMATURE RUBBER (continued)				
(vi) *Digitaria* spp. (and or) *Eleusine indica* *Paspalum commersonii* *Ischaemum muticum* dominant among the weeds	Sequential spray: 2 lb dalapon + 2/3–1 pint 2,4-D in 40–60 gallons water followed 2–4 weeks later with 10–15 lb sodium chlorate		Cocktail of 2 pints MSMA, 1 pint 2,4-D and 2–4 lb dalapon	As in sodium chlorate or MSMA formulation column or 1% solution of dalapon
MATURE RUBBER General mixed weeds	Cocktail of 15 – 20 lb sodium chlorate + 1 pint 2,4-D in 40–60 gallons water	Cocktail of 1 pint paraquat, ½ pint 2,4-D amine in 20–30 gallons water	Cocktail of 2 pints MSMA, 1 pint 2,4-D and 5 lb sodium chlorate	
General weed control—broad leaved herbaceous weeds dominant				A solution 1/300 of picloram
Woody brush	As above; in 100 gallons water			Picloram 1% solution *or* 0.5% solution of 2,4-D/2, 4-5T ester
Tetracera scandens				0.5% solution of picloram
Ferns: *Nephrolepis*, etc.	As under IMMATURE RUBBER			

* From Anon. (1967a, b, 1968)

Table 3. Cost of general weed control per "blanket" acre in immature rubber

Costs \ Chemicals	2 pints MSMA + 1 pint 2,4-D + 10 lb chlorate in 60 gal water	2 pints Gramoxone + ½ pint 2,4-D in 30 gal water	2 pint MSMA + 1 pint 2,4-D in 60 gal water	15 lb sodium arsenite in 100 gal water
Cost of chemicals	9.45	11.75	7.40	6.75
Cost of spraying	5.00	2.50	5.00	9.00
Total	$14.45	$14.25	$12.40	$15.75

a longer period of control than did hand weeding (Riepma 1962a, b). Simazine, for instance, extended the period of control by three weeks on a coastal clay soil and by nine weeks or more on a sandy soil.

*Table 4. Effect of some pre-emergence herbicides on common weeds**

Chemical	*Rate lb/a.i.*	*Axonopus compressus*	*Paspalum conjugatum*	*Eleusine indica*	*Cyperus sp.*	*Borreria latifolia*
Bromacil	2–4	√	?	√	√	√ ?
Diuron	2.4–4.8	√	√	?	NT	NT
Linuron	2.5–5.0	√	√	?	√	NT
Neburon	2.5–5.0	√ ?	√	—	√	—
Atratone	2.5–5.0	√	√ ?	√	√ ?	√
Simazine	2.5–5.0	√	√	√	√ ?	√
Banvel D	2.4–4.8	√ ?	√	NT	—	√ ?
Lasso	0.9–1.5	√	√	√	√	—
Atrazine	1.0–2.0	√	√	√	√	√

Note : √ = Effective
√ ? = Effective only at higher rates used
? = Very variable in effect
— = No effect
NT = Not tested

EFFECT OF CHEMICALS AND CULTIVATION ON PLANT SUCCESSION

The successful control of weeds depends on a systematic approach. The speed with which weeds establish can be realised when one considers that within four weeks from cultivation in an intercropping area, more than 50% of the ground was covered by weeds. The regeneration is not necessarily always as speedy as

* From Pushparajah & Woo (unpubl.); Riepma (1965b, c, d)

this; Riepma (1962b) showed that weed growth was more rapid when fertilisers were applied, and the rapid regeneration may have been aggravated by fertilisers in the intercropping situation. Riepma (1965d) also showed that soil types may influence weed regeneration and possibly their population make-up, but it is important to see the regenerating weed species in relation to the initial stand: *Table 5* shows that with cultivation, the profuse seeders *Eleusine indica*, *Cyperus* spp. and *Borreria latifolia* have begun to predominate.

Table 5. Changes in distribution of weeds on cultivation of soil

	% weed cover													
	Eleusine indica	*Axonopus compressus*	*Paspalum conjugatum*	*Digitaria longiflora*	*Digitaria sanguinalis*	*Tricholena rosea*	*Imperata cylindrica*	*Cyperus* sp.	*Borreria latifolia*	*Mikania cordata*	*Croton hirtus*	*Ageratum conyzoides*	*Stachytarpheta indica*	*Others*
Prior to cultivation	2	1	7	2	2	1	9	5	28	14	1	2	6	14
At 4 weeks after planting	23	—	—	6	—	—	—	18	15	—	3	—	—	—
At 12 weeks after cultivation	49	—	—	7	—	—	—	12	13	—	6	1	—	—

Similar effects have been observed when using chemicals to control the weeds. When a short-lived effect was obtained by using paraquat against a dominant stand of *Paspalum conjugatum* and *Melastoma malabathricum*, these weeds soon recolonised the area, but when paraquat was used on *Ottochloa nodosa* marked development of other species occurred—*e.g.* by germination of seeds of *Borreria latifolia* and *Cleome ciliata*. When Amitrole was used against an almost pure stand of *Melastoma malabathricum* the sprayed area was invaded from outside by *Mikania cordata* and *Imperata cylindrica*, but where the *Melastoma* was in a mixed population the regenerating weeds were *Scleria* spp. and *Tetracera scandens* (Riepma, 1963). More recently the use of "cocktails" in immature rubber, *i.e.* combinations of contact and systemic herbicides, has also resulted in the development of resistant species. After three spray rounds of an MSMA/2,4-D/sodium chlorate mixture on a strip infested predominantly with *Paspalum conjugatum*, *Sporobolus indicus* established as the main weed; while in the same area, use of a Weedazol (aminotriazole)/Gramoxone (paraquat) mixture resulted in a predominance of *Paspalum commersonii*. When sodium chlorate/2,4-D mixtures were used for some time, *Paspalum conjugatum* became the dominant species and weeds like *Brachiaria mutica*, *Cynodon dactylon*, *Eragrostis* spp. and *Panicum repens* were found to be resistant (Anon., 1967b; Wong, 1966a, b). It is likely that these latter weeds could, if they are present, eventually become dominant. In a third case where intercropping was carried out, *Eleusine indica* established itself as a predominant weed in the inter-row and eventually invaded the tree-rows, although the latter had, over a period of a year, been treated with three rounds of MSMA/2,4-D/sodium chlorate mixture. The encroachment was mainly from germinating seeds. Similar effects on changes in plant population are apparent when pre-emergence herbicides are used.

Besides the above factors influencing weed regeneration, the other factor to be considered is that of soil type. Selangor series, one of the more fertile rubber soils, has a higher nitrogen status and water table than the inland soils, and hence is likely not only to stimulate weed regeneration (Riepma, 1962a) but also to affect the predominant weed species. The change in canopy conditions resulting from the growth of the rubber, thus altering the light intensity, would also change the composition of the weeds.

FUTURE DEVELOPMENT AND OUTLOOK

It appears that with a tendency to use a fixed regime of mixtures of herbicides in many areas, the eradication of susceptible weed species is allowing resistant species to become dominant.

As has been said earlier, re-establishment of weeds in planting strips can be as much by encroachment from inter-row areas as by germination of seeds in the soil. While the encroaching weeds can be killed with post-emergence herbicides, those from seeds can probably be best prevented by the use of pre-emergence herbicides. A sequential spray of a post- and a soil-acting (pre-emergence) herbicide may prove more useful on profusely seeding species like *Eleusine indica, Paspalum conjugatum, Axonopus compressus, Borreria latifolia, Cleome ciliata,* etc. A selection of such combinations can initially be made from *Tables 1* and *4*. That such combinations would give longer periods of control has been shown by Riepma (1962a, b), who reported that a combination of Amitrole and simazine extended the period of weed control by more than six weeks over that obtained by Amitrole alone. Similarly, a combination of diuron (a pre-emergence herbicide) with a post-emergence herbicide, *e.g.* paraquat or MSMA, gave a better control of weeds than a combination of the latter or using them on their own; it is believed in this instance that the low levels of diuron used had acted more on the existing vegetation (Seth, 1970).

It must be realised that for economy in weed control, the long term point of view is the more important. It would be a false economy to concentrate on eradicating an existing weed species with a specific and cheap formulation, only to find that the succeeding population contained more noxious weeds or species more resistant to chemicals. Further, the change in canopy conditions and hence the amount of light penetrating to the ground vegetation will alter the composition of the weed flora and necessitate modifying the herbicides used once again.

Changes in weed population, resulting from follow-up spraying rounds, need to be combated with alternative herbicides appropriate to the altering vegetation, and the importance of selecting alternatives appropriate to each regime should be emphasised.

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DISCUSSION

Chairman: P. R. Wycherley

Chandapillai: The use of herbicides may alter the weed succession, depending on the site and other environmental factors. In eradicating weeds it is best to begin with pre-emergence herbicides, which control a wide spectrum of species. Do not allow the weeds to germinate at all. Such pre-emergence herbicides as Planavin (nitralin) and Lasso (methachlor) do not adversely affect the spread of the legume cover, but do reduce undesirable weeds.

Hartley: Can we look forward to a truly all-embracing illustrated catalogue to help the practical planter identify weeds?

Wycherley: The pre-war RRIM Planting Manual No. 6 illustrated the common weeds at that time, which were usually either sprayed with sodium arsenite or removed manually. The introduction of new chemicals has resulted in new weed problems and necessitated a new manual. Mr. Chandapillai and I have been working on the preparation of a manual illustrating the grasses; it contains a key for identifying them and will, we hope, appear in the next year or so.

WEED CONTROL IN OIL PALM NURSERIES

by

M.M. Chandapillai

SUMMARY

Results of screening trials with selected pre-emergence herbicides aimed to study their relative efficiency in weed control in oil palm nurseries sustaining different soil types are presented. Karmex (diuron) 80% W.P. applied at 3 lb/acre in 60 gallons water gave satisfactory weed control for a period of 4–6 months, resulting in a considerable saving on the cost of weeding polybag nurseries. The polybag palms placed on the treated soil have not shown adverse growth effects due to Karmex application, either in the nursery (even after the penetration of the roots into the treated soil), or after the palms were planted into the field. Approximate cost of initial spraying of Karmex in the nursery is also presented.

INTRODUCTION

The final stage in the rearing of oil palm seedlings before they are planted out into the field is the polybag nursery, where ground weeding has become an expensive nursery practice. A bare nursery ground is preferable, and to achieve bare ground is relatively easy by the use of herbicides as opposed to expensive manual weeding. However, herbicides containing 2,4-D, 2,4,5-T or dalapon cannot be used in the nursery even during its preparation, since these chemicals are known to produce bending symptoms in the seedlings with subsequent death or extreme fasciation of the leaves and leaflets. Mowing the weeds between the polybags is difficult as mechanical cutters cannot work close to the bags and frequent mowing makes the operation expensive. A more satisfactory and cheaper method of controlling weed regeneration in the polybag nursery is of economic importance. The trials reported in this paper were undertaken to study the use and efficiency of selected pre-emergence herbicides on the control of weeds in the polybag nursery.

MATERIALS AND METHODS

The four trials reported here consist of three nursery trials (A–C) and one field trial (D). Trial A in Negri Sembilan was a preliminary study designed to screen a few of the available pre-emergence herbicides to determine their relative efficacy in weed control. Trial B was a follow-up test on certain selected pre-emergence herbicides found promising in trial A. Trial C was to confirm the efficiency of Karmex (diuron) observed in the previous trials and in particular to see whether the palms had suffered any adverse effects, especially after the roots had penetrated the treated soil. Trial D was conducted in the field to study the performance of the nursery palms, previously subjected to Karmex spraying, after planting out and to see whether they suffered any adverse effect due to a possible residual effect of Karmex in the nursery.

Nursery Trial A in Negri Sembilan

The trial was established in June 1968 on a portion of an oil palm nursery on a Rengam series soil in Negri Sembilan. The nursery site was prepared by first blanket-spraying the existing vegetation with sodium arsenite and rotovating a week later. The clumps of grasses and other weeds were removed manually prior to application of the pre-emergence herbicides.

Treatment

The trial comprised five pre-emergence herbicides compared with one post-emergence (*i.e.* sodium arsenite as a standard estate practice) and one control (*i.e.* no herbicide applied). The treatments and the rate of application are shown below:

Herbicide treatment	*Active ingredient of the chemical*	*Rate (lb/acre) actual product*
Planavin (nitralin)	75 % w.p.	2
Karmex (diuron)	80 % w.p.	3
Telvar (monuron)	80 % w.p.	3
Sinbar (terbacil)	80 % w.p.	1
Treflan (trifluralin)	50 % e.c.	3
Sodium arsenite	—	2 % soln.
No herbicide (control)	—	—

The treatments were laid out in four randomised blocks of plot size 20′ × 20′. The herbicides were sprayed by mixing each with 80 gallons of water per acre. Five polybag palm seedlings were placed systematically within each plot one week after spraying.

The following observations were made within a recording area of 16′ × 16′ in each plot:

(1) The percentage cover of the regenerated weeds at 1, 2 and 3 months after spraying was estimated by a point quadrat method of sampling (Chandapillai, 1961). The method involves sampling 100 random points within each plot and enumerating the number of points touching the vegetation (once only), which is then expressed as the percentage of ground covered by the vegetation.

(2) The increment in length of the first fully opened palm frond.

Nursery Trial B in Bahau

The trial was established on a portion of a nursery on a Malacca series soil in Bahau in August 1968 with the following treatments in a randomised block design with two replications.

Herbicides	*Levels (lb/acre)*			
	L_1 *(Control)*	L_2	L_3	L_4
Karmex	0	1½	3	4½
Sinbar	0	½	1	1½
Telvar	0	1½	3	4½
Gesatamin (atratone) 50% w.p.	0	1½	3	4½

The ground was prepared according to routine estate practice but was further rotovated prior to spraying the herbicides. The polybag seedlings were emplaced on the treated soil in early September 1968 at a spacing of 3′ × 3′ in each plot of 20′ × 20′.

The percentage cover of weeds in plots was estimated by the point quadrat method mentioned earlier in an area of 16′ × 16′ within each plot.

Nursery Trial C in Negri Sembilan

This trial was established in May 1969 in a nursery on a Munchong-Durian complex soil in Negri Sembilan in order to confirm the effects of Karmex observed in the previous two trials, and in particular to see whether Karmex had any adverse effect on the growth of the polybag palm seedlings after the roots had penetrated into the treated soil.

The treatments compared three levels of Karmex at 1½, 3 and 6 lb per acre (actual product) with the untreated control. The trial followed a randomised block design where four treatments were randomised in each of the five blocks. A minimum of 40 polybag palm seedlings, surrounded by two guard rows of palms arranged at a spacing of 2′ 2″, formed the plot.

The experimental site was rotovated twice, levelled, and the clumps of existing vegetation removed manually. Karmex was sprayed in 60 gallons/acre. The rain which followed spraying was sufficient to help incorporation of the chemical into the soil.

The serially numbered polybag seedlings were emplaced in the nursery two days after spraying. The following observations were made:

(i) The number of fronds per palm and the length of the first fully opened frond at the time of spraying and three months after emplacement.

(ii) Visual assessment of the percentage weed regeneration at two and three months after spraying.

Field Trial D on an Estate in Negri Sembilan

The experimental nursery palms subjected to the various Karmex treatments in trial C were planted out at the end of three months' observation in the nursery, in a field consisting of a Malacca series soil. The planting followed exactly the same design and layout as adopted in the nursery trial.

The mean number of newly produced fronds and the length of the first fully opened frond at three months after planting into the field were recorded.

RESULTS

Nursery Trial A

The percentage cover of regenerated weeds at one, two and three months after spraying and the increment in length (cm) of the first fully opened frond for two months are given in *Table 1*.

Table 1. Weed cover (%) at 1, 2 and 3 months after spraying and the increment in length (cm) of the first fully opened palm frond during 2 months

Treatments	*Mean % cover of weeds* 1st month	2nd month	3rd month	*Increment in length (cm) of first fully opened frond (total of 5 fronds)*
Planavin	23.0	80.5	98.5	115.50
Karmex	14.5	28.3	81.8	121.75
Telvar	14.5	61.3	97.2	109.75
Sinbar	9.0	85.0	97.0	114.75
Treflan	35.0	89.5	98.2	109.50
Sodium arsenite	39.8	84.0	98.8	102.25
No herbicide	59.8	92.8	99.0	126.25
Mean	27.9	74.5	95.8	114.21
C.V. %	48.8	21.2	5.2	19.24
S.E. of mean	± 6.8	± 7.9	± 2.5	± 10.97
Min. 5% sig. diff.	20.2	23.5	7.5	32.58

Analysis of variance on the percentage weed cover showed highly significant treatment differences with Karmex—consistently the most effective herbicide throughout the three sampling periods. The equal efficiency of Sinbar, Telvar and Planavin with Karmex observed during the first month disappeared subsequently. No treatment differences were seen in the growth of young palms; inspection of the polybag seedlings did not reveal any abnormalities of growth.

The regenerated weeds comprised mostly sedges, *viz. Fimbristylis pauciflora, Cyperus rotundus, C. sphaceolatus, C. iria, C. diffusus, C. kyllingia* together with *Cynodon dactylon, Axonopus compressus* and *Paspalum conjugatum*. The occasional occurrence of *Eichornia crassipes* at the nursery site indicated the swampy nature of the experimental area, which coupled with the sprinkler irrigation enhanced the rapid growth of the sedges, which were unaffected by the herbicides.

Nursery Trial B

The percentage cover of the regenerated weeds three months after the application of treatments is shown in *Table 2.*

Table 2. Mean % cover of weeds at 3 months after herbicide application

Herbicides / Levels	Karmex	Telvar	Sinbar	Gesatamin	Average % cover
0	72	91	88	68	80
1	12	52	29	18	28
2	13	13	13	48	19
3	1	6	6	20	10
S.E. of mean			± 15.16		
Min. 5% sig. difference			45		

Analysis of variance of the data showed that differences between the four types of herbicides were not significant, while the levels at which the herbicides were applied showed significant differences ($P < 0.001$). The response to different levels of herbicides was largely linear. The overall mean values of the different levels (see *Table* 2) indicate the effectiveness of weed control at higher levels of application of the chemical.

Nursery Trial C

The mean percentage cover of the regenerated weeds assessed visually at three months after the establishment of the trial are shown in *Table 3*.

Table 3. Weed cover (%) at 3 months after spraying Karmex

Herbicide levels	lb/acre Karmex	Rep I	Rep II	Rep III	Rep IV	Rep V	Mean
0	No herbicide	85	100	80	80	80	85.0
1	1½	70	40	30	15	35	38.0
2	3	10	3	2	5	1	4.2
3	6	1	2	3	5	1	2.4
S.E. of mean			± 4.754				
Min. 5% sig. difference			14.65				

Fig. 1 (a) No herbicide (Control)

Fig. 1 (b) Karmex sprayed at $1\frac{1}{2}$ lb/acre

Fig. 1 (c) Karmex sprayed at 3 lb/acre

Fig. 1 (d) Karmex sprayed at 6 lb/acre

Analysis of variance of the data on percentage weed regeneration showed treatment differences to be highly significant ($P < 0.001$). The condition of the ground under the various treatments at the end of 3 months after establishment is shown in Fig. 1 (a), (b), (c) and (d).

The mean number of palm fronds and the length of the first fully opened frond at the time of spraying and three months after spraying are shown in *Table 4.*

Table 4. Mean number of fronds and the length (cm) of the first fully opened frond at the time of spraying and 3 months after spraying

Treatment levels	*Mean no. of fronds*		*Length (cm) of the first fully opened frond*	
	At spraying	*3 months after spraying*	*At spraying*	*3 months after spraying*
K_0	9.4	15.1	21.5	46.8
K_1	9.4	14.9	21.0	45.8
K_2	9.4	15.0	20.9	46.7
K_3	8.9	14.6	20.9	44.3
S.E.	± 0.106	± 0.117	± 0.665	± 1.276
Min. 5% sig. diff.	0.33	0.36	2.05	3.93

The significant differences existing at 5% level at the time of spraying (emplacement) in the number of fronds per palm allocated to the various treatments have not shown up at three months after spraying. No significant differences were established in terms of the length of the first fully opened frond either at the time of emplacement or three months after.

In order to reduce the experimental error by removing the effect of pre-treatment differences due to the inherent variability of the seedlings used in the study and to make sound post-treatment comparisons, the data on the length of the first fully opened frond was subjected to co-variance analysis. The unadjusted and the adjusted post-treatment lengths of the first fully opened frond under the various Karmex treatments are shown in *Table 5*. The covariance analysis increased the precision of the post-treatment data by more than 300%, and the regression coefficient was found highly significant. The analysis of variance on the adjusted post-treatment values showed, however, a significant treatment difference at 5% level due to Karmex sprayed at 6 lb/acre, which depressed the increase in frond length.

Table 5. The unadjusted and adjusted post-treatment length (cm) of the first fully opened frond

Treatments	Unadjusted	Adjusted
K_0	46.8	46.1
K_1	45.8	45.9
K_2	46.7	47.0
K_3	44.3	44.6
S.E.	± 1.276	± 0.695
Min. 5% sig. diff.	3.93	2.16

Field Trial D

The number of fronds and the length (cm) of the first fully opened frond of the palms three months after field planting are shown in *Table 6*.

Analysis of variance on both the number of fronds and the length of the first fully opened frond did not reveal any significant treatment differences, and showed that the field palms did not suffer from a possible residual effect of Karmex spraying at the nursery stage.

Table 6. Number of fronds and the length (cm) of the first fully opened frond 3 months after field planting

Treatment levels	No. of fronds	Length (cm) of first fully opened frond
K_0	3.60	78.88
K_1	3.77	79.31
K_2	3.77	79.09
K_3	3.78	75.76
S.E.	± 0.076	± 1.504
Min. 5% sig. diff.	0.23	4.64

DISCUSSION

The most salient observation which emerged from the various trials has been the marked efficacy of Karmex (diuron) in controlling weed regeneration in the polybag nurseries without causing ill effects on the subsequent growth of the polybag palms. Nursery trial A has demonstrated that although other pre-emergence herbicides (*i.e.* Sinbar, Telvar and Planavin) were as effective as Karmex during the first month after spraying, the effect of Karmex was found consistently better throughout the period of study (see *Table 1*). The semi-swampy nature of the nursery site and the practice of routine sprinkler irrigation had not considerably affected the efficacy of Karmex, as was the case with the other chemicals used. However, the succession of a sedge community comprising *Cyperus rotundus, C. iria, C. kyllingia, C. sphaceolatus, Fimbristylis pauciflora,* etc. in nursery trial A indicates that none of the pre-emergence herbicides used was effective against the dormant sedge seeds, the regeneration of which posed further problems of eradication. Under such situations, it may be better to resort to other methods of weed control such as to encourage creeping grasses by mowing, or by sequential spraying with suitable post-emergence herbicides. Although no significant difference was observed among the four types of herbicides employed in trial B in their effects on weed control, results (see *Table 2*) have indicated the overall efficacy of Karmex when compared on the basis of their cost of application. Trial B showed satisfactory control of weed regeneration until the end of the three months, and all indications suggested weed-free conditions might persist for another 2–3 months. The polybag palms did not show any adverse effect due to Karmex, although the roots had penetrated the treated soil. The highly significant treatment differences in terms of weed regeneration at increasing levels of Karmex application in nursery trial C (see *Table 3*) showed the efficacy of Karmex as a pre-emergence weedicide. The main objective of trial C was to see whether the polybag palms suffered any harmful effects when allowed to grow in the nursery even after the roots had penetrated the treated soil. The growth measurements of the palms (see *Table 4*) have indicated that the different levels of Karmex applied did not at all affect the growth of the palm seedlings except very negligibly at the 3rd level of herbicide. Although the analysis of covariance did indicate that application of Karmex at 6 lb/acre tends to depress the increment in frond length, the palms showed no ill effects or toxic symptoms. Whilst application of Karmex at both 3 lb and 6 lb/acre gave very good control of weeds (see *Table 3*), 3 lb Karmex/acre is recommended as the most desirable and economic rate to be adopted in the nursery, resulting in a considerable saving on the cost of weeding the polybag nursery.

The observation that the 3-month-old field palms, previously subjected to the various Karmex treatments in nursery trial C, did not show any significant difference either in the number of newly produced fronds or in the mean length of the first fully opened frond, suggests that the use of Karmex in the nursery soil had no adverse effect on the subsequent growth of the palms in the field. Parallel observations made by the author elsewhere in the field where Karmex was applied directly onto the weeding circles did not show ill effects on the subsequent growth of the young field palm (see also Sheldrick, 1969).

Economics of nursery application of Karmex

The approximate cost/acre of applying Karmex in the nursery is as follows:

Nursery preparation	$ ¢
Rotovation (2 rounds @ $10/- per acre/round)	20.00
Removal of grass clumps by manual picking @ $3.50 per man-day	10.50
Cost of 3 lb Karmex	30.00
Application cost including mixing, etc.	5.00
Total:	65.50

It is found that weed free conditions in the nursery persist for a period of 4–6 months after application of Karmex, resulting in a considerable saving of costs as compared with other forms of weeding.

CONCLUSIONS

Screening trials with selected pre-emergence herbicides designed to study their efficacy in controlling weeds in oil palm nursery have shown that Karmex (diuron) was the most efficient among the herbicides tested. Further studies have shown that Karmex applied at 3 lb/acre in 60 gallons water gave satisfactory weed control for a period of 4–6 months after application. The polybag palms placed on the treated soil have not shown any ill effects due to Karmex application even after the roots had penetrated the treated soil. Polybag plants from nurseries previously subjected to Karmex treatments did not show adverse effects in their subsequent growth in the field.

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DISCUSSION

Chairman: P.R. Wycherley

Cates: Did you observe *Cyperus rotundus* in any of the nurseries? I find it surprising that an application of 3–4 lb Karmex per acre could suppress this very resistant sedge.

Chandapillai: I agree that in waterlogged conditions *Cyperus rotundus* is impossible to eradicate by the method we have used.

Hew: Chemical control of weeds in oil palm nurseries has the additional advantage of avoiding damage to the polybags.

Does Mr. Chandapillai have any explanation of the fact that in trial A the best growth was obtained in the absence of herbicides?

Chandapillai: Although the increase in frond length was indeed greatest in the absence of herbicides, the increase was not statistically significant.

Paardekooper: We have found diuron and ametryne to be the most promising herbicides for weed control in rubber nurseries in Thailand. Rates of diuron above 2 lb/acre were somewhat phytotoxic to rubber seedlings, and 6 lb/acre caused high mortality. We apply the chemical immediately after planting the germinated seeds—*i.e.* on the same day. The seeds should be planted, when they have only just germinated, with no root showing. By this method we maintain weed-free conditions for at least a month, which is long enough, for after that gramoxone can be used.

Chandapillai: At the time the herbicide was sprayed in our nursery the seedlings had already grown, but they were not damaged.

Vellupillai: Did the author have any difficulty regarding the 'peelability' of the seedling stock, or with budding success? At what time were the stocks sprayed in relation to budding?

Chandapillai: We did not bud that particular nursery.

Barnes: There is quite a difference between the two situations which Mr. Paardekooper and the author described. In Mr. Chandapillai's experiments diuron was applied before the palm seedlings were placed in the nursery, so the only absorption would be via the roots. In the case of rubber seedlings emerging through treated soil, considerable absorption would occur through the young shoot. A high rate of application would be safe in one situation but not in the other.

Pushparajah: Concerning the effect of herbicides on budding success, our work has indicated that diuron adversely affects budding when applied at the rate of 5 lb a.i. per acre.

From the information given by the author I am not convinced that weed control has had any effect on the number or growth of fronds, because there were no significant differences between treatments. However, clean weeding may be beneficial in certain nurseries, particularly where there is likely to be competition for moisture between the palm roots and weeds. Where regular watering is carried out this competition would be less.

The residual effect of pre-emergence herbicides may be prolonged in wet conditions. Thus simazine, normally safe for use on maize, was found to be harmful when used in rather water-logged conditions.

Finally, it may be appropriate to point out that in the Ivory Coast allowing up to 50% weed regeneration after spraying, compared with maintaining bare conditions, has been found to give the optimum balance between the growth of the young rubber and the cost of maintenance. The presence of a certain amount of weed growth increases the quantity of organic matter in the soil, improves its structure, and facilitates rooting of the rubber and hence the uptake of nutrients.

Chandapillai: I would agree that as far as rubber is concerned growth in the early stages is satisfactory in clean-weeded areas, but that later on, the presence of a legume cover is beneficial because it contributes to the organic matter in the soil. The object of our work however, was to discover the best and cheapest method of weed control using pre-emergence herbicides. Frond length and number were measured only to detect any deleterious or beneficial effect on palm growth as a result of the herbicide.

Locke: We do not in fact recommend Karmex for use in rubber nurseries. Although economical, it may cause a reduction in budding success.

Wycherley: It costs about 5 cents to bud a plant, and the bud slip is worth about 2 cents, so a budding failure could cost up to about 10 cents.

Locke: But I am not defending the use of Karmex in rubber nurseries. Do not use it.

Hew: Weed control in oil palm nurseries is particularly important where cockchafers are present on the roots of the vegetation. I noticed that in one of the author's slides there was considerable cockchafer damage on the lower fronds, and I was wondering whether there is any difference in this respect in nurseries where weeds are well controlled and those where they are not.

Chandapillai: I have not looked into this particular point.

THE EFFECTS OF MAINTENANCE TECHNIQUES ON OIL PALM YIELD IN COASTAL CLAY AREAS OF WEST MALAYSIA

by

Hew Choy Kean and Tam Tai Kin

SUMMARY

Two experiments, one starting from the immature phase and the other after maturity, were carried out, comparing mechanical mowing of ground covers with other methods of field upkeep.

Mechanical mowing at monthly, bi-monthly or four-monthly intervals was found to have adverse effects on palm growth (as measured by frond length, weight and area) though not on the number of fronds produced. Fertiliser application significantly increased frond production. Palm nutrition was also adversely affected by mechanical mowing; leaf nitrogen and phosphorus especially were depressed in mechanically-mown plots.

Yield of palms in mechanically mown plots were greatly depressed. In the first experiment, over 3¾ years bi-monthly (previously monthly) mechanically-mown plots yielded the least crop at 26.13 tons f.f.b. per acre, 8.16 tons f.f.b. per acre less than the highest yielding treatment (naturals with *Mikania*) at 34.29 tons f.f.b. per acre. Four-monthly mechanical mowing (previously *Stylosanthes* slashed) yielded only 28.74 tons f.f.b. per acre for the same period. The number of bunches produced was the least in bi-monthly mown plots (3117 bunches per acre) followed by that of four-monthly mechanically mown plots (3449 bunches per acre). Fertilisers raised crop production in bi-monthly mown plots by 4.08 tons f.f.b. per acre over 3¾ years. In the second experiment over 6½ years, bi-monthly mown plots yielded the least crop (62.65 tons f.f.b. per acre; 5013 bunches per acre). Compared to the highest yielding treatment (bare plots) the difference was 9.34 tons f.f.b. per acre. Fertiliser application raised yields in bi-monthly mown plots by 6.60 tons f.f.b. per acre over a 2¾ year period.

Mechanical mowing has thus been found to be unsuitable as a labour-saving alternative to conventional methods of field upkeep. Palms in bare plots are high yielding as competition from ground covers is minimised. The undesirable effects of *Mikania* on palm yield were apparent when *Mikania* formed about 45% of the ground cover.

In the coastal clay areas in Malaysia, the general cover policy on many oil palm estates has been to grow and maintain pure legume covers, mainly *Pueraria* and *Centrosema*, during the period of immaturity. During this period, the palm circle is usually kept bare by manual clean-weeding to reduce competition by weeds for moisture and nutrients. The legume covers between palm rows are kept pure by regular and frequent selective manual weeding to remove all noxious growths and grasses, because a crop reduction of some 20% can occur when *Mikania* and lallang (*Imperata cylindrica*) become dominant (Gray & Hardon, 1967). Although this system of maintenance during the immature period has been shown to be beneficial to the palms in respect of growth and subsequent yield (Gray & Hew, 1964, 1967;

Hew & Tam, 1964–1969), it is very labour-intensive and may represent one-quarter or more of the total expenditure on replanting to maturity. In estates with large acreages of immature plantings, there are additional difficulties and costs in accommodating a large labour force if contract labour is not readily available. It was therefore necessary to investigate alternative methods of field upkeep in immature areas, the aim being to find suitable alternatives that have no adverse effects on palm growth and yield.

In mature areas, maintenance of ground vegetation is concerned mainly with (a) palm circle weeding, to minimise competition by other vegetation for nutrients and moisture and also to facilitate crop collection; (b) slashing and/or spraying of harvesters' paths to facilitate ease of entry into the field for harvesting, manuring and supervision; and (c) selective weeding of the interrows, either manually or chemically, to prevent the establishment of noxious weeds that have detrimental effects on palm growth and yield. This method of ground cover upkeep has been widely adopted and appears satisfactory from the aspect of palm yield. However, it was felt that mechanical control of ground vegetation in the harvesters' paths and interrow areas of mature fields on flat coastal areas required investigation because of possible savings in labour, weeding and supervision costs. Another aspect of ground cover control involves the presence of *Mikania* in the natural covers in mature areas. *Mikania* has been shown to depress both palm growth and early yields (Gray & Hew, 1967) but the *Mikania* in that investigation formed a pure stand. Its effects may not be so adverse if it constitutes only a small proportion of the ground cover. Experiments were therefore laid down at the Oil Palm Research Station, Banting, to compare methods of field upkeep both in immature and mature areas. These experiments and the results obtained are described in this paper.

I. IMMATURE AREAS

EXPERIMENTAL

An experiment was set up in November 1962 to compare five upkeep treatments in an immature D × P oil palm area on coastal clay (Selangor Series). The upkeep treatments were: (A) bare ground, maintained by spraying with 2% sodium arsenite monthly; (B) *Stylosanthes gracilis*, controlled by three-monthly manual slashing (later changed to mechanical mowing at four-monthly intervals from mid-1967); (C) natural covers, including *Mikania*; (D) monthly mechanical mowing of grasses (later changed to bi-monthly from mid-1967); and (E) *Pueraria* and *Centrosema* (later reverted to natural covers without *Mikania*). From June 1966, all upkeep treatments except D were done at bi-monthly intervals.

A split plot design, replicated four times, was used; main plots of upkeep treatments, each of 48 palms, were split for two levels of fertiliser application—manured and not manured. Sub-plots were each of 24 palms. Until December 1969, a total of 10 lb sulphate of ammonia, 4 lb C.I.R.P., 25 lb Nitro 26 and

Table 1. Frond measurements following various methods of upkeep

Treatments		Frond length (cm)			Frond wt. (g)		Frond leaf area (m^2)		No. of fronds/palm	
		2 yr*	3 yr*	6½ yr**	3 yr*	6½ yr**	3 yr*	6½ yr**	3 yr*	5½ - 6½ yr
(A) Bare plot	No fert.	243.5	342.2	504.7	2126	5067	6.7	13.6	31	25
	With fert.	236.2	330.0	526.4	1931	5278	6.8	13.6	30	26
	Mean	239.9	336.1	515.5	2028	5173	6.8	13.6	31	26
(B) *Stylosanthes* slashed	No fert.	225.6	329.4	493.5	1906	4222	6.4	12.5	30	25
	With fert.	236.5	330.1	511.3	1905	4758	6.2	12.6	30	27
	Mean	231.0	329.7	502.4	1905	4490	6.3	12.5	30	25
(C) Naturals with *Mikania*	No fert.	238.4	347.1	524.1	2043	5330	6.5	13.4	30	25
	With fert.	233.8	356.6	528.0	2162	5286	6.5	13.7	30	25
	Mean	236.1	351.9	526.0	2102	5308	6.5	13.6	30	25
(D) Mechanical mowing	No fert.	202.4	288.4	493.6	1447	4149	5.9	12.2	30	25
	With fert.	200.6	329.6	515.2	1940	4668	6.4	12.4	30	27
	Mean	201.5	309.0	504.4	1694	4409	6.1	12.3	30	26
(E) *Pueraria* and *Centrosema*	No fert.	208.5	331.4	530.4	1904	5297	6.3	13.3	30	25
	With fert.	212.1	321.4	512.2	1823	5011	6.4	13.2	30	26
	Mean	210.3	326.4	521.3	1863	5154	6.4	13.3	30	25
	No fert.	223.7	327.7	509.3	1885	4813	6.4	13.0	30	25
	With fert.	223.7	333.6	518.6	1952	5000	6.5	13.1	30	26
	Mean	223.7	330.6	513.9	1918	4907	6.4	13.1	30	25
S.E. Covers		± 7.0	± 9.0	±18.7	± 92	±431	±0.2	±0.6	±0.4	±0.6
S.E. Fertiliser		± 4.5	± 7.6	± 5.8	± 80	±110	±0.2	±0.3	±0.2	±0.4
S.E. Within Covers		±10.2	±17.1	±12.9	±180	±245	±0.4	±0.7	±0.4	±1.0
S.E. Within Fertiliser		±10.0	±15.0	±20.8	±157	±465	±0.4	±0.7	±0.5	±0.9

* Frond 1 measured.

** Frond 17 measured.

12 lb NPK2 (8% N, 8% P_2O_5, 17% K_2O, 2% MgO) were applied to palms in sub-plots getting fertilisers. The experiment was carried on from the immature period into the mature phase.

RESULTS

Frond development. Frond measurement data taken during the immature period indicated that differences in frond length between treatments were significant after two and three years, palms in mechanically-mown plots (treatment D) having the shortest fronds. Differences in frond weight after three years were also significant, with palms in treatment D having the lightest fronds. The leaf area of palms in treatment D was also significantly smaller than that of palms in bare plots and plots with natural covers including *Mikania*. There were no differences in the number of fronds per palm after three years. Data collected after 6½ years showed that palms in plots mechanically-mown (bi-monthly and four-monthly) had shorter, lighter and smaller fronds compared with other treatments; differences, however, were not statistically significant. There were no differences between treatments for number of fronds produced but fertiliser application significantly increased frond production (*Table 1*).

Nutrient status. The first leaf analyses, made after three years, are shown in *Table 2*. Differences between treatments for leaf nitrogen and phosphorus were significant; palms in mechanically-mown plots (treatment D) had the lowest leaf nitrogen and phosphorus levels. The application of fertiliser raised leaf nitrogen and phosphorus for palms in the *Stylosanthes* plots, mechanically-mown plots and plots with *Pueraria* and *Centrosema*. Overall differences between treatments for leaf potassium, magnesium, calcium were not significant.

Foliar analysis results of samples collected when harvesting commenced (3½-yr-old) showed that differences in leaf nitrogen, phosphorus, potassium, magnesium and calcium were significant; leaf nitrogen, phosphorus and potassium levels for palms in mechanically-mown plots were again significantly lower, while leaf magnesium was higher.

Significant differences in leaf phosphorus, magnesium and calcium levels were seen in foliar analysis data after seven years. Leaf magnesium levels in bi-monthly mown plots were significantly higher. The application of fertiliser had significantly raised leaf nitrogen levels in four-monthly mown plots, plots with natural covers including *Mikania*, and plots originally with *Pueraria*/*Centrosema*. Fertiliser application significantly raised leaf phosphorus levels in all treatments except bare plots.

Yield. Records of yield as expressed in the weight (f.f.b.) and number of fruit bunches produced are presented in *Table 3*. For the period 40–55 months after the experiment began, differences in f.f.b. production between treatments were

Table 2. *Leaf nutrient analysis data of frond 17 following different maintenance techniques*

Treatments		N %			P %			K %			Mg %			Ca %		
		3 yr	3½ yr	7 yr	3 yr	3½ yr	7 yr	3 yr	3½ yr	7 yr	3 yr	3½ yr	7 yr	3 yr	3½ yr	7 yr
(A) Bare plot	No fert.	3.03	2.86	2.70	0.167	0.162	0.161	0.87	1.04	0.82	0.34	0.35	0.25	0.62	0.55	0.45
	With fert.	3.03	2.85	2.73	0.166	0.169	0.158	0.94	1.16	0.78	0.31	0.36	0.24	0.57	0.52	0.45
	Mean	3.03	2.86	2.71	0.167	0.165	0.160	0.91	1.10	0.80	0.32	0.35	0.24	0.60	0.54	0.45
(B) *Stylosanthes* slashed	No fert.	3.00	2.80	2.64	0.167	0.165	0.162	0.95	1.14	0.78	0.33	0.36	0.26	0.58	0.48	0.47
	With fert.	3.06	2.94	2.74	0.173	0.171	0.168	0.94	1.10	0.80	0.33	0.36	0.24	0.58	0.52	0.44
	Mean	3.03	2.87	2.69	0.170	0.168	0.165	0.95	1.12	0.79	0.33	0.36	0.25	0.58	0.50	0.46
(C) Naturals with *Mikania*	No fert.	2.84	2.94	2.63	0.168	0.170	0.164	0.99	1.14	0.83	0.35	0.35	0.26	0.64	0.57	0.51
	With fert.	2.87	2.92	2.71	0.169	0.171	0.166	0.93	1.06	0.81	0.34	0.36	0.27	0.63	0.57	0.49
	Mean	2.85	2.93	2.67	0.168	0.171	0.165	0.96	1.10	0.82	0.35	0.36	0.26	0.63	0.57	0.50
(D) Mechanical mowing	No fert.	2.69	2.49	2.68	0.156	0.157	0.164	0.95	1.08	0.79	0.36	0.43	0.28	0.62	0.56	0.50
	With fert.	2.76	2.53	2.72	0.161	0.160	0.167	0.94	1.09	0.80	0.34	0.42	0.29	0.61	0.55	0.47
	Mean	2.72	2.51	2.70	0.158	0.159	0.165	0.94	1.09	0.79	0.35	0.42	0.29	0.61	0.56	0.48
(E) *Pueraria* and *Centrosema*	No fert.	2.99	3.06	2.60	0.171	0.174	0.161	1.00	1.18	0.79	0.33	0.34	0.26	0.58	0.50	0.45
	With fert.	3.09	3.10	2.67	0.173	0.182	0.167	0.98	1.14	0.81	0.32	0.35	0.24	0.58	0.55	0.43
	Mean	3.04	3.08	2.63	0.172	0.178	0.164	0.99	1.16	0.80	0.33	0.34	0.25	0.58	0.52	0.44
	No fert.	2.91	2.83	2.65	0.166	0.166	0.162	0.95	1.12	0.80	0.34	0.37	0.26	0.61	0.53	0.47
	With fert.	2.96	2.87	2.71	0.168	0.170	0.165	0.95	1.11	0.80	0.33	0.37	0.25	0.59	0.54	0.46
	Mean	2.93	2.85	2.68	0.167	0.168	0.164	0.95	1.11	0.80	0.34	0.37	0.26	0.60	0.54	0.46
S.E. Covers		±0.04	±0.08	±0.04	±0.003	±0.004	±0.003	±0.04	±0.03	±0.03	±0.01	±0.02	±0.02	±0.02	±0.03	±0.02
S.E. Fertiliser		±0.01	±0.03	±0.02	±0.001	±0.002	±0.001	±0.01	±0.03	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01
S.E. Within Covers		±0.03	±0.06	±0.03	±0.003	±0.004	±0.001	±0.03	±0.06	±0.02	±0.01	±0.01	±0.02	±0.03	±0.03	±0.03
S.E. Within Fertiliser		±0.04	±0.09	±0.05	±0.003	±0.005	±0.003	±0.04	±0.05	±0.04	±0.01	±0.02	±0.02	±0.03	±0.04	±0.03

Table 3. Yield records following different techniques of maintenance and fertiliser application

Treatment		F.F.B. (tons per acre)			No. of bunches per acre		
		40-55 months	56-86 months	40-86 months	40-55 months	56-86 months	40-86 months
(A) Bare plot	No fert.	6.52	26.67	33.22	1503	2628	4133
	With fert.	6.27	26.09	32.39	1201	2407	3610
	Mean	6.40	26.38	32.81	1352	2517	3871
(B) *Stylosanthes* slashed	No fert.	5.59	22.36	27.98	1046	2274	3318
	With fert.	5.32	24.17	29.51	1160	2419	3579
	Mean	5.45	23.27	28.74	1103	2347	3449
(C) Natural with *Mikania*	No fert.	8.69	26.15	34.89	1323	2430	3748
	With fert.	8.86	24.77	33.68	1258	2093	3350
	Mean	8.78	25.46	34.29	1291	2261	3549
(D) Mechanical mowing	No fert.	4.17	19.55	23.73	817	2142	2955
	With fert.	3.92	24.60	28.53	792	2485	3279
	Mean	4.05	22.07	26.13	805	2313	3117
(E) *Pueraria* and *Centrosema*	No fert.	6.94	23.19	30.17	1250	2319	3572
	With fert.	8.12	25.77	33.92	1389	2444	3828
	Mean	7.53	24.48	32.04	1319	2382	3700
	No fert.	6.38	23.59	29.99	1185	2359	3542
	With fert.	6.50	25.08	31.61	1160	2370	3528
	Mean	6.44	24.33	30.79	1172	2364	3535
S.E. Covers		±1.04	±1.87	±2.75	±171	±179	±314
S.E. Fertiliser		±0.42	±0.85	±1.10	± 60	± 98	±111
S.E. Within Covers		±0.95	±1.90	±2.47	±134	±220	±247
S.E. Within Fertiliser		±1.24	±2.30	±3.25	±196	±237	±359

significant, with monthly-mown plots yielding the least crop and plots with natural covers yielding the most. Differences in the numbers of bunches produced were also significant, with monthly-mown plots yielding the least number of bunches; the highest number was obtained from bare plots. When plots in treatment D were changed to bi-monthly mowing, during the period of 56–86 months of the experiment, they yielded the least crop while plots with natural covers yielded the least number of bunches. The differences in f.f.b. production between the highest yielding treatment (bare plots) and the lowest (bi-monthly mown plots) was significant.

When cumulative yields for the experimental period of 40–86 months were considered, bi-monthly mown plots still produced the least crop, followed by four-monthly mown plots. Bi-monthly mown plots were significantly lower-yielding than bare plots, plots with natural covers and plots originally with *Pueraria/Centrosema*. Four-monthly mown plots were also significantly lower-yielding compared to plots with natural covers. The fertilisers applied from 1963 to 1969 increased yields in the bi-monthly mown plots. For the same period, bi-monthly mown plots produced the least number of bunches, followed by four-monthly mown plots. The highest number of bunches was obtained from bare plots. The difference in bunch production between bare plots and bi-monthly mown plots was significant.

II. MATURE AREAS

EXPERIMENTAL

The experiment was started in June 1963 in a D × T oil palm area planted in October 1958 at 49 palms per acre, ex-rubber, on marine (Selangor Series) clay. The upkeep treatments, were: (A) natural covers, excluding *Mikania*; (B) bare plot, maintained by bi-monthly sodium arsenite spraying; (C) grass cover, maintained by bi-monthly mechanical mowing; and (D) natural covers including *Mikania*. Originally designed as a randomised block experiment with five replications, the plots, each of 48 palms, were split for fertiliser application in February 1967. Until December 1969 a total of 25 lb Nitro 26, 10 lb calcium ammonium nitrate and 6 lb C.I.R.P. were applied per palm in sub-plots receiving fertilisers. The covers in the area were originally *Pueraria* and *Centrosema* but reverted to natural covers when the experiment commenced.

RESULTS

Frond development. Frond measurement data taken after three, four and six years are shown in *Table 4*. Earlier growth of palms was slightly inferior for palms in mechanically-mown plots and plots with natural covers including *Mikania;* differences were, however, not significant. The later data again showed that palms in the mechanically-mown plots had the shortest, lightest and smallest fronds compared to palms in other treatments; again differences were not significant. Differences in frond production were also not significant for main (upkeep) treatments, but fertiliser application significantly increased the number of fronds produced per palm.

Table 4. Frond measurements following different upkeep treatments

Treatment		Frond length (cm)			Frond wt. (g)			Frond leaf area (m^2)			No. of fronds/palm produced between
		3 yr*	4 yr**	6 yr**	3 yr*	4 yr**	6 yr**	3 yr*	4 yr**	6 yr**	5 and 6 years
(A) Naturals excluding *Mikania*	No fert.	-	538.0	581.9	-	6402	7914	-	16.2	18.5	29
	With fert.	-	532.9	576.0	-	6374	7910	-	17.0	18.1	29
	Mean	557.2	535.4	579.0	6267	6388	7912	14.9	16.6	18.3	29
(B) Bare plot	No fert.	-	529.3	570.9	-	6226	7327	-	16.2	18.2	28
	With fert.	-	522.6	547.6	-	6347	7547	-	16.0	17.5	30
	Mean	533.8	525.9	559.2	6286	6287	7437	14.8	16.1	17.9	29
(C) Bi-monthly mechanical mowing	No fert.	-	525.4	554.8	-	5532	6834	-	15.2	17.2	28
	With fert.	-	521.4	561.0	-	5662	7551	-	15.0	17.7	30
	Mean	531.8	523.4	557.9	5843	5597	7192	14.5	15.1	17.5	29
(D) Naturals including *Mikania*	No fert.	-	528.0	569.0	-	6171	7540	-	16.4	19.0	28
	With fert.	-	522.8	565.7	-	6079	7634	-	15.6	18.2	30
	Mean	524.7	525.4	567.4	5823	6125	7587	14.5	16.0	18.6	29
	No fert.	-	530.2	569.2	-	6083	7404	-	16.0	18.2	28
	With fert.	-	524.9	562.6	-	6116	7660	-	15.9	17.9	30
	Mean	536.7	527.5	565.9	6055	6099	7532	14.7	16.0	18.1	29
S.E. Covers		±12.3	±10.9	±10.8	±314	±379	±358	±0.7	±0.5	±0.6	±0.8
S.E. Fertiliser		-	± 4.9	± 6.4	-	±118	±179	-	±0.2	±0.3	±0.5
S.E. Within Covers		-	± 9.7	±12.8	-	±237	±358	-	±0.4	±0.7	±1.0
S.E. Within Fertiliser		-	±12.9	±14.1	-	±414	±439	-	±0.6	±0.7	±1.1

* Frond 1 measured.

** Frond 17 measured.

Table 5. *Foliar analysis of frond 17 following various methods of upkeep*

Treatment		N %			P %			K %			Mg %			Ca %		
		2 yr	4 yr	6 yr	2 yr	4 yr	6 yr	2 yr	4 yr	6 yr	2 yr	4 yr	6 yr	2 yr	4 yr	6 yr
(A) Naturals excluding Mikania	No fert.	-	2.31	2.36	-	0.161	0.162	-	1.00	0.92	-	0.35	0.31	-	0.52	0.49
	With fert.	-	2.45	2.48	-	0.166	0.168	-	1.00	0.92	-	0.35	0.29	-	0.47	0.43
	Mean	2.71	2.38	2.42	0.167	0.164	0.165	0.93	1.00	0.92	0.31	0.35	0.30	0.54	0.49	0.46
(B) Bare plot	No fert.	-	2.45	2.41	-	0.167	0.168	-	0.98	0.87	-	0.36	0.30	-	0.53	0.46
	With fert.	-	2.54	2.57	-	0.171	0.170	-	1.05	0.90	-	0.36	0.28	-	0.47	0.46
	Mean	2.81	2.50	2.49	0.171	0.169	0.169	0.97	1.02	0.88	0.29	0.36	0.29	0.52	0.50	0.46
(C) Bi-monthly mechanical mowing	No fert.	-	2.15	2.34	-	0.156	0.163	-	0.93	0.89	-	0.39	0.32	-	0.55	0.45
	With fert.	-	2.40	2.49	-	0.168	0.169	-	1.01	0.97	-	0.35	0.30	-	0.49	0.42
	Mean	2.51	2.28	2.42	0.160	0.162	0.166	0.91	0.97	0.93	0.32	0.37	0.31	0.58	0.52	0.44
(D) Naturals including Mikania	No fert.	-	2.34	2.37	-	0.165	0.168	-	0.99	0.91	-	0.36	0.31	-	0.54	0.52
	With fert.	-	2.50	2.49	-	0.168	0.170	-	1.05	0.96	-	0.34	0.28	-	0.51	0.48
	Mean	2.67	2.42	2.43	0.167	0.166	0.169	0.92	1.02	0.94	0.29	0.35	0.30	0.60	0.53	0.50
	No fert.	-	-	2.37	-	-	0.165	-	-	0.90	-	-	0.31	-	-	0.48
	With fert.	-	-	2.51	-	-	0.169	-	-	0.94	-	-	0.29	-	-	0.45
	Mean	-	-	2.44	-	-	0.167	-	-	0.92	-	-	0.30	-	-	0.46
S.E. Covers		±0.04	±0.06	±0.02	±0.004	±0.003	±0.003	±0.03	±0.04	±0.03	±0.01	±0.01	±0.01	±0.03	±0.04	±0.03
S.E. Fertiliser		-	±0.02	±0.02	-	±0.001	±0.001	-	±0.02	±0.02	-	±0.01	±0.01	-	±0.01	±0.01
S.E. Within Covers		-	±0.04	±0.04	-	±0.002	±0.003	-	±0.04	±0.05	-	±0.02	±0.01	-	±0.03	±0.02
S.E. Within Fertiliser		-	±0.07	±0.04	-	±0.003	±0.003	-	±0.05	±0.04	-	±0.02	±0.01	-	±0.04	±0.03

Nutrient status. Leaf nutrient analyses were first made after two years, and results are shown in *Table 5*. The bi-monthly mown plots show significantly lower leaf nitrogen and phosphorus levels but higher leaf magnesium levels. One year later, significantly lower leaf nitrogen and phosphorus levels were also obtained from the mown plots. After four years similar results were obtained: leaf nitrogen and phosphorus levels were again lower in the mechanically-mown plots. The application of fertilisers significantly raised leaf nitrogen levels in all treatments, especially mechanically-mown plots. Leaf phosphorus levels in all treatments, except plots with natural covers including *Mikania*, were also significantly raised. Leaf potassium levels in mechanically-mown plots were also raised by fertiliser application. In the following year, similar results were obtained, with significantly lower leaf nitrogen and phosphorus levels in mechanically-mown plots. There was also a significant increase in leaf nitrogen levels where fertiliser was applied. After six years, leaf nitrogen levels in plots with natural covers including *Mikania*, plots mechanically mown, and plots with natural covers excluding *Mikania*, were significantly lower than those in bare plots. Fertiliser application significantly raised leaf nitrogen in all treatments, and also raised the leaf phosphorus in mechanically-mown plots and plots with natural covers excluding *Mikania*.

Yield. Yield records are shown in *Table 6*. For the period before the upkeep treatments were split for fertiliser application, differences in yield were significant, the lowest yielding treatment being bi-monthly mechanical mowing while the highest yield was obtained from bare plots. Differences in bunch production were, however, not significant, but bi-monthly mown plots produced the least number of bunches.

Over the whole period of the experiment, cumulative yield data showed that, of the upkeep treatments, bi-monthly mown plots had the lowest yield, being significantly lower than plots with natural covers excluding *Mikania* and bare plots. Differences in bunch production were, however, not significant.

After treatments were split for fertiliser application, interactions between treatments brought about significant differences in yield. Bi-monthly mechanical mowing brought about yields significantly lower than treatments of natural covers excluding *Mikania* and bare plots. Bi-monthly mown plots also yielded significantly fewer bunches than bare plots.

There were significant overall yield responses to fertiliser applications over the two-year period. The greatest yield response was obtained with the bi-monthly mechanical mowing treatment. There was also significant response in bunch production in the same treatment.

Table 6. Yield records following different upkeep treatments

Treatment		1 - 43 months F.F.B. tons per acre	1 - 43 months No. bunches per acre	44 - 78 months F.F.B. tons per acre	44 - 78 months No. bunches per acre	1 - 78 months F.F.B. tons per acre	1 - 78 months No. bunches per acre
(A) Natural covers excluding Mikania	No fert.	-	-	28.59	1795	-	-
	With fert.	-	-	33.11	1930	-	-
	Mean	39.82	3348	30.85	1863	70.65	5212
(B) Bare plot	No fert.	-	-	31.42	1933	-	-
	With fert.	-	-	32.16	2007	-	-
	Mean	40.21	3419	31.79	1970	71.97	5393
(C) Bi-monthly mechanical mowing	No fert.	-	-	23.93	1645	-	-
	With fert.	-	-	30.53	1891	-	-
	Mean	35.46	3244	27.22	1769	62.65	5013
(D) Natural covers including Mikania	No fert.	-	-	29.15	1844	-	-
	With fert.	-	-	29.00	1817	-	-
	Mean	36.17	3307	29.07	1830	65.20	5138
	No fert.	-	-	28.27	1805	-	-
	With fert.	-	-	31.20	1912	-	-
	Mean	37.92	3330	29.74	1858	67.62	5189
S.E. Covers		±1.78	±161	±1.38	±100	±2.98	±242
S.E. Fertiliser		-	-	±0.69	± 67	-	-
S.E. Within Covers		-	-	±1.38	±134	-	-
S.E. Within Fertiliser		-	-	±1.69	±138	-	-

DISCUSSION

From the data collected from the two experiments, it can be seen that the different methods of ground cover upkeep and maintenance have profound effects on the yield of oil palms, for crop could be reduced considerably. Mechanical mowing at monthly, bi-monthly or even four-monthly intervals cannot be recommended as a long-term field upkeep policy in immature or mature areas. It adversely affected palm growth (as measured by frond length, weight and leaf area) during both the immature and mature periods. Palm nutrition was also adversely affected by mechanical mowing; leaf nitrogen and phosphorus levels were consistently and significantly lower in the mechanical mowing treatments than levels in the other upkeep treatments.

As would have been expected, keeping the plots bare and thus reducing or virtually eliminating all competition from ground cover, had the most beneficial effects. This was shown by the yields from plots with this treatment; in mature areas over 6½ years, the highest was obtained from the bare plot treatment. These results were in line with those obtained by Lucy (1940) who found that clean weeding gave higher yields than four-monthly slashing of ground covers.

The *Mikania* in treatment D in mature palms (naturals including *Mikania*) formed about 45% of the ground cover. It can be seen from the data in *Tables 4* and *6*, that although growth of palms (as shown by frond measurements) in this treatment was comparable to the treatment where *Mikania* was excluded, yields over 6½ years were less. It would appear, therefore, that an effect of *Mikania* on palms in mature areas can be expected when it forms about 45% of the ground cover. In the immature trial, the *Mikania* formed a much larger proportion of the ground cover. Unfortunately, comparison from the yield data presented for the early period was masked by the effects of damage by rhinoceros beetle, bagworm and *Tirathaba* caterpillars. Later yield performance will need to be examined.

The fertilisers were applied with the object of ameliorating the depressive effects of mechanical mowing on palm nutrition, *i.e.* to arrest the fall of leaf nitrogen and phosphorus levels. As can be seen from the results of foliar analyses of these two experiments, there were very significant responses in leaf nitrogen and phosphorus to these fertiliser applications in the mechanically-mown plots. This was also accompanied by very significant yield responses.

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DISCUSSION

Chairman: D.E. Barnes

Smith: It is very interesting to learn that mechanical slashing causes a reduction in yield and frond production. What I would like to know is whether we should plant a cover crop at all in areas that are not too hilly. I know that a legume cover prevents erosion on steep land, but if there are no significant responses in yield and girth why spend money on establishing and maintaining such a cover? Would it not be preferable instead to keep good natural covers, but weed out *Mikania*, bracken and noxious growths?

Hew: We carried out a cover crop experiment in 1958 which demonstrated very convincingly the yield advantage of leguminous covers. We also carried out experiments which included treatments where, in order to reduce costs, the covers were maintained for only 1½ years. Although your point is valid, we ourselves are fully convinced of the beneficial effects of leguminous covers. Nevertheless, I believe that when the palms are mature, soft grasses can be tolerated, for we found in our experiments that after 7 years of harvesting the differences between the plots which were previously under leguminous cover and those which all the time had grasses were not significant. We therefore need to examine our cover crop policy again, and in doing so also bear in mind the likely market price of palm oil.

Pushparajah: From *Table 4* it is apparent that the increase in frond length between the 3rd and 6th year is similar in treatment C—bi-monthly mechanical mowing—to that in the bare plot. Similarly for frond weight: the increase is 1 350 g for the mown plot and 1 150 g for the bare plot. There is practically no difference in the increase in leaf area in the two treatments. This therefore implies that bi-monthly mechanical mowing may even be beneficial. This is suggested also by the leaf nitrogen levels (*Table 5*). In the second year the mown plot has 2.5%N, while the bare plot has 2.8%; averaged over the six years there is hardly any difference in nitrogen levels between the two treatments. I therefore suggest that the yield differences in the first 43 months (*Table 6*) of about 5 tons between the mown and bare plots could have been due to pre-treatment differences in yield.

Hew: Because there was such a huge response to fertilizers in the mown plot, the mean is increased; I think therefore that you should compare the minus fertilizer levels of the bare plot against the similar minus fertilizer data from the mown plot. The differences then are much more in favour of the bare plot treatment.

Pushparajah: Were the pre-treatment differences for the fertilized and unfertilized plots similar?

Hew: When we noticed that the nitrogen and phosphorus levels were depressed we applied the fertilizer. However, it takes about 1½ years before any depression in yield can be seen in the mown plot.

Tam: Mr. Pushparajah suggested that the yield differences in the first 43 months between mown and bare plots were due to pre-treatment differences, and not to the treatment itself. I have annual yield figures which show that for the first 1½ years there were practically no differences, and that differences in yield were only apparent from the 3rd year.

Awcock: I noticed from the slides that the whole inter-row area was mown. Why was it considered necessary to do this, and not just the planting strips or harvesting paths?

Hew: We wished, for experimental purposes, to compare extremes of treatment—completely sprayed (bare) with completely mown.

Awcock: You are thus comparing extremes which do not necessarily apply in estate practice?

Hew: I fully agree.

Awcock: The experiment seems almost designed to prove that mowing is detrimental! Ground cover in the experimental area was very light in any case, and there did not seem much purpose in mowing anyway. Do the authors have any trials where mowing is followed by spraying, so that the detrimental effects of mowing, which lie in the rapid regrowth of weeds, are avoided?

Hew: We have indeed carried out experiments on the lines you suggest, mowing alternating with spraying. Unfortunately we have no long-term results as yet.

Awcock: Have you made any observations on soil compaction where mowing was done?

Hew: Yes, we found that there was a harder pan around palms in the bare plot treatment than where mowing was done.

Awcock: Therefore if mowing has a depressive effect on yield, it is due to enhanced nutrient uptake by the weeds?

Hew: At the moment I can only say that this depressive effect is tied up with the microbiological mineralisation of the grass cuttings which are left behind after mowing. We tried to establish if a loss of nitrogen was taking place through denitrification.

Tam: We were considering removing all the fronds heaps in the mechanically mown plots by slashing them up, hoping in that way to control rat damage also. However, this idea did not work, for we still have rat damage.

Gray: As I was involved in setting up these experiments I would like to comment on Mr. Awcock's remark that these experiments were intended to prove that mowing grass was a bad thing. At that time we had no idea what mowing would do. On certain estates, particularly on inland soil, close cutting was a routine method of upkeep, and therefore we felt this had to be investigated. We also thought that mowing might help with rat control and make supervision easier.

DEVELOPING A 'ONE-SHOT' TREATMENT

by

A. K. Seth

SUMMARY

In trials on mixed weed swards in plantations, mixtures of either paraquat 0.75 lb/ac + diuron 0.75 lb/ac or paraquat 0.25 lb/ac + diuron 0.25 lb/ac + MSMA 1.5 lb/ac gave lasting control.

INTRODUCTION

In plantation crops in Malaysia, grasses are usually the dominant weeds. Amongst these *Paspalum conjugatum, Axonopus compressus* and *Ottochloa nodosa* appear to be the most important species, with *Eleusine indica* and *Digitaria* sp. also present commonly but in relatively small amounts.

Traditionally, sodium arsenite has been used for weed control but it presents serious toxicological hazards both to the user and also to young crop plants. Riepma (1962a, 1962b, 1963, 1965) in an attempt to arrive at safe and effective alternatives to sodium arsenite, evaluated a number of compounds, *e.g.* dalapon, Amitrole–T, disodium methylarsonate and paraquat, and concluded that paraquat is the most effective treatment for use against *Axonopus compressus;* in the short term paraquat was also the most effective treatment against *Paspalum conjugatum* and *Ottochloa nodosa.* For prolonged control, however, in particular of *P. conjugatum,* Amitrole–T and DSMA were found to be more effective than paraquat. Headford (1966) while studying measures for the control of *P. conjugatum* also evaluated Amitrole–T and DSMA but found that their effects were very slow to appear. After a series of trials, he recommended the application of paraquat (0.25–0.5 lb/ac) 3 weeks after an initial application of a sub-lethal dose of Amitrole–T (0.375 lb/ac). This treatment gave rapid and lasting control of *P. conjugatum.* Dalapon followed by paraquat was found to be more effective against *O. nodosa* and a few other grasses. These sequential applications of two chemicals, although technically effective, had the disadvantages in practice of needing two applications per spray round, weed recognition and a relatively high level of supervision. Thus a wide spectrum, simple to apply, one application ('one-shot') treatment appeared highly desirable. As paraquat had already been shown by Riepma (*l.c.*) to be the most effective chemical in the short term, further work was undertaken evaluating this chemical in mixtures with other herbicides with a view to prolonging its effects against common weed species, in particular *P. conjugatum.*

Of a large number of tank mixtures of paraquat with herbicides and various additives, the most striking improvements were obtained from mixtures of paraquat and photosynthesis inhibitors and with MSMA. Results from trials evaluating mixtures of these herbicides are presented in this paper.

MATERIALS AND METHODS

All trials were carried out on *P. conjugatum*-dominated swards under fully open conditions (no shade). Other weeds present were *O. nodosa, A. compressus* and *Digitaria* sp. Experimental sites were chosen both on inland as well as fertile coastal clay soils. Vigorously growing thick mats of vegetation in the inter-row areas were used for the trials. There were four randomized replicates per treatment. Chemicals were applied in 40 gal/ac with a hand-pumped knapsack sprayer.

The herbicides used were Gramoxone (2.0 lb/gal paraquat ion), Karmex or Diran 950 (0.8 lb/lb diuron), Ansar 529 M (6.6 lb/gal MSMA), MSMA 529 (4.0 lb/gal MSMA), Hyvar X (0.8 lb/lb bromacil) and Gesaprim W (0.5 lb/lb atrazine).

The effect of treatments were recorded as visual estimates of percentage control relative to unsprayed plots (0=no effect, 100=complete kill).

RESULTS

Choice of a photosynthesis inhibitor

Initially trials were carried out comparing a typical representative from the substituted urea (diuron), uracil (bromacil) and triazine (atrazine) groups, either alone or mixed with 0.5 lb/ac paraquat. The rates of photosynthesis inhibitors used in the first trial were 0.25 lb/ac and 0.5 lb/ac, whereas in the second trial higher rates, 1.0 lb/ac and 2.0 lb/ac, were used. Of the herbicidal inhibitors sprayed alone on standing vegetation, only diuron had any activity and only at the highest rates used (*Tables 1* and *1A*). Mixed with paraquat, diuron and bromacil at 0.25 lb/ac and 0.5 lb/ac had very similar effect, but at 1.0 lb/ac and 2.0 lb/ac diuron appeared to be a slightly better additive. Atrazine, particularly at higher rates, was considerably less effective than either diuron or bromacil.

Rates of paraquat and diuron

Trials comparing the activity of paraquat and diuron at various rates of application showed that despite certain anomalies there was a tendency for activity to increase as rates of paraquat increased from 0.25 or 0.5 to 0.75 or 1.0 ion/acre (*Table 2*). With diuron, activity tended to increase with each increase in rate from 0.25 to 0.5 to 1.0 to 2.0 lb a.i./acre.

Table 1. Comparison of diuron, atrazine and bromacil alone and in combination with paraquat for the control of P. conjugatum

Treatments	*Rate in lbs a.i./ac*	*% kill weeks after spraying* 2	4	6	8	10	12
Diuron	0.25	—	—	—	—	—	—
Diuron	0.5	1	—	—	—	—	—
Bromacil	0.25	—	—	—	—	—	—
Bromacil	0.5	—	—	—	—	—	—
Atrazine	0.25	—	—	—	—	—	—
Atrazine	0.5	—	—	—	—	—	—
Paraquat	0.5	60	38	21	8	—	—
Paraquat + diuron	0.5 + 0.25	72	65	54	41	23	10
Paraquat + diuron	0.5 + 0.5	73	72	46	37	25	3
Paraquat + bromacil	0.5 + 0.25	79	74	47	28	19	5
Paraquat + bromacil	0.5 + 0.5	83	66	64	30	18	5
Paraquat + atrazine	0.5 + 0.25	79	64	44	28	14	<5
Paraquat + atrazine	0.5 + 0.5	76	72	55	41	16	<5

Table 1 A

Diuron	1.0	40	15	3	2	—	—
Diuron	2.0	68	42	29	9	—	—
Bromacil	1.0	—	—	—	—	—	—
Bromacil	2.0	—	—	—	—	—	—
Atrazine	1.0	—	—	—	—	—	—
Atrazine	2.0	—	—	—	—	—	—
Paraquat	0.5	60	38	16	6	—	—
Paraquat + diuron	0.5 + 1.0	90	83	71	61	37	18
Paraquat + diuron	0.5 + 2.0	85	78	61	47	31	12
Paraquat + bromacil	0.5 + 1.0	88	82	68	46	24	14
Paraquat + bromacil	0.5 + 2.0	80	76	54	40	12	9
Paraquat + atrazine	0.5 + 1.0	73	56	34	8	2	—
Paraquat + atrazine	0.5 + 2.0	64	54	30	13	7	2

In a further trial (*Table 3*) paraquat (0.5 and 0.75 lb/ac) was evaluated in mixtures with 0.5, 0.75 and 1.0 lb/ac diuron. Again, increasing the paraquat rate from 0.5 to 0.75 lb/ac improved activity. Similarly the 0.75 lb/ac rate for diuron was better than 0.5 lb/ac but the activity with the 1.0 lb/ac rate was similar to

Table 2. Effect of paraquat/diuron mixtures on P. conjugatum*—dominated sward under fully open conditions*

Paraquat (lb ion/ac)	% kill															
	1st week				3rd week diuron lb/ac				5th week				7th week			
	0.25	0.5	1.0	2.0	0.25	0.5	1.0	2.0	0.25	0.5	1.0	2.0	0.25	0.5	1.0	2.0
0.25	57	60	84	—	57	60	88	—	47	36	80	—	32	33	73	—
0.5	66	74	77	80	50	80	88	95	38	62	60	82	22	45	45	65
0.75	76	80	71	77	76	78	82	91	65	65	70	73	59	60	60	65
1.0	—	82	81	72	—	83	90	91	—	67	77	82	—	49	53	78

Table 3. Effect of paraquat/diuron mixtures on P. conjugatum*—dominated sward under fully open conditions*

Paraquat (lb ion/ac)	% kill																				
	1st week			2nd week			3rd week			4th week diuron (lb/ac)			5th week			6th week			7th week		
	0.5	0.75	1.0	0.5	0.75	1.0	0.5	0.75	1.0	0.5	0.75	1.0	0.5	0.75	1.0	0.5	0.75	1.0	0.5	0.75	1.0
0.5	75	72	77	80	85	90	75	80	88	70	75	77	62	71	60	56	62	66	45	56	42
0.75	90	90	85	78	93	90	75	90	90	73	89	85	70	87	80	65	80	78	60	75	70

that obtained with 0.75 lb/ac. Thus under fully open conditions the best combination appeared to be a mixture of 0.75 lb/ac paraquat + 0.75 lb/ac diuron. The degree of improvement that can be obtained with these compounds was well illustrated in one trial where 0.75 lb/ac paraquat ion alone gave 4 weeks' control (60% kill taken as adequate control), whereas 0.75 lb/ac paraquat + 0.75 lb/ac diuron gave control for well over eight weeks (*Fig. 1*).

Substitution of paraquat with another contact herbicide in paraquat/diuron mixture

To confirm further the synergistic action of paraquat and diuron, an additional trial was carried out in which sodium chlorate was substituted for paraquat. Although sodium chlorate, like paraquat, is a contact herbicide its mode of action is unrelated to photosynthesis. Results presented in *Table 4* show that the activity of a sodium chlorate and diuron mixture was very similar to that of sodium chlorate alone applied at a similar rate. The activity of paraquat/diuron mixtures on the other hand was once again greater than could be expected from each herbicide used alone.

Fig. 1

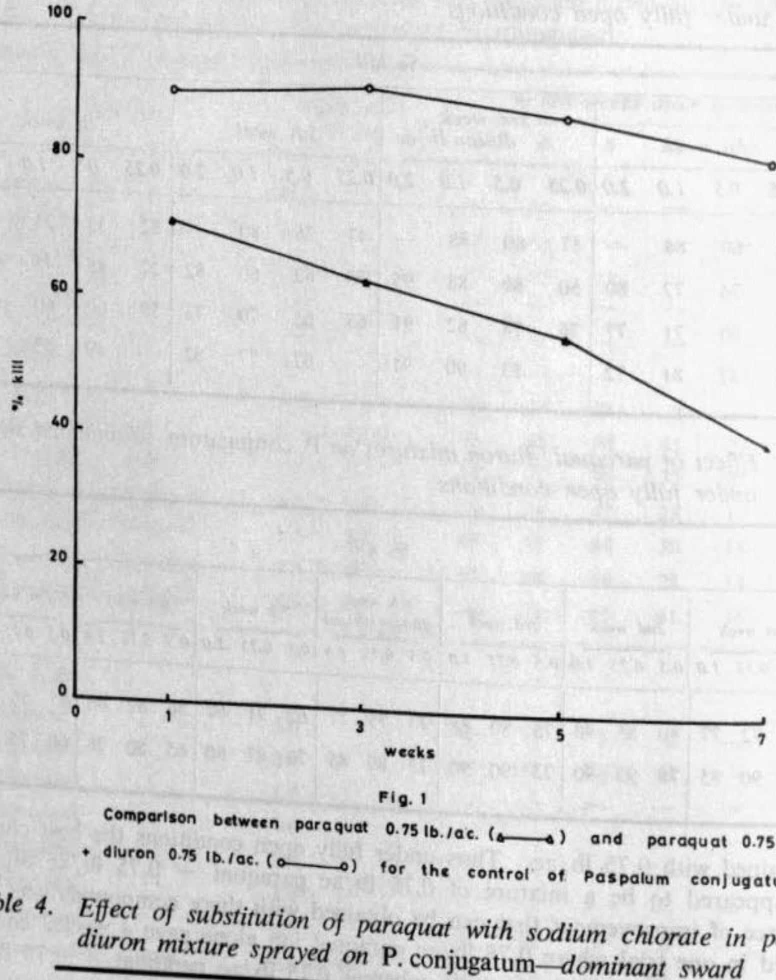

Fig. 1

Comparison between paraquat 0.75 lb./ac. (△——△) and paraquat 0.75 lb./ac. + diuron 0.75 lb./ac. (○——○) for the control of Paspalum conjugatum.

Table 4. Effect of substitution of paraquat with sodium chlorate in paraquat/diuron mixture sprayed on P. conjugatum*—dominant sward*

Treatment	*Rate (lb/ac)*	*% kill weeks after spraying* 2	4	6	8	10
Diuron	0.5	28	10	—	—	—
Paraquat	0.5	70	55	30	10	—
Sodium chlorate	15.0	55	40	20	10	—
Sodium chlorate + Diuron	15.0 + 0.5	57	45	25	13	—
Paraquat + Diuron	0.5 + 0.5	80	75	70	55	35

Mixtures of paraquat/diuron/MSMA

Trials comparing paraquat, diuron and MSMA alone on two separate areas dominated by *P. conjugatum* and *O. nodosa* respectively show that MSMA is the most effective chemical against the former, followed by paraquat which in turn is better than diuron (*Table 5*). However, against *O. nodosa* paraquat was the most effective chemical, with MSMA providing very limited control. Diuron as a post-emergence spray had practically no effect.

Table 5. Control of pure stands of Paspalum conjugatum *and* Panicum nodosum *with MSMA, paraquat and diuron*

		% control							
		Paspalum conjugatum				*Panicum nodosum*			
Treatment	*Rate (lb/ac)*	*1st*	*3rd*	*5th*	*7th*	*2nd*	*3rd*	*4th*	*5th*
		(week after spraying)							
*MSMA	0.8	65	38	5	—	—	—	—	—
MSMA	1.6	83	59	12	—	64	27	10	5
*MSMA	2.4	86	90	65	40	—	—	—	—
MSMA	3.2	97	92	70	63	73	30	16	10
paraquat	0.25	55	23	8	5	70	67	55	35
paraquat	0.5	60	38	22	7	76	73	65	45
paraquat	0.75	70	63	55	40	88	88	80	60
paraquat	1.0	79	67	59	30	95	95	88	66
diuron	0.25	15	5	—	—	—	—	—	—
diuron	0.5	20	10	—	—	5	—	—	—
diuron	1.0	40	25	5	—	5	—	—	—
diuron	2.0	68	70	55	30	5	—	—	—

* MSMA at 0.8 and 2.4 lb/ac was not evaluated against *Panicum nodosum*.

In an attempt to obtain a treatment effective against a wide range of species, but requiring lower rates of herbicidal application than the chemicals applied alone or in the two component mixtures described above, combinations of paraquat, diuron and MSMA were tried. Because of its effectiveness against *P. conjugatum*, MSMA was chosen as the third component. In a large series of trials, a range of MSMA rates from 1.0 to 3.0 lb/ac were tried in combination with 0.25 lb/ac paraquat + 0.25 lb/ac diuron. The results obtained (*Table 6*) show that rates of MSMA higher than 1.5 lb/ac produced little or no increase in activity; thus an optimum combination appeared to be a mixture containing 0.25 lb/ac paraquat + 0.25 lb/ac diuron + 1.5 lb/ac MSMA.

Table 6. Evaluation of various rates of MSMA in combination with paraquat for the control of Paspalum conjugatum

Treatments			*% control weeks after spraying*					
Paraquat + *(lb/ac)*	*Diuron* + *(lb/ac)*	*MSMA (lb/ac)*	*1*	*2*	*3*	*4*	*5*	*6*
0.25	0.25	1.0	83	70	59	57	46	40
0.25	0.25	1.5	87	83	76	75	72	68
0.25	0.25	2.0	88	84	79	75	73	71
0.25	0.25	2.5	89	87	84	80	75	73

This triple component mixture was then compared on a *P. conjugatum*-dominant sward with 3.2 lb/ac MSMA, 0.75 lb/ac paraquat + 0.75 lb/ac diuron and a sequential application of 0.375 lb/ac Amitrole–T followed two weeks later by 0.5 lb/ac paraquat. The results presented in *Table 7* show that the paraquat/diuron and the triple component mixture were the best treatments; further experience in the field has shown these treatments to be of particular value for the control of mixed grasses.

Table 7. Comparison of paraquat/diuron and paraquat/diuron/MSMA mixture with MSMA alone and a sequential application of Amitrole–T and paraquat on Paspalum conjugatum*—dominant sward*

Treatments			*% control weeks after spraying*				
Paraquat (lb/ac)	*Diuron (lb/ac)*	*MSMA (lb/ac)*	*1*	*3*	*5*	*7*	*9*
0.25 +	0.25 +	1.5	90	90	87	86	75
0.75 +	0.75 +	—	90	90	87	80	—
—	—	3.2	97	92	70	60	50
Amitrole–T: 0.375 lb/ac → Paraquat: 0.5 lb/ac			—	75	56	45	42

DISCUSSION

The main group of herbicidal photosynthesis inhibitors tested in the present study, *i.e.* urea, uracil and triazine, are basically pre-emergence herbicides, entering plants through roots. Consequently they are much more active against germinating weed seedlings than for elimination of standing vegetation. It is not surprising, therefore, that these chemicals when applied alone at the rates evaluated in the present experiments gave poor control of an established weed stand.

The effectiveness of the mixtures of paraquat with photosynthesis-inhibiting herbicides was greater than could be expected from the performance of each herbicide used alone. The modes of action of paraquat (Mees, 1960; Calderbank, 1968; Funderburk & Lawrence, 1964) and diuron, bromacil and atrazine (Moreland & Hill, 1962 and 1963; van Overbeek, 1964; Hilton *et al.*, 1964; Hoffman *et al.*, 1964) are related to photosynthesis. In the presence of high light intensity and oxygen, paraquat acts very rapidly—within 30 minutes in many situations. The inhibition of photosynthesis by the herbicidal additives discussed above is likely to slow up the activity of paraquat by inhibiting the Hill reaction. It is believed that this permits greater paraquat uptake and/or movement within the plant, with the result that the mixture gives much longer control than either component used alone. This is further confirmed by the observation that the substitution of paraquat with a contact herbicide with a mode of action unrelated to photosynthesis is unable to provide greater activity in mixture with diuron.

Because of the rapid action of paraquat, a two-component mixture containing a relatively slow-acting herbicide like MSMA was not considered. However, in the presence of low rates of both paraquat and diuron, addition of MSMA improved activity, particularly against *P. conjugatum*.

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DISCUSSION

See joint discussion at end of next paper.

NEW RECOMMENDATIONS FOR WEED CONTROL UNDER YOUNG OIL PALMS

by

A.K. Seth, Abu Bakar bin Baba and S. Sivarajah

SUMMARY

A tank-mix of paraquat 0.25 lb/ac + diuron 0.25 lb/ac + MSMA 1.5 lb/ac, gives on an average 14 weeks control of most of the common weeds in oil palm circles on inland and coastal soils. Weed control using this treatment as compared to manual weeding leads to better palm growth, possibly due to reduced damage to surface feeding roots, improved soil structure and reduced moisture loss. Following chemical weeding, savings in cost, labour and time are also achieved.

INTRODUCTION

In a previous paper Seth (these *Proceedings*) presented results from replicated small plot experiments in which paraquat, diuron and MSMA were used either alone or in mixtures for the control of the common plantation crop weeds, e.g. *Paspalum conjugatum, Ottochloa nodosa (Panicum nodosum), Axonopus compressus, Eleusine indica* and *Digitaria* sp. In general, mixtures containing either paraquat/diuron or paraquat/diuron/MSMA were found to control a wider spectrum of weeds for a longer period than either of these chemicals used alone.

The most effective mixtures were subsequently compared with each herbicide used alone and with manual weeding in long term trials. The results from these trials are presented here.

MATERIALS AND METHODS

Four large scale trials (2 on inland and 2 on coastal soils) were started during 1967–68. In all cases application of herbicides began between 3–9 months after field planting. There were four randomized replicates per treatment. Spraying was carried out using a blue 'Polijet' operated at 15 lb/in^2 pressure and a walking speed between 1–2 m.p.h. aiming to achieve a volume rate of 40 gal/ac. Manual weeding, consisting of scraping of weeds, was carried out using a changkol. Both chemical and manual weeding rounds were carried out as and when necessary.

Palm growth was assessed by measuring the diameter of the base of the stem, using calibrated 'giant' metal calipers, and also the length of the second fully-opened frond from ground level to the tip of the terminal leaflet. These measurements were taken once every six months.

The relative leaf area was estimated in trials 1 and 4 at 30 and 18 months respectively by the method of Hardon *et al.* (1969).

P. conjugatum was the dominant weed on all the four trial sites. Varying amounts, between 10–30%, of *O. nodosa*, *Digitaria* sp. and *A. compressus* were also present. The effects of the herbicidal treatments on weed growth were assessed visually once every two weeks.

RESULTS AND DISCUSSION

In the initial two trials, manual circle weeding was compared with paraquat 0.5 lb/ac, MSMA 3.2 lb/ac, diuron 2.0 lb/ac and a mixture of paraquat 0.5 lb/ac + diuron 2.0 lb/ac. While spraying around young palms no special precautions were taken to avoid damaging fronds lying close to the ground. However, in spite of scorching these lowermost fronds, palm growth with chemical weeding, as measured by girth and frond length increments, was better than with manual weeding. (*Tables 1 and 2;* Trials 1 and 2).

In the first series of trials, the main objective was to evaluate the long term effects of chemicals on palm growth. Accordingly the rates of paraquat, diuron and MSMA were higher than those recommended for field usage in an earlier paper presented by Seth (these *Proceedings*). In the second series two further trials

Table 1. †Immature palms: Average basal diameter (inches) at various intervals from the commencement of weeding

Treatments			*Trial 1 (inland soil)*					*Trial 2 (coastal soil)*			
			6 m	*12 m*	*18 m*	*24 m*	*30 m*	*6 m*	*12 m*	*18 m*	*24 m*
Paraquat	0.5	lb/ac	7.9	11.1	13.8	16.9	18.6	—	9.2	15.1	16.8
Diuron	2.0	„	8.1	10.7	13.6	16.3	18.9	—	—	—	—
MSMA	3.2	„	7.8	10.8	13.4	16.4	18.6	—	—	—	—
Paraquat + Diuron	0.5 2.0	„ „	8.0	11.4*	14.1*	17.3	19.0	—	9.3	15.3	17.0
Hand-weeding			7.7	10.6	13.2	16.4	18.1	—	9.0	14.9	16.6
									(Trial closed)		

Treatments			*Trial 3 (inland soil)*	*Trial 4 (coastal soil)*		
			6 m	*6 m*	*12 m*	*18 m*
Paraquat	0.5	lb/ac	5.6	12.2	17.4	20.14
Paraquat + Diuron + MSMA	0.25 0.25 1.6	„ „ „	5.4	11.8	17.1	19.51
Hand-weeding			5.1	11.9	17.1	18.98
			(Trial closed)			

† Duration in field before start of spraying:
Trial 1: 5 months. *Trial 2*: 5 months. *Trial 3*: 6 months. *Trial 4*: 9 months.

* Significantly different from manually weeded controls at 5%.

were undertaken in order to study the cost/effectiveness and safety of mixtures containing lower rates. The treatments included paraquat 0.25 lb/ac + diuron 0.25 lb/ac + MSMA 1.6 lb/ac, paraquat alone at 0.5 lb/ac and hand-weeding. (*Tables 1 and 2;* Trials 3 and 4). Measurements of growth obtained over the 18 months that Trial 4 has been in progress confirm that the growth of palms chemically weeded by these treatments is as good, or better, than under a hand-weeding regime.

Table 2. †Immature palms: Average height (inches) of the palm taken from ground level to the tip of the second fully opened frond at various intervals from commencement of weeding

Treatments			Trial 1 (inland soil)					Trial 2 (coastal soil)			
			6 m	12 m	18 m	24 m	30 m	6 m	12 m	18 m	24 m
Paraquat	0.5	lb/ac	88.5	118.6*	147.4	182.2	198.8	—	106.8	152.4	175.1
Diuron	2.0	,,	90.6	116.8	145.2	177.0	203.9	—	—	—	—
MSMA	3.2	,,	85.5	113.0	140.8	178.5	193.3	—	—	—	—
Paraquat + Diuron	0.5 2.0	,, ,,	89.2	117.7*	144.1	178.5	200.4	—	99.7	153.0	173.4
Hand-weeding			86.25	111.2	140.4	176.2	189.4	—	98.0	149.9	172.4
								(Trial closed)			
			Trial 3 (inland soil)					Trial 4 (coastal soil)			
			6 m					6 m	12 m		
Paraquat	0.5	lb/ac	75.7					125.4	172.0		
Paraquat + Diuron + MSMA	0.25 0.25 1.6	,, ,, ,,	72.2					123.5	166.6		
Hand-weeding			72.6					122.5	167.5		
			(Trial closed)								

† Duration in field before start of spraying:

Trial 1: 5 months. *Trial 2*: 5 months. *Trial 3*: 6 months. *Trial 4*: 9 months.

* Significantly different from manually weeded controls at 5%.

A very large proportion of the necessary nutrients are absorbed from the topsoil which is actively explored by many feeder roots when conditions are ideal. Cultural practices discouraging root growth are likely to reduce the ability of the plants to absorb. The poorer growth of palms with manual weeding could have been due to damage to the surface feeding roots resulting from the scraping of topsoil to remove weeds. In contrast, in the chemically weeded plots, the roots remain undamaged and the mulch left by the dead weeds provides an environment for improved soil structure and moisture retention for continued growth of the surface feeding roots.

The observations, presented above, are supported by Ruer (1969) who showed in oil palm experiments on deep tertiary sands that the deeper (anchor) roots absorbed little water and the pruning of surface roots significantly reduced water uptake. Likewise in tea, Wilson (1969) pointed out that the mulch developed on the soil surface following herbicide usage for weed control, accumulation of prunings and fallen leaves, must be allowed to remain undisturbed as most of the nutrient uptake takes place within this region. The frond No. 17 of the chemically weeded palms was also found to possess greater leaf area (*Table 3*). As a good correlation exists between total area and area of frond No. 17 (Corley & Hardon, 1970), it is concluded that the palms under the chemical weeding regime possessed a greater capacity for photosynthesis, which in turn could influence the growth rate.

Table 3. Immature palms: Average length (inches) and leaf area (inches²) of frond No. 17 at 18 months after commencement of weeding

Trial 4 (coastal soil)

Treatments		*Length of frond (inches)*	*Leaf area of frond (inches²)*
Paraquat	0.5 lb/ac	131.0	
Paraquat + Diuron + MSMA	0.25 " + 0.25 " + 1.50 "	129.7	5 211.1
Hand-weeding		129.8	4 670.9

The length of weed control and the cost of treatments

The average length of weed control achieved and the cost of each treatment are presented in *Table 4*. The duration of weed control with manual weeding was 4–6 weeks. Paraquat used alone provided control for 8 weeks; the addition of diuron or diuron and MSMA extended this period of control to 12–14 weeks. On a cost/efficiency basis the best chemical treatment was a tank-mix of paraquat 0.25 lb/ac + diuron 0.25 lb/ac + MSMA 1.5 lb/ac. Not only was weed control with this treatment cheaper than hand-weeding but there was also a striking saving in the labour required for weeding. In fact, the results indicate that with the same labour force a paraquat/diuron/MSMA treatment can be used to maintain 5 times the area that could be covered by manual weeding.

It is important to point out, however, that to gain the full benefit, both on a cost basis and from the agronomic point of view, chemical weed control should be started within three months after field planting and cost comparisons made over a twelve-month period or more. It has generally been observed that following initial spray rounds very little weed growth takes place around the base of the palm, thus limiting subsequent spraying towards the perimeter of the circle.

Table 4. Immature palms: Cost comparison of chemical and manual weeding based on the first two years after field planting

Treatments			*Average period of control (weeks)*	*Chemical cost ($)*	*†Chemical cost per planted acre ($)*	*††Labour cost per planted acre ($)*	*Total cost (chemical + labour) ($)*	*Average monthly cost ($)*
Hand-weeding								
Coastal soils			4	—	—	2.50	2.50	2.50
Inland soils			6	—	—	2.50	2.50	1.67
Paraquat	0.5	lb/ac	8	11.00	2.75	1.00	3.75	1.87
Paraquat +	0.25	,,						
Diuron +	0.25	,,	14	13.60	3.40	1.00	4.40	1.26
MSMA	1.5	,,						

† Spray factor from sprayed acre to field acre of 1:4.

†† Labour cost for spraying is $1.00 per field acre per round.

Chemical	*Formulation used*
paraquat	Gramoxone containing 2.0 lb/Imp. gal. paraquat ion.
diuron	Karmex or Diran 950 containing 0.8 lb/lb diuron.
MSMA	Ansar 529 or Cock's Head MSMA 529 containing 6.6 and 4.0 lb/Imp. gal. MSMA respectively.

Gramoxone at $44.00 per gallon = $5.50 per pint.

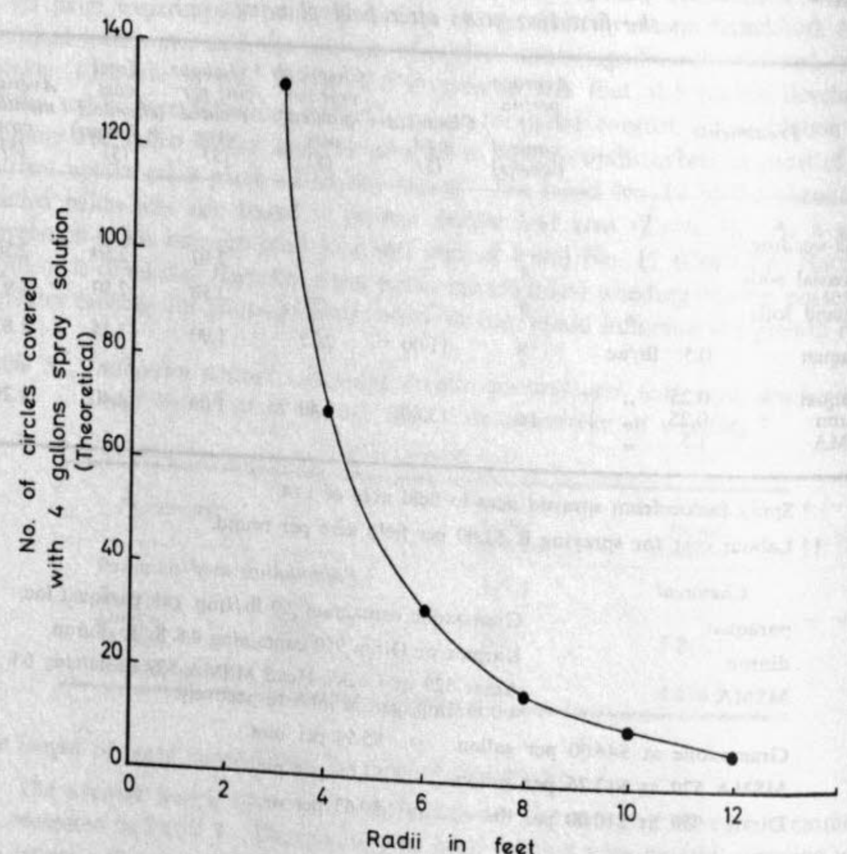
MSMA 529 at $13.25 per gallon = $1.65 per pint.

Diran 950 at $10.00 per lb. = $0.63 per oz.

The radius (size) of the circle maintained free of weeds also has a marked effect on the cost of weeding. *Fig. 1* presents data on the number of palm circles that one expects to cover at various radii with a 4-gallon tank of spraying solution. The volume rate aimed at in these cases was 40 gal/acre. As can be seen, the number of palm circles covered declines exponentially from 128 at 3 ft radius to only 7 at a 12 ft radius.

To summarise, the results from long-term field experiments over the last few years have shown that the new treatment, a tank-mix of paraquat 0.25 lb/ac + diuron 0.25 lb/ac + MSMA 1.5 lb/ac, gives on an average 14 weeks control of most of the common weeds in oil palm circles on inland and coastal soils. Weed control using this treatment as compared to manual weeding leads to better palm growth, possibly due to reduced damage to surface feeding roots, improved soil structure and reduced moisture loss. Following chemical weeding, savings in cost, labour and time are also achieved.

Fig. 1



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DISCUSSION

(Of this and the preceding paper)

Chairman: D.E. Barnes

Cates: Would there be any advantage in substituting MSMA for Paraquat in the mixture? What is the advantage of including paraquat?

Seth: Various combinations of chemicals were evaluated; MSMA on its own is very effective against *Paspalum conjugatum,* and can be added for this reason. When dealing with a mixed weed stand it may be unwise to omit paraquat.

Hew: I am intrigued by the use of the giant caliper to measure the base of the palm. Could it not be used with greater accuracy where there were no weeds around the base of the palm? Secondly, sprayed palms may have a bigger weed-free area around them than hand-weeded palms, and thus have a growth advantage. Could you please elaborate on this?

Seth: Taking girth methods with a giant caliper is not a very efficient method. Later on we took other measurements like leaf area, which gives a more accurate assessment of growth. Height and girth were still measured however, because they do show a trend. Weed growth immediately under the palm tends to be light, whether chemical or manual weeding is employed. In the initial stages of growth, when the fronds are erect, there is a much heavier weed growth, but as the palm grows older the weeds tend to be confined to the periphery of each planting circle.

The circle size for a 3-yr-old palm is inevitably very big, and the number of palms sprayed per gallon is less than when weeding is begun when the palm is older.

Hew: Were the radii of the hand-weeded and sprayed circles the same? If not, spraying gives an advantage.

Seth: They were the same.

Paardekooper: Some preliminary work that we have done has also suggested that a standard mixture of paraquat, diuron and MSMA could be very useful under smallholders' conditions. On the other hand it would be extremely difficult to distribute three separate chemicals and ensure that they are mixed in the right concentrations. To what extent is it possible to mix the three separate chemicals in diluted form and then distribute them to smallholders?

Chairman: There are on the market commercial preparations like diuron and MSMA which have been used for several years. Unfortunately it is not very easy to mix paraquat with these two in concentrated form because paraquat is cationic. You can mix two, but a three-component mixture is not possible at the moment.

Seth: It is possible to use a col form of paraquat to make a permanent suspension of paraquat and diuron, but the concentrates of paraquat and MSMA do not mix very well together, although they do so in diluted form. But I agree that the objective ought to be to try and produce a product having all three herbicides in one bottle.

Pushparajah: Where various combinations of paraquat and diuron were used, were any differences in the type of regeneration observed—*i.e.* whether from the rootstocks or from germinating seeds? This might give an indication of how long weed control would last.

Seth: In most cases very efficient control of grasses was obtained, and new growth was mainly broad-leafed weeds arising from seeds. The most common were *Borreria* and *Ageratum*; the former had never before been regarded as a major problem in trial areas, but is now beginning to appear as a dominant weed. In one area 75% of the cover was *Borreria*. Under shaded conditions, and when very young, it is no problem to control; but in the open a well-established stand of *Borreria* can be a problem to eradicate. Even 2,4-D does not give very efficient control.

Hew: In your recommendations you do not suggest any levels of surfactant. At such low concentrations of diuron, surfactants are quite important.

Seth: We tried adding surfactants, but in our trial work there was no evidence to suggest that by adding wetting agents or other surfactants there was appreciable improvement in control. This is anomalous, for there are several reports, particularly from work in cotton, that the addition of wetting agents to diuron appreciably improves its activity.

Hew: Could the lack of benefit be due to the types of surfactants used?

Seth: Possibly; we only examined non-ionic surfactants which under normal conditions should give the expected improvements, but I agree that a wider range should be explored.

Chairman: In many instances we have found that combining herbicides produces an additive effect—*e.g.* sodium chlorate + 2,4-D, sodium chlorate + MSMA, or 2,4-D + MSMA—compared with using them separately. Paraquat is unusual in that it appears to have a synergistic effect, which is rarely encountered in this kind of situation.

We have also established some very clear surfactant effects, in that adding a rather high level of surfactant has initially given complete control of weeds.

Seth: There is an interesting synergistic effect between paraquat and diuron which we intend to study further.

Hartley: We have found in certain areas sprayed with mixtures of Gramoxone (paraquat), diuron and MSMA that creeping weeds such as *Lygodium, Mikania* and grasses have grown into the sprayed circle from adjacent unsprayed areas. Palms thus became overgrown with *Mikania*, which is quite expensive to pull off. Unless we extend the circle sufficiently far to keep the creeping weeds well away from the palm, we cannot maintain the degree of control which you have described.

Seth: Perhaps *Mikania* ought to be treated as a separate issue and special control measures taken accordingly, rather like lalang, where regular patrols are carried out. Mr. Hew's work has shown that *Mikania* can reduce yields substantially. With ring-weeding, circle size is critical, for too small a circle tends to get invaded very quickly by creepers.

Wong: The one-shot spraying technique is most suitable in areas where the circle has been invaded by grass, where the synergistic action of diuron and paraquat can be utilised. Have you tried using diuron as a pre-emergence treatment while the circle is still free of weeds after a few rounds of manual circle-weeding?

Seth: It is possible to use diuron as a pre-emergence chemical, but creeping grasses, legumes, *Mikania, etc.* still have to be pulled back regularly from around the palms. A second disadvantage is that less mulch is formed by spraying bare ground compared with spraying established weeds. Nevertheless it is possible to circle-weed with diuron at rates which will give residual activity, and to control peripheral weeds manually or chemically.

Owen Jones: We have been using MSMA, 2,4-D and sodium chlorate for some time in our cocoa areas, with the result that *Brachiaria mutica* has appeared. Have you got a one-shot treatment for getting rid of this weed?

Seth: The best treatment is a sequential one—dalapon followed either by paraquat or sodium chlorate.

Owen Jones: We find that this weed invades from the drain edges after excavation or drainage equipment has been working. *Brachiaria* encroaches on to the spoil from the drains, and after manual weeding or slashing of any kind it spreads very quickly. We found that even a sequential spray is not sufficient and we have to do a fair amount of spiking. However, I have heard that *Brachiaria* is a pilot coloniser and will eventually be suppressed by other weeds. Have you any comment to make on this?

Seth: Whether or not it is suppressed or remains dominant depends on a combination of environmental and other factors. It is not possible to generalise.

Owen Jones: But if it was not going to become dominant would it be worthwhile spiking it, for spiking is a very costly operation?

Seth: *Brachiaria mutica* can be very competitive and it is worthwhile removing it as far as possible.

Owen Jones: We have found that *Mikania* is fairly well eradicated by a chain-slasher, and then tends to be succeeded by grasses. A certain amount of circle-spraying close to the palms is then necessary.

PERSISTENCE OF PICLORAM/2,4-D MIXTURE* AND DALAPON IN SOIL

by

J.S. Lowe

SUMMARY

Data presented suggest the recommended rates of picloram/2,4-D mixtures and dalapon have a residual phytotoxicity of one month and four days respectively when sprayed onto bare soil. Soil covered with vegetation may receive only 12% of the sprayed chemical, which means that by the time the weeds have been killed there is no residual soil phytotoxicity for all practical purposes.

The use of chemicals by the plantation industry to control obnoxious weeds and facilitate harvesting has increased each year as labour has become less economic. However, as the result of press sensationalism there has been a tendency to think of all chemicals as permanently poisoning the environment.

The persistence of herbicides in the soil has received a tremendous amount of investigation in Europe and the United States of America, and if one surveys this literature it is difficult not to become both depressed and confused because the differences in time of residual phytotoxicity show extremely wide variations. (*Table 1*).

Table 1. Residual toxicity of herbicides

Herbicide	*Normal rates lb/acre*	*Rates used in trials lb/acre*	*Author*	*Residual phytotoxicity (months)*
Amitrole	2–10	3–18	Sund (1956)	1–5
Atrazine	2–4	2–4		4–7
		3–8	Sheets & Harris (1965)	12
Simazine	2–4	2	Sheets & Harris (1965)	7–18
Dalapon	6–12	7.4–20		1
		6–8	Day *et al.* (1959)	1–2
Diuron	0.6–6.4	3.6–4	Weldon & Timmons (1961)	5–7
	2			15
T.C.A.	4–30	12.5–67	Jensen (1957)	7–12
		16–30	Rai & Hamner (1954)	4
Tordon 22K	0.02–0.25	1		6
		4–8		15
2,4-D	0.25–1	1½–2	Behrens (1962)	1–1½
		4.5		2–11

* Formulation used was Tordon, Dow Chemical International Inc.

However, there is little work from Malaysia on this subject, although it can be seen from the residual toxicity data quoted that if such persistence was applicable to South East Asia then the weeding problem of the plantation industry would be very much simpler and less expensive to control.

As most of the workers point out, residual phytotoxicity depends on many factors: the dosage rate (dilute concentrations of herbicides are normally more readily broken down than higher concentrations because the latter markedly affect the soil pH); organic content of the soil; its pH; rainfall; soil temperature; ultra violet light; and the degree of absorption onto the soil particles. For Malayan inland soils many of these variables will be small, for the climatic and soil conditions are fairly constant; therefore, one could expect that any residual phytotoxicity data would be applicable to a very large proportion of the plantations of the area. In view of these considerations it was decided to attempt to estimate the residual phytotoxicity of two herbicides, Tordon 101 and dalapon.

TORDON

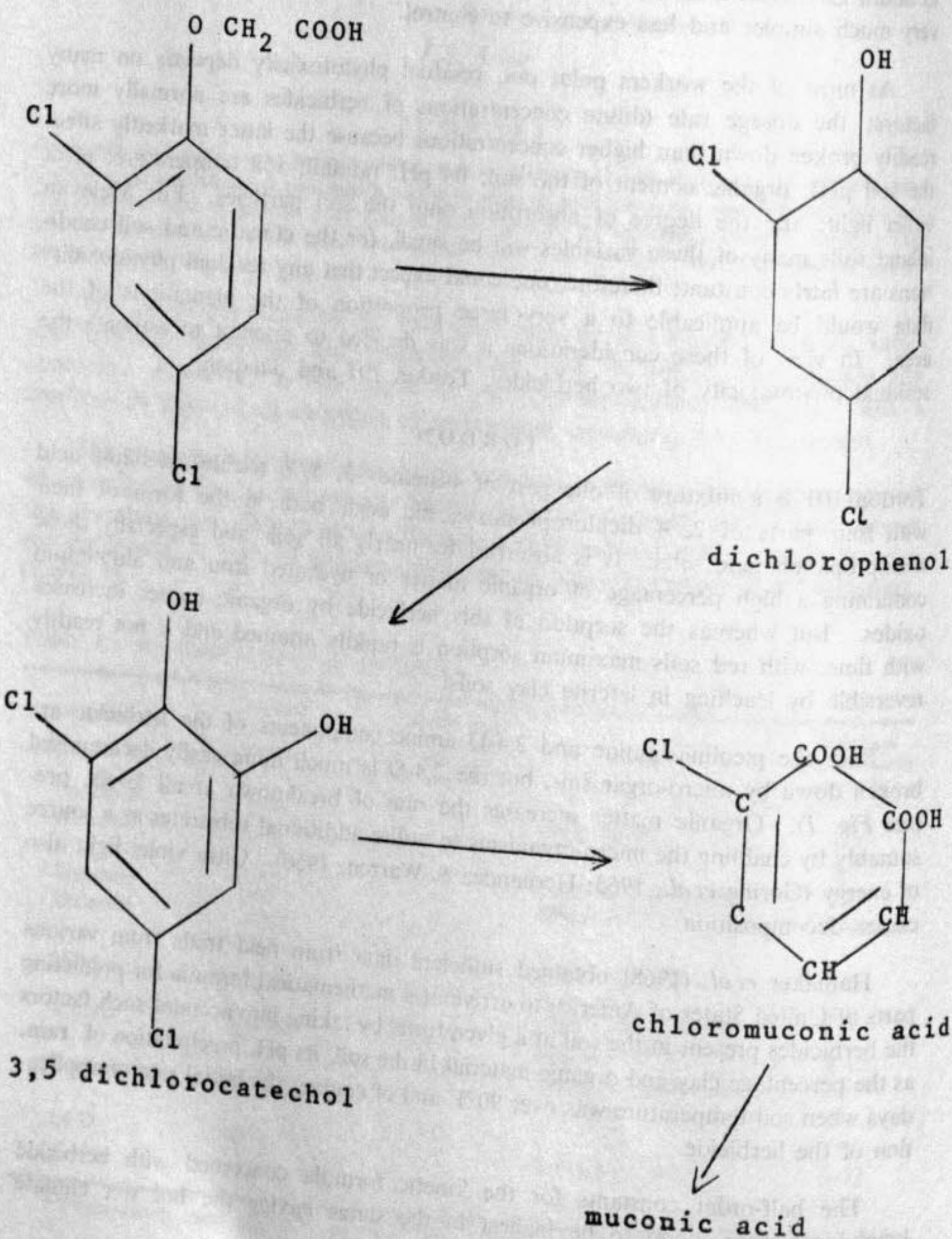
Tordon 101 is a mixture of one part of 4-amino—3, 5, 6 trichloropicolinic acid with four parts of 2, 4 dichlorophenoxyacetic acid, both in the form of their triisopropanolamine salts. It is absorbed by nearly all soils and especially those containing a high percentage of organic matter or hydrated iron and aluminium oxides. But whereas the sorption of this herbicide by organic matter increases with time, with red soils maximum sorption is rapidly attained and is not readily reversible by leaching in laterite clay soils.

Both the picolinic amine and 2,4-D amine components of the herbicide are broken down by micro-organisms, but the 2,4-D is much more easily decomposed (see *Fig. 1*). Organic matter increases the rate of breakdown at all levels, presumably by enabling the micro-organisms to utilise additional substrates as a source of energy (Goring *et al.*, 1965; Hernandez & Warren, 1950). Ultra violet light also causes decomposition.

Hamaker *et al.* (1968) obtained sufficient data from field trials from various parts of United States of America to arrive at a mathematical formula for predicting the herbicides present in the soil at a given time, by taking into account such factors as the percentage clay and organic material in the soil, its pH, precipitation of rain, days when soil temperature was over 90°F and of course the initial rate of application of the herbicide.

The half-order constants for the kinetic formula concerned with herbicide breakdown were found to be highest in the states having the hot wet climate which approaches that of S.E. Asia.

Fig. 1. Degradation of 2,4-D



Bovey *et al.* (1968) have shown that in Puerto Rico, maize, sorghum, wheat, rice and cotton could be grown in soils 3 months after treatment with either the picloram/2,4-D mixture at 6 lb a.i./acre, or 2,4-D and 2,4,5-T, both at 24 lb a.i./acre without any effect on the fresh weight. They attributed this to the fact that 23 inches of rain had fallen in this period and leached away toxic quantities of the herbicides. Weise (1968) reports that soya bean showed visible symptoms of herbicide toxicity above 2 oz a.i./acre, but no effect on yield up to 8 oz a.i./acre. The fact that soya bean is so sensitive to herbicide residues, showing cupping of its leaves and some growth distortion at levels far below those which have any practical effect on the yield, means it is universally used as an indicator plant.

METHOD

The site for the experiment was a 1/10 acre plot near Johol, Negri Sembilan on a Rengam series soil, containing a large proportion of clay; like most inland soils, the organic material was low and in order to produce poor conditions for the breakdown of the herbicide, the area was stripped of all grass and weeds by *changkolling*. The area was divided into five plots of eight subplots, and the picloram /2,4-D mixture at 2½ pints/acre in 40 gallons of water was sprayed on four of the plots—the fifth was the control. This rate is in excess of that recommended or required for any application to broad-leaf plants in Malaysia. The spray went on the soil at a time when there was a prolonged dry period. Seeds of maize, water melon, soya bean, *Pueraria, Desmodium, Centrosema* and *Calapogonium* and cuttings of Cassava were planted in the control and one sprayed plot after two weeks of weathering; just prior to the planting the soil was again *changkolled* to a depth of about 3 inches, so that the herbicide was fairly distributed in the top 3 inches of each of the subplots.

Rainfall data was collected from three meteorological stations situated within 15 miles of the site; the results are given in *Table 2*.

The 7th December plantings when viewed on 23rd December and 4th January showed good growth in all cases except for a slight check in the case of *Calapogonium* visible on 23rd December, but not detectable two weeks later, and for soya bean, a more marked stunting of growth and curling of leaves on the 23rd December, but some recovery by 4th January.

Of the 23rd December plantings the soya bean seeds only showed some check initially, but this was not detectable on 4th January. Because the herbicide, Tordon, did not persist as long as anticipated, a further area of 1/10 acre which had been sprayed with 2½ pints of the picloram/2,4-D mixture on 10th November was handed back to the estate and groundnuts were planted on 6th January. Even up to the time of harvesting some leaves of groundnut showed the toxicity symptoms of inward curling leaves, but the yield was eminently satisfactory at 865 lb/acre.

Table 2

Rainfall data during term of experiment (in.)

Date		*Tampin**	*Kuala Pilah**	*Kuala Jelai*†
Nov.	9–14	Nil	Nil	Nil
	15	0.68	0.92	0.75
	16	0.05	Nil	Nil
	17	0.62	0.66	0.68
	18	0.01	0.16	0.10
	19–22	Nil	Nil	Nil
	23	Nil	1.46	1.12
	24	0.65	Nil	Nil
	25	1.15	0.12	0.75
	26	0.35	1.16	0.95
	27	2.01	1.73	1.82
	28	0.12	Nil	Nil
	29–30	Nil	Nil	Nil
Dec.	1	0.09	0.15	0.12
	2–4	Nil	Nil	Nil
	5–13	1.18	7.41	2.84
	14	1.08	Nil	Nil
	15–31	records lost	8.90	4.50

* Perkhidmatan Kajichuacha Malaysia.

† Dunlop Estates Ltd.

Temperature of bare soil averaged: 25.8°C in the 1st week
27.1°C in the 2nd week
27.7°C in the 3rd week

RESULTS

The area was sprayed on 9th November and seeds first planted on 23rd November; on 7th December a second lot of seed was planted; on 21st December and 6th January further batches were planted.

The results of the 23rd November batch were as follows:—

Growth	*OBSERVATIONS* *7th December*	*23rd December*	*4th January*
Control (all species except melon)	good growth	good growth	good growth
Pueraria	smaller leaves	some growth	recovery especially of later germinating seeds
Desmodium	good growth	good growth	good growth
Centrosema	good growth	good growth	good growth
Calapogonium	wrinkled leaves	some recovery	some recovery
Maize	good	good	good
Tapioca	no discernable difference	n.d.d.	n.d.d.
Soya bean	stunted distorted leaves	some recovery	some recovery
Water melon	experiment cancelled—control seeds did not grow, although those in the treated plot did.		

The above experiment was on bare soil which took the full quantity of the sprayed chemical. Normally conditions on the plantation are such that the soil is covered with vegetation of some sort; it was therefore decided to try and find out just how much chemical came into contact with the soil under such conditions. As a direct assay of the chemical was not practicable, use was again made of soya bean as an indicator plant.

Mikania is readily killed by less than 10 fl oz of the picloram/2,4-D mixture per 20 gallons water. The experiment was therefore conducted using multiples of this dosage: control nil, 10 fl oz, 20 fl oz, 40 fl oz, 80 fl oz in 20 gallons water; employing a double head jet several areas of sheet *Mikania* were sprayed. The next day when the spray had completely dried from the leaves, the *Mikania* and what other vegetation was present was stripped from the soil and samples of the top two inches of soil collected in three plant pots per treatment. Ten soya beans were then planted in each pot and the pots lightly watered every day. The results summarised in *Table 3* show that growth of the soya bean seedlings appeared normal in the 10, 20 and 40 fl. oz. treatments, the percentage germination did not differ from that of control, while in the highest rate of 80 fl. oz. there was die-back in 9 out of the 30 seedlings, and a further 8 seeds failed to germinate. The leaves of several of the seedlings rolled inwards, suggesting some toxic effect of the picloram/2,4-D mixture.

Table 3. Growth of soya beans in soil sprayed with picloram/2,4-D

Amount of herbicide in 20 gal. water	*Seeds germinated*	*Die-back*	*Remarks*
Control (Nil)	21	0	—
10 fl oz	22	0	—
20 fl oz	21	0	—
40 fl oz	20	0	toxic symptoms
80 fl oz	21	9	toxic symptoms

The results of this experiments suggest that much less than 12% of the sprayed chemical made contact with the soil, for although the soya bean is easily killed by the lowest spray rate of 10 fl oz, 80 fl oz of herbicide had to be sprayed onto the *Mikania* before the soil had absorbed similar toxic levels of herbicide.

Where vegetation is interposed between the spray and the soil it absorbs a vast majority of the chemical. An aerial spray of a jungle area near Segamat with 3 gallons of a mixture of 2,4-D, 2,4,5-T and Tordon also demonstrated how little of the herbicide ever reached the ground, for while the top and middle canopy trees were defoliated and to a large extent killed by the chemical they absorbed, the delicate ground seedlings of the same species responded by vigorous growth to the loss of shade—so much so that it was not possible to achieve the mass of dead vegetation necessary for a successful jungle burn. If the herbicide had made the slightest contact with such seedlings death or damage would be inevitable. Markle *et al.* (1967) have similarly reported that when a thick growth of running live oak was treated with picloram, only 10% of the applied material reached the soil. Picolinic acid is acknowledged to be more persistent than either 2,4-D or 2,4,5-T, and yet even on bare soil its persistence under Malaysian conditions is not much more than a month for the rates used in the above experiments—rates that are slightly more than the recommended maximum for any application, *i.e.* 12½ oz a.i./acre. When the same rates are sprayed onto cover plants, the persistence is much reduced for it seems only about 12% of the applied spray comes into contact with the soil. However, quite contrary impressions could be gained from sensational press statements quoting work conducted in Saskatchewan, Canada, and Puerto Rico, where rates of 12 and 27 lb a.i/acre respectively were used. The purpose of experimenting with such quantities of any highly active pesticide seems questionable.

A warning is required at this stage. Although less than 12% of herbicide came into contact with the soil, it persists in the vegetative matter or cover plants, and if this organic material is incorporated in the soil by rotovation or other forms of cultivation while still in the green state the soil can be rendered toxic to sensitive plants.

A plot of land was divided into six subplots of 12 ft × 18 ft, two subplots were sprayed with Tordon 101 at the rate of 2 pints in 20 gallons water/acre, and two at 1 pint/acre, the other subplots acting as control. The day after spraying, six samples of soil were collected from each of the subplots. The control samples consisted of the vegetation and top soil associated with the roots while similar samples were taken from two of the sprayed plots, one from the 2 pints/acre and one from that sprayed at 1 pint/acre; the remaining samples from the sprayed plots consisted of the top soil shaken loose from the roots of the vegetative cover. Ten seeds of soya bean were planted in each pot and all were lightly watered. Germination of the seeds commenced on the third day after planting. Unfortunately, the percentage germination of the soya bean was much reduced, and while a blotting paper germination test gave 61% success, in the control only 43.3% seedlings survived to become mature plants. These results were considered normal for this batch of seed obtained from the College of Agriculture, Serdang *via* Dr. Standifer. *Table 4* gives the final result.

Table 4. Survival of soya bean seedlings in Tordon-treated soil

	Control	*1 pt/acre*		*2 pts/acre*	
	Veg + Soil	*V + S*	*Soil*	*V + S*	*Soil*
% survival of seedlings	43.3	16.6	36.6	0	30.0

Clearly the herbicide that had been absorbed on the vegetation had not been broken down in the 3–4 days prior to effective germination. Because of the poor quality seed no attempt was made to determine how long the Tordon remained toxic in the soil. However, it does not seem likely that a plantation manager will spray chemicals onto an area that is scheduled for rotovation in the immediate future.

DALAPON

Dalapon is a herbicide that is used at 12–15 lb/acre on *lalang*, but unlike picloram it cannot be called a chemical with high activity; 2,2 dichloropropionic acid is rapidly broken down by micro-organisms (Thiegs, 1962). Especially in moist warm soil and even in a pure aqueous solution it breaks down under a Malaysian ambient temperature of 27°C at the rate of 1% per hour. *Figure 2* gives the path of the breakdown.

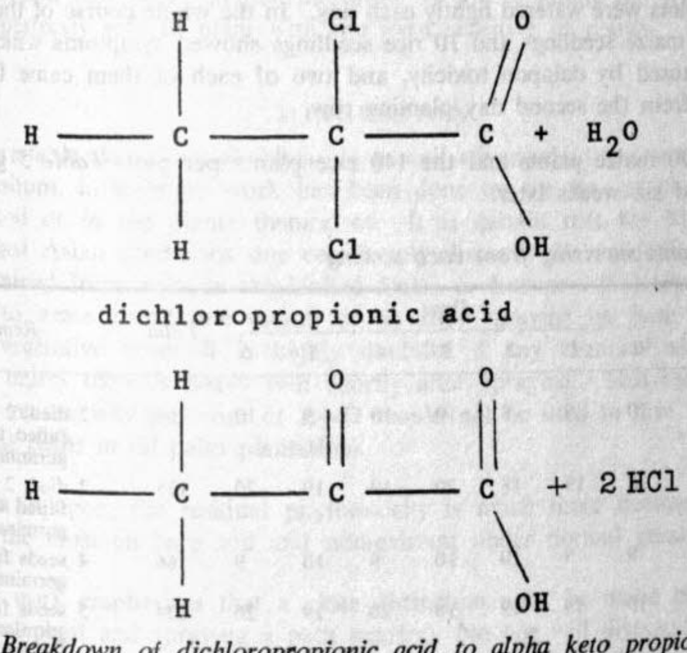


Fig. 2. Breakdown of dichloropropionic acid to alpha keto propionic acid or pyruvic acid

Thiegs (1962) also showed that although a massive dose of 50 ppm (roughly equivalent to 40 lb/acre) took 4–5 weeks to disappear in the moist soil at 38°C, a second similar dose disappeared in one week, indicating the build-up of a population of micro-organisms that could utilise dichloropropionic acid. From such a population, Hirsch and Alexander (1960) isolated and characterized 3 strains of *Pseudomonas* and 5 strains of *Nocordia;* Thiegs (1962) isolated Flavo-bacteria, Magee & Colmer (1959) Agrobacteria, while Jensen (1957) added *Trichoderma, Chonostachya* and *Arthrobacter*.

If *lalang* is treated with 15 lb dalapon/100 gal water/acre, this represents 1½ g chemical per sq metre, and of this only a proportion will come into contact with the soil. It can, therefore, be surmised that the life of dalapon is likely to be a few days at most. This was confirmed by the following experiment.

METHOD

Four plots of land measuring 12 × 18 ft in the previously mentioned estate area were stripped of all vegetation and the surface broken up by means of *changkols.* One of the plots acted as control, while each of the other plots received a spray of dalapon at one of the following rates: 16.6, 33.3 and 50 lb/acre. Maize seed and IR8 rice seed was planted in rows at a distance of 1.5 ft between maize seed and 9 in. between rice seed. The first row of each crop was planted immediately after spraying, and subsequently a fresh row was planted every day thereafter for a week. The plots were watered lightly each day. In the whole course of the experiment only 3 maize seedlings and 10 rice seedlings showed symptoms which might have been caused by dalapon toxicity, and two of each of them came from the control plot from the second day planting row.

Of the 70 maize plants and the 140 rice plants per plot, *Table 5* gives the results viewed six weeks later.

Table 5. Plants surviving from each sowing

	Days 0	1	2	3	4	5	6	Total	Remarks
Control:									
Maize	10	9	8	10	10	9	10	66	2 died, 2 seeds failed to germinate
IR8	20	19	18	20	19	19	20	135	2 died, 2 seeds failed to germinate
16.6 lb/acre:									
Maize	9	9	10	10	9	10	9	66	4 seeds failed to germinate
IR8	19	19	19	18	20	19	20	134	5 seeds failed to germinate, 1 plant died
33.3 lb/acre:									
Maize	9	7	9	8	9	10	9	61	1 died, 8 failed to germinate
IR8	18	17	18	20	19	20	20	132	6 seeds failed to germinate, 2 plants died
50 lb/acre:									
Maize	10	10	10	10	10	9	9	68	2 failed to germinate
IR8	17	18	18	19	19	20	19	130	5 seeds failed to germinate 5 plants showed browning of leaves and died

Ants seemed to be the cause of most of the seeds failing to germinate, and could have induced the conditions which caused the plants to die even in the control plot. Even so, it can be deduced that during the three to four days required for both the rice and maize seeds to germinate and the radicle to come into contact with the dalapon-treated soil, decomposition of the chemical was virtually complete, and there was no progressive increase in toxicity symptoms in either rice or maize with the increase of chemical per acre. A suggestion of toxicity of rice was observed in the 50 lb/acre plot for the first two planting rows, but the effect was very mild.

Dalapon is a systemic herbicide and is not quick acting; *lalang*, for example, can be expected to show signs of dying 3–4 weeks after being sprayed, and even shade grasses such as *Axonopus* or *Panicum* take 2–3 weeks. Therefore, it can safely be said that once dalapon has done its job of killing the grasses the soil will be perfectly safe to plant with the most sensitive of plants.

DISCUSSION

It is regrettable that although Malaysia is well advanced in the use of chemicals in agriculture, little or no work has been done on the fate of those chemicals in the soil or in the plants themselves. It is certain that for Malaysian and South East Asian conditions one can largely discount the residual phytotoxicity data obtained from work in the United States or Europe. Picloram is probably present to some extent one month or so after spraying on bare soil, but on normal vegetative cover it is highly doubtful if any chemical at all reaches the soil unless there is heavy rain shortly after spraying. This means there is no good reason why picloram or 2,4-D should not be used to give weed control in harvest paths in oil palm plantations.

With dalapon, the residual phytotoxicity is much more fleeting—perhaps 4 days at the most on bare soil and non-existent under normal grass cover.

The work emphasizes that a clear distinction must be made between over-spraying a plant and spraying a path nearby. No one will dispute the fact that if oil palm seedlings are oversprayed with many chemicals the results are disastrous. Turner & Bull (1967) give many examples, but it is the age of the plant that is all-important.

A 4-month old nursery palm seedling suffered severe damage when oversprayed with 4 g a.i. of picloram/2,4-D mixture, yet a year-old palm showed no effects when sprayed with 16 g a.i. Similarly, dalapon can be used to kill all forms of palm and bamboo, yet the amount increases markedly with the vigour of the plant, 50 g a.i. dalapon being needed to ensure death of the meristem of a coconut palm aged 3 years, but only 10 g a.i. for seedlings 6 months after germination.

Until it has been shown whether any 2,4-D or dalapon ever reaches the soil in normal estate spraying, one can discount the idea that there is danger in the roots absorbing sufficient chemical to affect growth in any way. It also means that where planters are using diuron as a residual pre-emergence herbicide in the ring weeding of oil palms, they must ensure that the soil is exposed enough to receive the herbicide, otherwise they are wasting money.

Curiously, while the herbicides under discussion are readily rendered inactive outside the plant, it would appear they are absorbed by the plant intact (Wells, pers. comm.; Foy, 1961), and can be exuded by the roots as an unaltered molecule when the plants are grown in nutrient solution. Whether this applies under normal field conditions is not known. If it were so, then a small residual effect of these chemicals would be possible until the plant was dead.

CONCLUSION

When the recommended rates of picloram/2,4-D mixtures and dalapon are used in the control of weeds the residual phytotoxicity period is short for all practical purposes. Very sensitive plants, such as soya bean, show some toxic symptoms one month after the soil has been sprayed and allowed to weather, but there is no effect on growth. Dalapon has perhaps four days residual phytotoxicity when sprayed on bare soil.

On soil that is well covered by vegetation—the conditions which require chemical weed control—not more than 12% of the chemical ever reaches the soil unless washed there by rain, although it can remain unchanged once absorbed into the plant until the plant is dead.

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DISCUSSION

Chairman: D.E. Barnes

Wood: In situations where chemicals do not have any residual herbicidal effect, is this because they are broken down or because they are leached away? Will they then reappear somewhere else? It may sound far-fetched now, but twenty years ago who would have thought DDT had anything to do with eagles' eggs?!

Lowe: Dalapon and 2,4-D are easily broken down in the soil, the latter within a few days. Picloram was absorbed on to the clay in the Rengam series soil with which we were working, and it would be difficult to prove that it had leached away.

Chairman: Picloram is not broken down by bacterial decomposition, is it?

Lowe: It is, but at a much slower rate than 2,4-D.

Wood: Will this cause any microbiological imbalance through over-feeding some of the microflora?!

Chairman: Further to Mr. Wood's question, what would be the fate of any picloram which had been sprayed on the foliage, as the leaves decompose? Would it then become available in the soil, or would it be retained by the mulch?

Lowe: Broad-leafed weeds take about 4 weeks to die completely after a Tordon spray, by which time the Tordon will have been destroyed. This view can be contradicted, but only in situations where very high rates of the chemical have been used.

Varghese: I have noticed some very persistent effects of Tordon on palms in polybags, and am therefore wondering what its effects might be on the microbiological flora of the soil?

Lowe: This is a very complex subject; for instance, what microorganisms are involved?

Varghese: We found experimentally that adding Tordon to soil in the laboratory caused drastic changes in the microflora. Fortunately, under field conditions these changes are only temporary.

Chairman: When comparing the half-life of one chemical with another, the dosage rate should be considered. Thus, as the dosage rate of Tordon increases, so does the half-life. The rates of application recommended for normal estate use in this country are far below any that would cause residue problems.

Lowe: One reason for presenting this paper is to stimulate some research on this particular point about the residual effect of the chemical.

Wong: Could damage be caused by the vapour of Tordon applied in the field? We have found that after spraying Tordon or 2,4-D on hot, still days that the vapour of these chemicals can be smelt several yards away. Could the vapour be taken into the stomata and damage the leaves?

Lowe: Tordon and 2,4-D are not volatile; therefore unless they have been applied with a mist-blower this effect would not occur. I am surprised that you say you can smell the chemical.

Pushparajah: There are many forms of 2,4-D.

Lowe: I was referring to 2,4-D amine.

Chairman: Esters of 2,4-D are volatile and can be detected, but the sodium salt and the free acid tend to be less so, while lithium salts are much less volatile. For this reason, lithium salts are used around plants very susceptible to other forms of 2,4-D. Tordon is much less volatile than 2,4-D.

SOME PESTS OF OIL PALM ON THE EAST COAST OF SABAH

by

S.N. Young

(Presented by R.A. Gillbanks)

This paper summarises observations made over several years on an oil palm estate of nearly 6 000 acres established in 1962. The estate is situated in the Kunak district of Sabah and is approx. 6 miles from the sea; the soil is largely a volcanic basalt type but small outcrops of sandy shale also occur, together with flatter areas of a colluvium. Some 600 acres had previously been planted with tobacco, the rest being jungle, most of which had been exploited for timber. Pests have been encountered since the earliest days of planting; initially these were predominantly mammals, but insect pests reached serious proportions once the plantings began to mature. Because of their potential importance it is considered essential that an investigation should be made into possible pest problems in areas such as this before planting begins.

MAMMALS

Most estates in this area are at least partially surrounded by forest or secondary jungle which provide abundant natural habitats for many of the pests. Although mammals, and sometimes birds, cause more damage to oil palm at certain stages of development than insects in this part of Malaysia, they have received little attention from those concerned with pest control. As a result, the amount of accurate data available, as distinct from the considerable volume of folklore, is limited and hence the basis for control measures has been both uncertain and unscientific.

Most pests can be characterised by the type of damage they cause, as for example, rodent damage which is distinctive irrespective of the size or species responsible. It is however, necessary to distinguish between potential pests and harmless members of the natural fauna. For example shrews and 'moonrats' in particular were considered pests of oil palm in the early years, whereas an examination of their dentition would have shown their feeding habits to be mainly insectivorous. This was not done, and considerable payments were made as bounty for the tails of these relatively harmless animals. The policy sometimes adopted of 'shooting anything that moves' is therefore highly undesirable.

The major mammalian pests encountered on this estate were, in order of importance: porcupines, elephants, pigs, rats, and periodically squirrels and monkeys. These are considered separately.

Porcupines

These are very large rodents, their spine arrangement differing according to species. The three species encountered in Sabah are:

Hystrix brachyura	—	common porcupine
Thecurus crassispinis	—	thick-spined porcupine
Trichys lipura	—	long-tailed porcupine

On this property, *H.brachyura* has been almost entirely responsible for the damage caused by this group of pests, although individuals of the long-tailed variety have sometimes been encountered.

Porcupines were often found to have moved into a new clearing even before it had been completely planted. In an area of 30–40 acres planted on one day it was not uncommon to find next morning that patches of up to 8 acres had been destroyed in the interval. Very often, the damage occurred several chains from the jungle edge and from observations of fresh scratchings and occasional shed spines it was subsequently found that the majority of the pests lived within the clearing itself, burrowing beneath the timbers of the old stand. When control by smoking out was attempted during daylight hours, burrows were found to contain entire families of up to five, or even more. It was observed that a burrow was rarely used more than twice, (possibly because of the abundant human smells in a planting, which could cause frequent movement to new habitats,) and so the damage pattern does not remain stable.

Damage caused by this pest is very characteristic, the young palm being completely gnawed through, its fronds scattered, and the apical bud (or 'cabbage') gouged out. Attacks were largely confined to patches, although a clearing could contain a number of such patches. This contrasted with experience in West Malaysia (Pahang), where damage was less widespread and resulted from several different groups or families operating independently in their own territories.

In attempting control of porcupines, it was found that baiting with poisoned tapioca, even after a period of pre-baiting with non-poisonous mixtures, was ineffective, with the young palm remaining much more attractive as a food source. Possibly the correct bait formulation has yet to be derived. Conway (1965) stated that control by hunting and paying a bounty for each animal killed was virtually useless in that the figures of pests killed bore little relation to the total population. However, this method was found to give good results on this estate and the pest population was markedly reduced. This success is probably in part attributable to the food value of the animals; when numbers in the clearings had been reduced, labourers also sought out the pest in the surrounding jungle.

Elephants

The species of elephant found in Sabah is *Elephas maximus*, the true Asian elephant, identical to the species in Sumatra. Whilst according to folklore it was introduced in captivity and later released, it certainly exists in the wild state in Sabah. Except for the occasional lone individual, elephants normally occur in herds of five to seventeen and their attacks have been regular. The type of damage is unmistakeable: young palms are usually completely uprooted and their centre shoots torn out. Older palms are pushed over and the centre shoots similarly damaged, with recovery being impossible; damage of this type was recently seen in a 6-yr-old planting. Most attacks occur during late evening and dusk although dawn incursions are not uncommon.

Devices to frighten the elephants, such as the carbide gun, have proved ineffective in control, the apparatus often being rendered useless by the elephants themselves *e.g.* by trampling. Shooting an individual has been a useful control measure but only a temporary one since the herd returns some months later, very often to the same spot. However, elephants are protected in Sabah, with illegal killing incurring prosecution and a heavy fine. A herd can usually be frightened away by a fusillade but departure is only temporary.

Little is known about the migratory movements of elephants in Sabah. The writer agrees with the statement (Conway, 1965) that a satisfactory solution to the elephant problem will only follow full knowledge of its migratory movements, obtained by tracking, after which attempts can be made to restrict it to certain areas away from cultivation.

Pigs

The wild pig *Sus barbatus*, commonly known as the bearded pig (babi janggut), is indigenous to Sabah, living in the forests and scrub land. It is capable of a high reproduction rate like its domestic counterpart, with which it compares in size when full grown. Damage usually takes the form of young palms being uprooted; more recently however, these animals appear to have developed a taste for oil palm fruit, especially in the boundary areas. Whilst loose fruits are preferred, a severely chewed ripe bunch some 4 ft above ground level has been seen by the writer, the animal obviously standing on its hind legs to achieve this. Damaged fruit is normally severely masticated, often with the kernel crushed, giving the impression of having been chewed and then spat out.

Whilst pigs have never become serious pests on this estate, they have always been present. As with elephants, attacks appear to be very regular. During the early years of planting, pigs were considered to be of such importance to the young palms that professional hunters were employed at a rate of one per thousand acres. Whilst this rate might seem excessive, excellent control was achieved, despite a very high pig population, merely by patrolling jungle boundary fences. Nowadays, very effective control is achieved with hunting, since pigs are a food source and nightly hunting expeditions by labourers are commonplace. A strong boundary fence of barbed wire is also of considerable value in preventing attacks provided it is well maintained. As with porcupines, poison baits with tapioca have proved ineffective in control, the baits usually being completely ignored.

Rats

Although there is an endemic population, rats are not a serious problem, with such damage as occurs at present being of little or no economic importance. Damage only became apparent when palms came into bearing, with loose fruit and sometimes bunches being sporadically gnawed.

Where necessary, baiting has been carried out using formulations of the antiocoagulant group of poisons, *e.g.*, warfarin and coumachlor. The action of these substances is to inhibit fibrin production in the blood stream, thus preventing clotting. As a result normal minor injuries, especially pregnancy, cause small lesions and internal haemorrhage, leading to death. Since the action of these poisons is a cumulative one and illness is slow to develop, the rat does not associate the symptoms with feeding and hence the condition known as 'bait shyness' is avoided. Should rats become a serious problem, adequate control should be achieved by baits containing these poisons.

Since rats frequently nest in the palms themselves (in rotting bunches or frond axils) it is important to maintain a high standard of sanitation on the estate. Regular pruning is normally sufficient to reduce such nesting places to a minimum, supplemented with removal of large masses of detritus during harvesting rounds.

Squirrels and Monkeys

Damage by squirrels and monkeys has been sporadic and mostly confined to jungle boundaries. Control is by shooting; this is assisted by slashing a boundary perimeter about 10 ft wide, which gives the hunters a clear field of fire.

INSECTS

Until 1966 no appreciable outbreaks of insect pests had occurred in Sabah (Conway, 1965), although it was stated that 'elsewhere such problems have arisen and we must expect to encounter them here'. This forecast has indeed proved accurate.

Most oil palm plantings support a variety of insect pests, although their numbers are usually limited. This endemic population is normally controlled by parasites and predators. The former are mostly small wasps and flies whose eggs are laid, hatch and subsequently the larvae feed in the body of the insect; the latter include ladybirds, spiders and assassin bugs which catch and kill the pests. The level of natural control however is not constant, and fluctuations in pest populations are influenced by other factors. For example, it has been observed on this estate that prolonged dry weather appears to have an adverse effect on populations of parasites and predators, thus allowing one or more pest species to develop almost unchecked, leading to pest outbreaks.

Red Spider mite

Red spider mites appeared first in nurseries early in 1964, becoming serious also soon after planting into the field. *Oligonychus* sp. was first identified, but probably *Tetranychus piercei* also occurs. Various insecticides have been used in control but only formulations of dimethoate and metasystox have proved effective. In the absence of natural control, the regular appearance of this pest has necessitated routine use of these compounds. Whilst the pest is no longer of importance since planting has been completed, it is of interest to note that it is usually seen during microscopic examination of oil palm pollen during testing for viability; almost any sample of fresh pollen will yield two or three of these mites.

Caterpillars

(a) *Darna* (*Orthocraspeda*) *trima*. This pest has been present on this estate almost since its inception, even occurring in the nursery where it was controlled by hand-picking. Until recently natural control has been adequate, but during the period January to March 1969 a severe outbreak affected 1 400 acres of mature palm, reducing the leaf area of some trees by up to 60%. This outbreak coincided with an abnormally prolonged drought. When a 10-day census system was introduced (Wood, 1968), it was found that up to 12 000 caterpillars could occur per census point of six fronds.

The caterpillar is dark chocolate brown in colour dorsally and when full-grown is about 15mm long. There are four rows of dark brown spines situated sub-dorsally and two rows in a lateral position; the lateral anterior three pairs and the lateral eighth pair are dark brown and the remaining lateral spines are almost clear with a greenish tinge. The larvae feed almost exclusively on the undersurface of the leaf, eventually giving it a tattered, shredded appearance.

The cocoon is small and globular-oval in shape; when newly formed it is covered by a light-brown webbing but this does not persist for long. Cocoons are sometimes found attached to the pinnae at their point of insertion on the palms but also occur on trunk epiphytes and in copious amounts at the palm base on exposed roots and rotting frond bases. It has been observed that caterpillars on the point of pupation crawl down the fronds and fall, either to be caught up in the epiphytes or into the weeded circles, where many are killed by ants and other insects before obtaining refuge in the palm base.

The moths of both sexes are similar, having a dark brown head and thorax, the forewings dark brown with four black stripes and the hind wings dark grey. The females are distinguishable by their simple antennae, those of the males being bipectinate. The moths generally assume a characteristic stance, their bodies being positioned almost perpendicular to the surface and with the forelegs being held clear of the sitting surface.

Little appears to be known of the life cycle of *D. trima*. From the writer's observations, the normal duration of the various stages appears to be as follows:

egg	5 — 7 days
larva	17 — 30 ,,
pupa	10 — 12 ,,
adult	12 — 15 ,,

The shorter time seems to prevail during periods of drought, which appear to provide the most suitable environmental conditions for rapid completion of the life-cycle.

Attempts made during the drought period to control the caterpillar by spraying Dipterex (trichlorphon) at various concentrations and using mist blowing equipment were unsuccessful. However, with the onset of wet weather natural control occurred through the appearance of disease, the precise nature of which has yet to be determined, but which may be of virus origin. Within a short space of time the population was severely decimated, being virtually eliminated in some areas, including cocoons.

It has been observed by the writer that diseased caterpillars show distinct symptoms. There is a backward movement towards the midrib from the usual feeding place of the pinna edge. Signs of apparent discomfort are shown by spasmodic wrigglings and contortions preceding a quiet period before death some hours later. The brown colour loses its lustre and the body becomes less turgid and is easily ruptured by any slight injury. A fungal mycelium grows on a small proportion of the dead caterpillars, but this is secondary.

Other predators occurred, *e.g.* the bug *Sycanus dichotomus*, but their level was inadequate. Possibly the use of contact insecticides contributed to this by reducing their numbers. It is felt that under normal weather conditions control is best left to natural means, even though some leaf damage may ensue before this control becomes fully effective. If possible, use of insecticides should be avoided. If sprays are to be used, it is suggested greater use should be made of the stomach poisons supplemented by a sticking agent, since natural enemies are affected to a lesser degree by these poisons and the adjuvant makes them persist for longer periods on the foliage.

(b) *Bagworms*

The most serious species of bagworm on this estate is *Mahasena corbetti* which, together with *Metisa plana* in smaller numbers, was recently responsible for moderate to serious damage over 850 acres. *Cremastopsyche pendula* has also been identified but appears confined to domestic fruit and shade trees.

The length of the life-cycle of *M. corbetti* is not precisely known but seems to be about 3 months between the time when eggs are laid and emergence of the male moth after pupation. Young larvae feed on the leaf surface, and as they grow make irregularly-shaped holes and finally eat the leaf edges, giving them a very ragged appearance. Pieces of leaf tissue are used by the caterpillar for case construction. The full-grown caterpillar attaches the case to the leaf and pupates inside it, with its head towards the opening. After emergence, one-half of the empty pupal case of the male can be seen projecting from the original larval case. Fertilisation is effected by the male moth alighting on the case of the female (which, being apterous, never leaves the case) and inserting his abdomen between the case and the female; females are in fact, little more than egg sacs. Since the female is wingless, spread of this pest is through larval mobility, usually assisted by wind. It is not uncommon to see hundreds of caterpillars, each suspended by a gossamer thread, swaying in the wind.

A census system (Wood, 1968) shows not only the population size but also the stage in the life-cycle; knowledge of the latter is important since sprays of contact insecticide, such as Dipterex, are reported to be most effective if their application is timed to coincide with the period when most of the individuals are young larvae. In a recent aerial spraying trial on this estate it was found that the youngest larvae survived whereas up to 95% kill of 10-day old larvae was obtained; the age variation occurs when hatching takes place over a period of time. With older caterpillars, the case undoubtedly becomes too thick for penetration by most formulations, but advantageous use of lead arsenate could be made for as long as the larvae continue to feed.

Some natural control of bagworms by such insects as *Sycanus dichotomus* and various flies of the Tachinid family has been observed, but their numbers are insufficient for effective control. There does not appear to be any significant form of microbiological control of bagworms, unlike with *Darna*, and the pest does not appear to be severely influenced by changes in weather conditions in Sabah. Experience to date, although results are incomplete, indicates that it is possible to confine bagworm outbreaks within reasonable limits by spraying insecticides on this estate; they must be applied aerially since ground conditions preclude the use of effective spray equipment for tall palms.

Metisa plana populations are smaller than those of *Mahasena* and control measures are similar. The appearance of the adult male and the life-cycle are similar to those of *M. corbetti*.

(c) *Other caterpillars*

Setora nitens is present but populations have never reached the economically significant levels experienced in West Malaysia. Individuals have been found in the midst of *Darna* attacks. Pupation is usually on the ground. Many pupae have been found parasitised in some way; sometimes ants have been seen within the cocoon, presumably having consumed its contents. Possibly natural control is effective in preventing this caterpillar from reaching significant numbers at present.

Thosea asigna is similar to *Setora* in structure and colour except that it is blotched whereas *Setora* is distinctly striped. A minor outbreak of this caterpillar has occurred in the district. Other species, *T. vetusta* and *T. bisura*, have also been identified, but no serious damage by these species has been reported. Small outbreaks of both *Thosea* and *Setora* can be effectively controlled by judicious application of lead arsenate.

Acknowledgement. This paper is published by permission of Messrs. Harrisons and Crosfield (Sabah) Sdn. Bhd., Sandakan, Sabah.

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DISCUSSION

Chairman: P.D. Turner

Chairman: One commends planters like Mr. Young who make original observations and record them. Although as he says there is still a considerable volume of folk-lore on pests, recent research work is supplying us with accurate data. I would ask why (repeating the speaker's own query) have rats, endemic to Sabah, not become a serious problem there as they are in W. Malaysia?

Wood: It is odd that *R. tiomanicus*, the major problem in West Malaysia, has not affected palms in Sabah, since the species occurs there. Such rat problems as do occur are with *R. rattus diardii*, the house rat, localised around living sites. Learning may be involved—once a few *R. tiomanicus* find that oil palm estates provide a good environment, this may be the beginnings of the rat problem that I expect eventually to occur in Sabah.

Davidson: First, is it necessary to wait for rats to build up before taking action? Could they not be deterred in advance? Second, after a flood in one area in Sabah, very severe rat damage occurred, apparently by a swamp rat which later disappeared of its own accord.

Another pest we find a great problem, especially in peat areas but now spreading to other soils, is termites. What is the West Malaysian experience of this pest?

Wood: There is little that can be done before rats become a problem, because we do not know which rats will occur, nor where they will originate. I am not sure which rat it could be that appeared after the flood—I wonder if it is the ricefield rat (*Rattus argentiventer*) which occasionally causes severe damage in W. Malaysia, or possibly the swamp giant rat (*Rattus mulleri*)—the latter would be a first record as a pest. The situation would be worth investigating if it occurred again.

Serious termite damage in W. Malaysia is rare. Local application of heaps of powder of a chemical like dieldrin, on the runs, might well be effective. The workers carry it into their nests and the colony is destroyed.

Chairman: Presumably it would not be economically worthwhile to control rats before they become serious?

Davidson: Mr. Wood said that rats were bound to find sooner or later that oil palm fruit was suitable food. My point is, can we not prevent this by applying some form of repellent?

Gillbanks: It should be possible to treat bunches, with barium carbonate for example, but this would be far too expensive to be practicable. A continued census of rat damage would permit control measures to be taken as and when necessary.

OBSERVATIONS ON AND CONTROL OF LEAF-EATING CATERPILLARS IN OIL PALM

by

K. Arulandi

The oil palm industry in Malaysia has expanded rapidly over the past two decades, with the planting of vast acreages. The extensive monoculture is conducive to the development of pest outbreaks, which spread rapidly. There is, therefore, a need for constant vigilance and a demand for rapid implementation of control measures whenever necessary to avoid economic loss. Only leaf-eating caterpillars are discussed, in particular two types of nettle caterpillars (Cochlidiidae) and bagworms (Psychidae).

The object of this paper is to record the various spraying methods possible and to stress the necessity of suitable equipment to deliver insecticide in an efficient and, more important, speedy manner to the topmost fronds of palms. The practical difficulties encountered and the results achieved by the various types of equipment in combating outbreaks of nettle caterpillars and bagworms by spraying with insecticide are discussed. The observations on population dynamics and control measures undertaken during periods of high build-up were made on an estate in the coastal area of Selangor on 2–9 yr-old palms replanted from rubber.

Initially the caterpillars existed in insignificant numbers causing minor damage to the leaves. In mid-1969 an infestation of the bagworm *Metisa plana* occurred, with *Cremastopsyche pendula* and *Mahasena* sp. also present in very small numbers. This was followed at the end of the year in the same area by an infestation of nettle caterpillars, predominantly *Ploneta diducta*, a small proportion of *Darna trima* and a few *Setora nitens*. The main pests during this period therefore were *M. plana* and *P. diducta*. These pests and their entomology are described by Wood (1968), an account of *P. diducta* being given by Leitch (1966).

THE PESTS

M. plana occurs on the upperside of the pinnae and generally confines itself to the tips of the fronds, preferring the younger whorls more exposed to sunlight. Young larvae scrape the upper epidermis in more or less circular patches which later turn brown. Older larvae eat through the leaf tissues leaving circular holes resembling 'shot holes'. The holes coalesce with progressive necrosis of the leaf tissue, eventually resulting in the skeletonization of the palms. The larvae feed for about eight weeks before pupating on an inclined position on the undersurface of the leaf.

Larvae of *P. diducta* feed for about five weeks on the underside of the leaves, and when fully fed attain a length of about 25 mm. They confine themselves to the lower fronds, but in severe infestations spread through the entire crown. Palms along the roadside and open patches appear to be more prone to infestation. The damage is caused by the young caterpillars scraping small patches of leaf tissue on the underside of pinnae in more or less elongated patches, leaving the transparent upper epidermis which turns brown. Later they set themselves along the edges of the pinnae and work backwards, feeding voraciously on the entire lamina, giving the leaves a serrated appearance. If the outbreak is left unchecked the pinnae can be completely consumed leaving only the midrib, resulting in total defoliation within a short period. The defoliated palms appear to produce shorter fronds later.

ASSESSMENT OF PEST POPULATIONS

Regular assessment of the pest population by a census technique has immense value in forecasting outbreaks. Such a census keeps track of the progress of infestation and follows the life-cycle of the pests, helping to combat them at a stage when they are most vulnerable to insecticides. A post-treatment census also is useful in that it reveals the effectiveness of any given treatment.

On this estate pest census was carried out at monthly intervals by the method suggested by Wood (1968). One pest surveyor and a helper can cover 100–150 acres per day, costing 6–8 cts. per acre per round.

CONTROL—EQUIPMENT

The control of sporadic caterpillar outbreaks in young palms aged 2 yr presented no difficulty. A manually-operated knapsack sprayer of 4 gal capacity in the hands of a 2-man team was found to be satisfactory. This team was able to cover 6 acres per day at a cost of $1.11 cts. per acre.

In older palms 3–6 yr of age, with a height of up to 20 ft, insecticides can be applied by a motorized knapsack sprayer or mist blower. This machine weighs approximately 30 lb and has a capacity of 2 gal. When operating properly a good coverage was obtained, but during the spraying the mist blower was found to be inefficient mechanically, with overheating and minor breakdowns occurring frequently, thus necessitating the presence of a competent fitter in the field. The unit could spray only 200–350 palms per day. Costs were $1.65 cts. for labour, 50 cts. for fuel and 80 cts. replacement of spares including depreciation of the machine, making a total of $2.95 cts. per acre.

A stirrup pump connected to a long bamboo lance fitted with a nozzle of diameter of 3/64 in. gives a fine jet. However, this equipment does not give adequate coverage and is wasteful. It appears unsuitable for covering large acreages. One stirrup pump with 2 men working can cover only about an acre per day; labour costs amount to about $6.62 cts.

The "Conomist", a tractor-mounted low-volume air-blast sprayer, was found suitable for tall palms because of its ability to deliver the insecticide to a height of more than 40 ft. Power from the tractor rotates a fan, producing a high velocity air-stream into which is injected the insecticide solution. Spraying at the rate of 25 gal/acre, the unit was capable of treating about 20 acres per day, costing approximately $1.30 cts. per acre.

For large areas, where rapid coverage is essential, aerial spraying is the only feasible means of insecticide application. Under a wide range of conditions its costs compare favourably with other techniques. A Piper Pawnee–235, the only agricultural aircraft available in Malaysia, was employed for spraying the caterpillar-infested area. It should be noted that the acreage covered by it per day will vary considerably depending on the distance of the airfield from the spraying site and the length per run over the area to be treated. Other factors such as output rate, loading efficiency at the airfield etc. are also important. To speed up loading of insecticide, 500 gal tanks were used to mix the solution while the plane was away spraying. A motor pump loaded the solution into the aircraft within one minute. Many factors such as speed of aircraft, pump pressure and swathe width contribute to obtaining the desired gallonage per acre. The Company (Malaysia Air Charter) that hires out the aircraft charges a fixed rate for hiring and an additional charge per flying hour. Spraying 1 000 acres with Dipterex 95 SP (trichlorphon) cost about $1.90 cts. per acre, whereas 550 acres sprayed with lead arsenate cost $3.00 cts. per acre on this estate.

Consideration should be given to the feasibility of utilising a road in the estate in a replanted area which can be converted for temporary use as an airstrip, provided the approaches are clear of obstacles such as telephone wires, transmission lines, rubber trees, palms, etc. A strip with a surface free of potholes and bumps, having minimum dimensions of $1\,800 \times 40$ ft and a further 50 ft on either side of it will be ideal. The refilling equipment should be at the end of the landing strip to achieve a fast turn-round after loading. The area to be treated must be provided with ground markers set alternately along rows and interrow lines in a 30 ft triangular planting, to obtain a swathe of 40 ft.

The above total cost per acre per round excludes cost of chemical. At the time of spraying, Dipterex 95 SP cost $3.35 cts. per lb and lead arsenate $1.20 cts. per lb.

Comparisons of performance and cost of the various types of spraying equipment are given in *Table 1*.

Table 1. Comparison of five different types of spraying equipment

	acres per day per machine	*Tank capacity (gals)*	*Normal gal per acre*	*Palms which can be treated*	*Cost per acre, Malaysian dollars* Labour	Fuel	Spares depreciation sundries	Total
Stirrup Pump	1	4	40	< 7 yr	6.60	—	0.02	6.62
Knapsack mist-blower	4	2	15–20	< 6 yr	1.65	0.50	0.80	2.95
Hand-operated knapsack sprayer	6	4	8	< 2 yr	1.10	—	0.01	1.11
'Conomist' tractor-powered mist-blower	20	60	25	< 10 yr	0.65	0.15	0.50	1.30
Piper Pawnee	1 000	100	1	> 4 yr	1.40 including hire charge	—	0.50	1.90

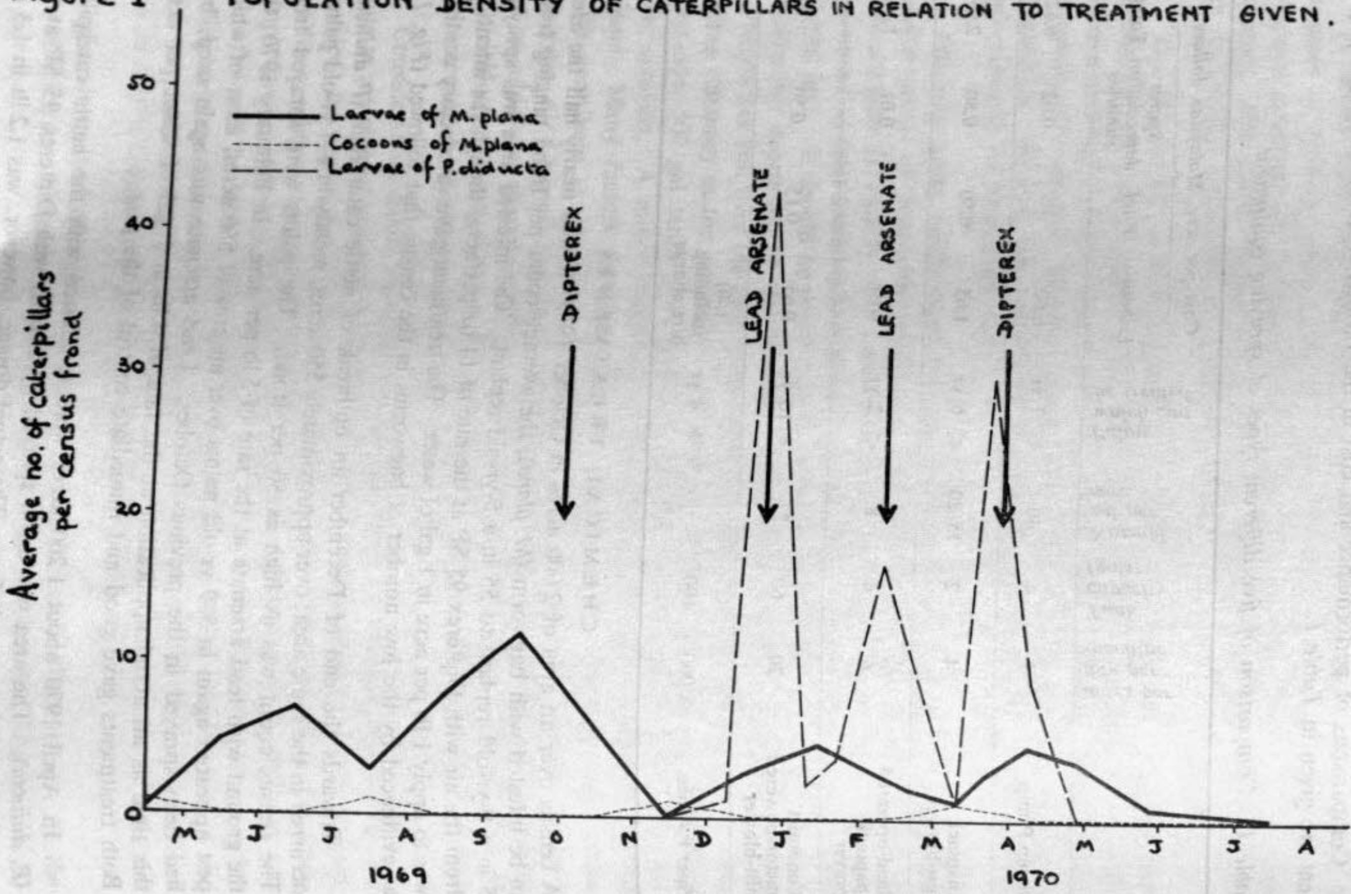
CHEMICAL TREATMENTS

A census over an area of 2 000 acres in October 1969 showed nearly half the area to be infested with bagworm (*M. plana*), the average count per frond ranging from 5 in a 9-yr-old replant to 55 in a 5-yr-old replant. The infested area was sprayed from the air with Dipterex 95 SP at the rate of 14 oz per acre, though the intention was to apply 1 lb per acre in 1 gal of water. The treatment gave satisfactory control, as evidenced by the low number of bagworms in the census that followed (*Fig. 1*).

Towards the end of December an outbreak of nettle caterpillar (*P. diducta*) occurred in the same area, over approximately 550 acres, mostly in 4–7 yr-old palms. The census count was as high as 80 per frond. The palms were sprayed from the ground with lead arsenate at the rate of 5 lb per acre. In February 1970 the pest appeared again in 5–9 yr-old palms over an area of 550 acres, most of which had been sprayed in the previous October. Lead arsenate was again used, but this time as an aerial application at the rate of 4 lb in 1 gal of water per acre. Both treatments gave good and immediate control of the pest.

In April 1970 about 1 260 acres were re-infested with the nettle caterpillar (*P. diducta*). The area was again sprayed by aircraft with Dipterex 95 SP at the same calculated rate as before. The actual dosage, however, was 1.2 lb in 1.3 gal

Figure 1 POPULATION DENSITY OF CATERPILLARS IN RELATION TO TREATMENT GIVEN.



of water per acre. A rapid decline in the number of the pests was noticed within ten days of treatment and subsequent control was good.

Details of the three aerial spraying treatments conducted on this estate are given in *Table 2.* Lead arsenate frequently tends to choke the nozzle of the aircraft, hence only 29% of the total time was spent on actual spraying. By using a road on the estate as an airstrip, an increase of 16% in spraying time for the second Dipterex application was achieved, compared with flying from Subang nine miles away.

Table 2. Details and costs of aerial spraying

Date	*Treatment*	*Acres*	*Flying time*	*Refilling time*	*Total time*	*Percentage of time flying*	*Spraying cost per acre*	*Ground support cost per acre*	*Total cost per acre*
16 Sept 1969	Dipterex 14 oz/acre	1 000	200 min	214 min	414 min	48%	$1.41	$0.50	$1.91
22 Feb 1970	Lead arsenate 4 lb/acre	550	151 min	374 min	525 min	29%	$2.66	$0.32	$2.98
14 Apr 1970	Dipterex 1.2 lb/acre	1 260	341 min	192 min	533 min	64%	$1.52	$0.40	$1.92

OTHER OBSERVATIONS

It was noticed that large continuous areas of oil palms were more prone to attack by these caterpillar pests than small fields surrounded by mature rubber. Mean caterpillar counts, per census frond, between May 1969 and March 1970 showed 4.26 bagworms and 2.99 nettle caterpillars in a 229 acre block, compared with 0.02 and 'nil' in an 87 acre block isolated all round by rubber.

It was also noted that immature palms were less susceptible to heavy outbreaks of caterpillar pests. Small numbers are generally present in immature areas bordering mature oil palm fields suffering an infestation. Heaviest attacks were in palms 5–7 yr of age.

The young larvae are more susceptible to treatment than older caterpillars.

CONCLUSION

In the selection of insecticides, preference was given to a stomach poison (*e.g.* lead arsenate) and a short residual contact insecticide (Dipterex). The broad-spectrum long residual contact insecticides would have given a rapid "knock-down" but these were avoided in order to ensure the survival of natural enemies of the pests. Assassin bugs, wasps, spiders and other enemies were evident in the area even during post spray periods. Parasitic tachinid flies continued killing nettle caterpillars. By June 1970 the infested area was restored to a pest-free state.

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DISCUSSION

Chairman: P. D. Turner

Chairman: Two important points raised by Mr. Arulandi were the need for constant vigilance and rapid implementation of control measures, once an outbreak becomes serious. Nationally, this demands sufficient trained observers, and points the need for more extension work to teach smallholders how to recognize pests and how to deal with them. The cost of 6–8¢ per census round is a cheap insurance premium against unexpected pest attacks. The problem of when to spray, and when to leave alone to allow possible natural control to occur is also a vexing one, for it must be assumed that leaf-eating pests lead to crop loss.

Cates: Possibly ultra-low volume (ULV) applications would prove effective in reducing costs, by reducing ferrying times. We were able to get down as low as 4 oz/acre, effecting considerable economies, in the British Solomon Islands when spraying against delphacids and army-worms on rice. Is there any experience in Malaysia?

Wood: I know of no work on ULV application from the air in oil palms. The coverage with ordinary low volume spraying (down to 1 gallon/acre) is good. We have a preference for using trichlorphon against most caterpillars, but I am not aware if it can be applied in ULV formulation. Ground application with a hand-held ULV apparatus gives an excellent coverage, as gauged by using ultra-violet tracers, so the possibility of using it exists.

A further point is aircraft availability. We hope that (due to continuing natural control pressure) the aircraft sprayer is like a fire-brigade: essential to have, but not too often used! The question of financial backing for the operator arises, unless other outlets can be found. Then there may be clashes of interest, as exemplified by a recent need to send Malaysia's (then) single spraying aircraft to East Malaysia, when it was wanted in W. Malaysia and *vice versa*.

Third, Dr. Turner is correct in assuming that leaf eating pests lead to crop loss. A recent (unpublished) experiment at Chemara shows that a strong correlation exists between the amount of artificial defoliation and subsequent crop loss.

Kirsch: There *is* a ULV formulation of trichlorphon available, successfully used in South and Central America.

On the question of safety, I wonder if anchored balloons would be better spray-run markers than flagmen?

Wastie: In rubber, we had a lot of trouble with balloons. Big ones inflated with hydrogen just couldn't penetrate the canopy, and small ones soon burst. We now prefer the painted umbrella type of marker.

BIOLOGICAL CONTROL POSSIBILITIES OF SOME INSECT AND WEED PESTS IN SABAH

by

R. A. Syed

BIOLOGICAL CONTROL

It is an indisputable fact that no organism can multiply indefinitely without limits. All the available space in the world would be insufficient to accommodate even a single species of plant or animal if its population could continue its natural tendency to grow without any outside check. The limiting factors are physical, *e.g.* unsuitable climate and soil, scarce food and space, or biological, *i.e.* parasites, predators, pathogens etc. Action of all the environmental factors, physical and biological, in the regulation, determination, or governance of populations, within certain upper and lower limits, is termed 'natural control'.

Natural enemies, *i.e.* the parasites, predators and pathogens, play a major role in the natural control of populations. In stable communities, such as the primary forests, the environmental resistance to the growth of population of any particular species is well adjusted, and it oscillates within certain established tolerable limits. In mono-cultures, on the other hand, because of super-abundance of food and space, the environmental resistance to certain animals and plants may be lowered, and their populations may tend to increase. If the natural enemies are able to cope with the increase in population, the pest would remain under natural control. On the other hand, if these are weak or absent (as may happen in the case of an introduced pest), increased infestation or an outbreak may follow. In other words the population would become unstable, and its oscillations would be greater, and irregular. Manipulation of the natural enemies, in order to restore the balance of population to an economically tolerable level, is termed 'biological control'. The extent of success determines the degree of biological control achieved.

It is understood that each organism has its own natural enemy complex which, of course, may be similar for closely allied species or genera. In any attempt to strengthen this complex, it is imperative that the complex should be fully understood. Assistance in the increase in number of a certain natural enemy already occurring in an area (augmentation), help in survival of a particular species of natural enemy under unfavourable conditions (conservation), or strengthening the natural enemy complex by addition of one or more species from another area (introduction); for all of these, proper knowledge of the pest, its environment, its natural enemies etc., is necessary. Breeding techniques for the target pest or an alternative host and for the natural enemies have to be developed. In short, extensive basic studies are indispensable requisites for an attempt at biological control.

Doutt (1964) has summarised the historical development of biological control. According to him the value of biological control, as a method of suppressing pests, was strikingly demonstrated to the world by the control of cottony-cushion scale (*Icerya purchasi* Mask.) on citrus, by vedalia beetle (*Rodolia cardinalis* Muls.) in 1889 in California. 'It is of interest that after Koebele [a California entomologist who obtained vedalia from Australia] went to Hawaii he did some of the earliest practical work with an insect disease, the fungus *Metarrhizium*, in 1897, and possibly the first work in biological control of weeds when he sent insects that fed on *Lantana* from Mexico to Hawaii, in 1902. After this early period many countries initiated biological control projects and achieved such satisfactory results as to encourage continuing support of this type of research. World-wide developments since 1900 have been too extensive to mention more than a few here. Outstanding work in biological control has been done in Australia, Canada, Chile, Fiji, Hawaii, Israel, Japan, New Zealand, the U.S.A. and the U.S.S.R. to name only a few. Outstanding successes have been obtained, in over 60 countries, in all parts of the world. Modern biological control laboratories have been established in many countries, and superb contributions, both theoretical and practical, are appearing each year from these centres. The Commonwealth Institute of Biological Control, with headquarters in Trinidad is especially noteworthy for its contributions. From the Institute's beginning till 1958, Dr. W. R. Thompson, who has done much to put biological control on a truly scientific basis, was director' (Doutt, 1964).

Since 1958, the C.I.B.C., directed by Dr. F. J. Simmonds, has acquired a truly international and world-wide character. At the various stations and sub-stations of the Institute some 50 entomologists are working on 95 projects, shipping over the past few years an average of approximately 700 shipments p.a. totalling about 3 million individuals of 124 beneficial species to 27 countries. Successful introductions of natural enemies have been made against at least 37 species of pests in 25 countries (Simmonds, 1969). In Sabah a sub-station of the C.I.B.C. was established in 1969 to work on the possibilities of biological control of oil palm bagworms.

A major sphere of activity of the C.I.B.C. is the procurement and shipment of suitable natural enemies to other parts of the world. This involves heavy expenditure, requires trained personnel, and is beyond the individual means of developing nations. By virtue of the extended sphere of activity of the C.I.B.C., its entomologists are working in or near almost all the major regions of the world. This helps in procurement of the beneficial insects and expert advice at a very low cost.

It would be relevant to consider the economics of biological control. Unfortunately figures for all the savings accrued as result of successful biological control are usually obscure. Simmonds (1967) has discussed the economics of biological control and has given the available figures of savings as a result of successful projects helped or handled by the C.I.B.C. De Bach (1964) has given the figures for California, which amount to savings of over $115 million for the period 1923 to 1959.

while the total budget, for all the work in biological control, was just over $4 million —a net saving of over $110 million.

It is sometimes believed that native pests cannot be controlled by biological means. Pimentel (1963) in a review has shown considerable evidence that native and introduced pests have been successfully controlled by introducing parasites and predators which attack allied species or genera of pests in different habitats. Of 66 examples of pest species, successfully controlled by biological means and in which the habitats of the species could be documented, 39% involved the use of an introduced parasite or predator from an allied species or genus. He cited 10 examples of native pests which have been controlled by introducing parasites or predators of allied species or genera from a different habitat. He has further stated that such natural enemies 'may prove especially effective against native pests'.

CLIMATE OF SABAH

Sabah extends from 4 degrees to 7 degrees latitude north. The climate is remarkably equable, with temperatures on the coast varying from 74°F in the early morning to 88°F at mid-day. Night temperatures are around 72°F along the coast, but are lower at higher altitudes. It has an evenly distributed annual rainfall of 60–160 inches: 60–80 inches on the south-east coast extending from Tawau to Lahad Datu and in the area lying east and south-east of Tambunan, Keningau and Tenom; 140–160 inches in the area extending inland from Brunei Bay; and 80–120 inches in the rest of the country.

Climate and soil conditions being favourable, a luxuriant tropical rain forest covers Sabah and it has aptly been described by Urquhart (1959) as a green desert. According to him the state has greater agricultural possibilities, in relation to its size, than any other tropical country. In spite of its great potential, agricultural development in Sabah was insignificant until after the second world war. Since then, the acreage under rubber and coconut has increased, and large areas have been planted with oil palm and cocoa. However, commercial planting of abaca and tobacco has been discontinued.

INSECT PESTS AND BIOLOGICAL CONTROL POSSIBILITIES

According to Conway and Tay (1969) there are no serious pest problems on rubber.

Coconuts have been damaged by periodic outbreaks of leaf-eating caterpillars of which nettle caterpillars (*Setora nitens* Wlk.) is the most important. Outbreaks of coconut leaf moth, *Artona catoxantha* Hamps., have been less common. The rhinoceros beetle (*Oryctes rhinoceros* L.) has been a pest in a few localities.

The important pests of oil palm in Sabah are nettle caterpillars and bagworms on mature palms, and red spider mites on nursery palms. *Darna trima* (Moore) is widespread. Recently (in May, 1970) there was a minor outbreak of *S. nitens* on oil palm in one estate. Amongst bagworms, *Mahasena corbetti* Tams. is by far the most serious pest. Others which are also of considerable importance are *Metisa plana* Wlk. and *Cremastopsyche pendula* Joannis.

A large number of insect pests of cocoa has been listed by Conway and Tay (1967). These include ring bark borer, *Endoclita hosei* Tindale; branch borers, *Zeuzera* spp.; white plant hopper, *Colobesthes falcata* Guer.; some species of bagworms particularly *Clania* spp.; a looper, *Hyposidra talaca* Wlk.; and the iridescent beetle, *Rhyparida iridipennis* Jac. During my limited stay in Sabah I have noticed the last-mentioned in outbreak proportions.

Possibilities of biological control of a few of the above-mentioned pests will be considered individually.

Setora nitens Wlk.

S. nitens was recorded in 1936 on coconut at Tawau in mainland Sabah. Since 1936 there have been several outbreaks in Tawau and Kudat areas, affecting up to 4 000 acres. In the worst affected areas the coconut plants are almost completely defoliated, and loss of up to 70% in copra production has been estimated. In May 1970, a minor outbreak occurred on oil palm in one estate near Sandakan.

Augmentation of the endemic natural enemies of the nettle caterpillar has been tried in the past, and in one locality increase of parasitism from 8–18% was reported. It may, however, be added that the usefulness of encouraging indigenous natural enemies is limited, except under certain conditions, *e.g.* after catastrophic destruction of natural enemy populations. Since the outbreaks occur repeatedly, probably the natural enemy complex is weak and therefore introduction of exotic species of natural enemies might prove useful. But, before any introduction, a careful study of the natural enemies and bionomics of the pest should be made. This would help in finding the weak links in the natural enemy complex, which might then be strengthened. For example, if no egg parasites of *S. nitens* are recorded, parasites from some other area might be introduced.

During the latest epidemic of *S. nitens* in Kudat, about 60% of larvae were seemingly infected with a viral disease. This should be identified and possibilities of field use of the disease should be explored.

Darna trima (Moore)

Reports of the Department of Agriculture, Sabah, mention that no nettle caterpillar had been observed on oil palm till 1962; small numbers were recorded in 1963. Since then it has become one of the most serious pests of oil palm in Sabah. It is also known to be a serious pest of cocoa in Java (Paereles, 1924).

Besides *Platyplectrus natadae* Ferriere, which was recorded on *D. trima* in Java (Ferriere, 1941), no other parasite of this pest is known. A fungal disease is reported to have wiped out an entire population of *D. trima* on 750 acres of oil palm in Sumatra (De Jong, 1925). An allied species, *D. catenata* Sn., is attacked by *Chaetexorista* sp. nr. *javana* and *Chrysis* sp. in Celebes (Tams, 1930).

Casual observations indicate that there are no parasites of *D. trima* in Sabah. However an Asopinid bug, which preys on the larvae, is invariably present in the infested areas. A virus infection has also been observed to kill large populations of this pest in some areas of the East Coast. The diseased specimens were sent to the Insect Pathology Unit at Oxford and they have isolated, from these, a small spherical non-occluded virus. This is considered to be the cause of the death of the larvae and collapse of the pest population (J. S. Robertson, pers. comm.).

After a careful survey, if *P. natadae* (the only known parasite of *D. trima*) is found to be absent, it could be introduced from Java. The reported fungal disease from Sumatra could also be tried. Parasites of *D. catenata*—which is reported to be present in Sabah—could also be surveyed and if *Chaetexorista* sp. and *Chrysis* sp. are absent, these could be introduced. A further survey for natural enemies of *Darna* spp. might reveal some additional species and should therefore be carried out.

The recently recorded virus could be used, mainly as an emergency measure, at the time of heavy outbreaks. A preliminary experiment carried out in one oil palm estate indicated that the infection can easily be initiated by spraying a water suspension of crushed diseased larvae. The virus would have an advantage over the insecticides in being very specific, capable of spreading by itself and, possibly, in being effective for a much longer period than the insecticides.

Bagworms

Bagworms are a serious problem to oil palm growers in Sabah. It is likely that they may also become a serious pest of cocoa. Several species of bagworms are known to feed on cocoa (Reports of the Department of Agriculture, Sabah), and localized infestations have been observed at several places.

Under a project sponsored by the Department of Agriculture, Sabah, the Commonwealth Institute of Biological Control is investigating the possibilities of biological control of bagworms on oil palm. Details of progress have been reported in the C.I.B.C. reports. Search for suitable natural enemies, for introduction into Sabah, is in progress in the West Indies by the West Indian Station of the C.I.B.C., and similar work in southern and central South America and India has been suggested. Some of the natural enemies from the West Indies and other places might be introduced. It is hoped that some of these might succeed in controlling or reducing the damage by bagworms.

WEEDS AND BIOLOGICAL CONTROL POSSIBILITIES

A weed is a plant that occurs where it is not wanted. Since the soil and climatic conditions are almost optimal for the growth of vegetation, weed problems are acute in Sabah. Some of the weeds, like lallang (*Imperata cylindrica*) are just hard to kill. Some, like Siam weed (*Eupatorium odoratum*) and *Lantana camara*, although easily killed, recover quickly. The struggle against weeds in Sabah is expensive, laborious, frustrating and endless.

In some countries biological control has solved some of the worst weed problems so far experienced. The object of this method is not eradication, but simply the reduction of a weed to a negligible status. Unfortunately, this method of control is usually adopted when others have failed, although there is no reason to use it as a last resort. In the early years of biological control, fear was expressed that introduced insects would become pests of a crop. Though the theoretical possibility of such a thing happening cannot be ruled out, because the insect may change in a way causing a new food plant to be accepted, these changes are, as in all evolution, rare, and they are usually the product of a great period of time. Constancy rather than change is the great rule of nature (Huxley, 1954). In short, if proper care is taken in selecting insects of restricted diet, practically no risk is involved.

The proportion of success in the biological control of weeds is highly encouraging. There have been few, if any, failures where a serious attempt has been made, and at least partial success has attended every real effort (Dodd, 1954).

Eupatorium odoratum and *Lantana camara*

Besides lallang, these are the most important weeds in Sabah. Siam weed (*E. odoratum*) readily occupies the areas cleared from forests and competes with young plantation crops, retarding their growth to a considerable extent. In older plantations it makes harvesting and field maintenance difficult. The Sabah Land Development Board has requested the C.I.B.C. to look into the possibilities of its biological control. Under a project financed by the Nigerian Institute for Oil Palm Research, the West Indian Station of the C.I.B.C., Trinidad, has made a survey for insects associated with *E. odoratum*. A large and varied insect fauna was found to be associated on this weed. *Ammalo insulata* Wlk. and *Apion brunneonigrum* B.B. have been found to be most specific, and have been recommended for introduction into Nigeria. These insects are now being considered for introduction into Sabah, for the control of *E. odoratum*.

A large number of insects are known to attack *Lantana camara*, and many of them have been tried in Hawaii, Fiji, India and Australia with considerable success. The C.I.B.C. has surveyed the natural enemies of *L. camara* in the West Indies, India, Pakistan and West Africa. The West African Station of the C.I.B.C. introduced *Teleonemia scrupulosa* Stal. to Uganda in 1963, and it has proved very successful in the Serere area. Although this particular species is known to occur in Sabah, some, like *Diastema tigris* Guenee, *Syngamia haemorrhoidalis* Guenee, *Ophiomyia lantanae* (Frogg.) and others may be considered for introduction into Sabah.

PESTICIDES AND BIOLOGICAL CONTROL

Development of modern pesticides appeared very promising in the beginning, but gradually it has been realized that the ill effects of pesticides, which include disturbance of natural balance, sometimes outweigh their usefulness.

'It is surprising insect pests are not a continuing problem, since an oil palm estate in Malaysia would appear to be an environment extremely suitable for pest increase. There are many insect pests which are able to find, in oil palm areas, an abundance of all that they need to complete a full life-cycle, and yet, as a rule, they persist at very low densities. Such pests include several species of leaf-eating caterpillars, various aphids, scale insects, and many others. There is strong evidence that such pests are regulated by biological factors. However, outbreaks of pests occur very frequently in oil palm and other plantations' (Wood, 1968). There could be several factors responsible for the outbreaks but 'there are a number of examples of outbreaks, on a grand scale, of leaf-eating caterpillars (mainly bagworms and nettle caterpillars) in oil palms, which have followed the use of certain insecticides, initially applied against minor outbreaks, either of the pest which itself has later become severe, or against an entirely different pest such as cockchafers. It is difficult to prove that these outbreaks have been caused by insecticide use, and in each individual case there is often an alternate possibility. There is no consistent alternative, however. Whilst absolute proof is lacking, the use of some modern insecticides in oil palms has so often been followed by severe pest outbreaks as to leave little doubt that such chemicals can be the cause of these outbreaks' (Wood, 1968).

The experience of planters in Sabah is no different. In the big oil palm estates, insecticides have to be applied on an ever-increasing scale, and yet the pest problem is on the increase.

Pesticides are a very potent weapon and their use has to be continued if man is to meet the ever increasing demand for agricultural produce. Their use must, however, be deliberate, selective and suited to the environment. Each pest problem must be studied on an individual basis of natural enemy/pest life histories, habits and interrelationships, in order to establish the pesticide programme which would complement biological control. Man has, and is continuing to adapt the environment to his use, and his success is a triumph of man's technology, but he must not misuse his resources. He cannot master the environment by the destruction of the ecological chain: co-operation, not conquest, should be the aim.

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DISCUSSION

Chairman: P.D. Turner

Chairman: Although there have been a number of successes with biological control methods, we are still largely dependent on chemicals in many cases. Biological control work is intricate and time-consuming and often unrewarding, but the potential rewards are high. Co-ordination at an international level is important, and in this, Commonwealth organisations have played a big part.

Galpine: *Darna trima* broke out in Tungut (Sabah) affecting about 200 acres. A chemical spray was used, for various reasons not very successfully. However, the virus disease appeared, spread rapidly, and cleared up all spray survivors. What are the chances of storage of disease organisms and manual propagation during outbreaks?

Syed: I am in close contact with the Insect Pathology Unit, Oxford, on this problem. The virus has, of course, to be tested against mammals to ascertain that it is non-pathogenic to humans. Deep-frozen storage of diseased individuals, which can be ground up and sprayed on, would probably be satisfactory.

Wood: Would Dr. Syed comment on the frequently expressed view that biological control by introduced natural enemies is likely to be more successful against introduced pests than native ones? Secondly, what is his view about rearing predators and parasites for mass release at critical times?

Syed: Undoubtedly chances are better with an introduced pest, but still there are good chances with native pests. One looks for enemies of insects related to the pests in other areas. This point is covered in the paper, where I mentioned that of 66 examples of successful biological control of a pest, 39% involved an introduced natural enemy from a related host.

Regarding the second point, an egg-parasite, *Trichogramma*, is mass-released in parts of the U.S.A. and it controls certain pests. I know of no others in practice, but no doubt they could be developed. In general, we consider the best policy is to import and establish the natural enemies; if outbreaks later occur, only then are chemicals necessary. After this, augmentation may be used to restore the natural enemies.

Wood: Specifically, on the last point, I was thinking of release of a generalised but efficient predator, perhaps itself normally held in check by egg parasites.

Syed: If you mean the bugs that feed on *Darna*, breeding might be difficult unless an alternative host could be found. Certainly it might be worth looking into—one cannot give a categorical answer.

Chairman: Dr. Syed, have you noticed any increased interest in biological control lately?

Syed: Lip service, of course, continues to be paid to it, but the weight of organised opposition is considerable.

THE RHINOCEROS BEETLE, *ORYCTES RHINOCEROS*, IN YOUNG OIL PALMS PLANTED AFTER RUBBER ON SOME ESTATES IN WEST MALAYSIA

by

H. S. Barlow and Chew Poh Soon

SUMMARY

As a result of further questions raised by an initial survey of problems associated with the control of *Oryctes rhinoceros* (L.), a detailed survey was undertaken of 105 acres of a 2-yr-old oil palm replanting on the coast in Northern Perak. This area was under serious attack by the beetle. The area was surveyed, and the larvae collected from rotting rubber stumps and counted by species and stage of development.

Preliminary evidence was obtained to suggest that approximately 40% of the females after feeding tend to range more widely than the remainder of the population. A low natural incidence of disease was noted, the virus disease, *Rhabdionvirus oryctes* Huger being the commonest, and the fungus *Metarrhizium anisopliae* (Metschnikoff) Sorokin considerably less common.

Further experiments using diseased larvae to infect healthy larvae indicated that field trials for propagating *R.oryctes* to control the beetle on an economic level would be worthwhile.

A mark and release experiment was conducted over three weeks. Approximately half the beetles marked remained feeding for about 24 hours. No instances were recorded of beetles remaining in feeding holes for longer than 158 hours, and in general the females appeared to spend slightly longer feeding than the males. A small proportion of the beetles returned for further feeding.

A comparison of infestations indicated that in a case of very serious infestation more than 200 adult beetles were found per acre over the 18-month period when the palms were most affected by damage, and that in a severe infestation a search for larvae at an intensity where ½–1 acre are covered in 1-man day, approximately 50% only of the third instar larvae, pupae and teneral imagines are collected, the earlier stages being almost unscathed.

A study of the effect of rainfall on beetle activity indicated that feeding activity was inhibited by rain. There was no evidence that beetle activity was correlated with phases of the moon.

A comparison of the costs of sustained beetle patrols and larval searches indicated that larval searches were preferable, even though costs may initially be higher.

INTRODUCTION

O. rhinoceros (L.) is a common pest of young oil palms in W. Malaysia. It posed a severe problem on a number of oil palm estates on the West Coast, in replants after rubber. The beetle breeds in the rotting stumps of the felled trees and the adults emerge and attack the young palms: 22 such estates covering about 37 000 acres of oil palms were involved. Managers of estates received a questionnaire about the problem. It appeared that the damage was more severe on coastal than on inland estates, on which damage was negligible. Most managers supposed that attack was from beetles breeding within the estates rather than invaders from outside. On control, there was an indication that denser ground cover was associated with reduced attack, although it by no means eliminated damage and that, of the methods in use, collection of adult beetles from palms, drenching of spears with insecticides and collection of grubs from rotting logs, none was sufficiently effective.

It was clear that more information and improved control were required and an investigation was initiated, the results of which are described.

OBJECTIVES AND METHODS

A block of 105 acres of immature oil palms planted in November 1968 at 60 palms to the acre on a coastal estate with a high water table, in the Bagan Serai area of Perak, was surveyed during March and April 1970.

Studies were made of the dispersal range of adult beetles, feeding habits and the nature of larval infestations, including the incidence of larval disease and parasites on adults.

The profile of an attack by adult *Oryctes rhinoceros* over the years of replanting was investigated.

THE STUDY AREA

The block is roughly rectangular, divided by paths or 8 ft drainage ditches into four approximately square smaller areas A, B, C & D of 27, 25, 23 and 29 acres respectively. The long axis is east/west with 1967 oil palms (in bearing and relatively free from attack at the time of the survey but heavily attacked in previous years) on the north side and mature rubber on the other three sides.

The 1939 rubber was felled May—August 1968. The stand per acre in tapping at the time of felling was A: 44, B: 90, C and D: 62 trees respectively. Rubber trees were felled and burned on site, but stumps were left in the ground. These had decayed considerably and doubtless provided the initial breeding grounds at an early stage in replanting.

The ground cover was by no means uniform, but the predominant species were *Asystasia coromandeliana*, grasses (mainly *Paspalum conjugatum* and *Ischaemum muticum*), creepers (mainly *Mikania scandens* and *Passiflora foetida*), and smaller areas of the legume *Pueraria phaseloides* and the fern *Nephrolepis biserrata*.

Selective spraying had been adopted, one round approximately every 6 weeks, to control undesirables, in particular, *I. muticum*. This had resulted in cover depth varying from little or none much of the time to covers more than 3 ft high. A rigorous comparison of the effects of different heights of cover on the larval infestations was thus impossible, although it was noticeable that in areas bare of cover the incidence of larval infestation in the stumps was generally higher than in areas of high cover. All palms in the area were numbered, to provide individual identification, and mapped.

INSPECTION OF BREEDING SITES

All rotting stumps were searched in a round from mid-March to mid-April. The number of *O. rhinoceros* eggs, larvae (stages 1, 2, 3) pupae, and adults (males and females distinguished) were recorded, in addition to the numbers of larvae (all stages) of lucanid and cetoniid beetles and the dynastid *Xylotrupes gideon* (L.). The results are shown in *Table 1*. It will be noted that the numbers of second

Table 1. Oryctes rhinoceros *stages and grubs of related beetles taken in the experimental area, March—April 1970*

		Number per acre												
		Oryctes rhinoceros												
		Adults			*Larval instars*									
	Acres	*Male*	*Female*	*Pupae*	*3*	*2*	*1*	*Eggs*	*Total*	X. gideon	*Lucanidae*	*Cetoniidae*	*Total eggs, larvae and pupae/acre*
A	27	2.1	1.9	.7	31.4	17.5	6.8	.4	60.8	.5	17.2	3.8	78.3
B	26	1.0	.5	.7	42.6	10.1	2.0	5.5	62.4	.1	35.0	2.2	98.2
C	23	1.5	.8	.5	48.2	3.6	7.1	7.5	69.2	1.1	8.3	3.9	80.2
D	29	.6	.3	.3	28.0	6.0	.9	.2	36.3	.0	17.8	.5	53.7

and third instar larvae found were much higher than the numbers of eggs and first instar larvae, even taking into account the much shorter duration of these stages. This is undoubtedly due to the fact that the eggs and first instar larvae frequently escaped detection, evidenced by neighbouring areas where, with regular monthly searches of stumps, large numbers of third instar larvae were found in successive months.

One point of interest is the marked predominance of males (63%) over females (37%). Of the 90 females taken, 27 (30%) (compared with Hoyt's (1963) Malayan figure of 22%) were found to be mature on dissection of the abdomen. For comparison, numbers of male and female adult beetles taken from the palms over the whole area between 12th February and 13th April were: males 515 (50%), females 525 (50%). Similarly, the results of breeding experiments (see below) indicate that approximately equal numbers of males and females reach maturity. Approximately equal numbers were observed feeding on palms. Thus it appears that although similar numbers of males and females develop and feed, a smaller proportion of the females return to breeding sites in the vicinity. It seems that approximately 40% of the females range further afield in search of a breeding site.

From the figures given in *Table 1* it can be seen that in stump inspections, *O. rhinoceros* predominated (71%), with lucanidae 25%, cetoniidae 3% and *X. gideon* 1%.

It was noted that the habitats of the lucanid and cetoniid larvae differed slightly from those of *O. rhinoceros*. The latter were seldom if ever found in small pieces of rotting wood, whereas this was not unknown in the case of the former.

The distribution of species of larva by stump is shown in *Table 2*.

Table 2. Distribution of species of larva in stumps of felled rubber

Fd	Estimated no. of stumps examined		Percentage of stumps found to contain representatives of the indicated beetles				
			O. rhinoceros, *lucanid and/or cetoniid*	O. rhinoceros *only*	*Lucanidae only*	*Cetoniidae only*	X. gideon *only*
A	1 100		5	9	3	<1	<1
B	2 300		2	6	4	<1	—
C	1 400		2	6	2	<1	<1
D	1 700		2	3	3	<1	—
Total	6 500	Average	3	6	3	<1	<1

DISEASES

The main diseases of *O. rhinoceros* in Malaysia are the virus disease, *Rhabdionvirus oryctes* Huger and the fungus *Metarrhizium anisopliae* (Metschnikoff) Sorokin, and an attempt was made to record any affected individuals. The majority of the diseased larvae were in the third instar. The difficult problem of identification of diseases is further complicated by the tendency of diseased larvae to exhibit symptoms of both diseases at once. As far as could be seen, 2 individuals had symptoms of *M. anisopliae* and 23 of the virus *R. oryctes* (*i.e.* overall only 0.5% of all grubs found). Dead larvae soon decompose, so natural incidence of the diseases might well be higher than indicated by these figures. In addition one third instar larva was found to be parasitized by the grub of an unidentified species of scoliid wasp.

In an attempt to check the natural incidence of disease, all larvae taken during one day's searching in Field C were kept in individual tins, and supplied with earth and rotting wood from the stumps in which they originated, until they pupated and hatched, or death supervened. Out of 88 larvae collected, 28 died of concussion (Surany, 1960) within the first 2 weeks, and of the remaining 60, ten died of what appeared to be *R. oryctes* and one of *M. anisopliae* (to which it succumbed in the teneral adult stage). Twenty-one males and 28 females emerged successfully.

In addition, on two occasions when larvae apparently diseased with *R. oryctes* were found in a stump, the remaining larvae (in all cases third instar) were held separately until pupation and emergence, or death. Out of a total of 19 such larvae, 14 died with typical symptoms of *R. oryctes*, and the remainder developed normally. This suggests that the disease, once established in the rotting stump, is virulent.

An infection experiment was conducted in an attempt to determine the virulence of the disease. A number of test tubes were filled with approximately 380 mg. of sterilised damp coconut sawdust. In this were mixed, in various proportions, macerated larvae which had apparently died of *R. oryctes* in the field. One *O. rhinoceros* larva was placed in each tube and the tube was then corked and examined daily to determine the time taken for the larvae to die. The results are shown in *Table 3*.

When considering the apparent success of the South Pacific Commission with similar propagation in Samoa (Marschall, 1970) it is necessary to bear in mind the possibility that a certain endemic resistance to the disease may have been built up in the beetle population in Malaya. Nevertheless the results shown in *Table 3* indicate that treatment of the breeding sites with strong concentrations of infected macerated larvae may help appreciably in the control of the insect.

Table 3. Time elapsing between exposure to R. oryctes *virus and death of larvae*

Proportion by volume of macerated diseased larva	*Mean no. of days of survival (Note 1)* *1st instar larva*	*2nd instar larva*
Nil (Control)	All survived (*Note 2*)	5 survived (*Note 2*)
1 : 150	5.5 | (*Note 3*)	—
1 : 75	5.4 |	—
1 : 25	3.3	4.8
	S.E. ± 0.49	1.64

Note 1. Period of observation was 31 days.

Note 2. Six larvae were used for each treatment, on both controls and infected batches.

Note 3. Means not joined by a vertical line are significantly different from each other at 1% level.

MARK AND RELEASE EXPERIMENT

In order to investigate the feeding habits of the beetle, and its range of activity, beetles from the two central fields B & C were used for a mark and release experiment. All adult beetles found feeding on the palms during a 3-week period were numbered sequentially and then returned to their feeding holes. Marking was carried out by scoring grooves on the elytra with a triangular file, lines on one elytrum standing for the tens, the other for the units. Hundreds were indicated by filing a small nick on the surface of the prothorax. Cumber (1957) has shown that such marking in no way affects the well-being of the beetles. This was also our experience.

Preliminary experiments with cellulose paint proved unsatisfactory. The paint failed to stick on the elytra and was easily rubbed off when the beetles came into contact with earth and decaying wood.

All the palms in the area were searched every day except Sundays and one day when rain prevented all work. However, all palms to which beetles had been returned on the previous Saturdays were checked on the Sundays in order to maintain continuity. Location of palms in which they were feeding and frequency of recapture at a particular palm were noted.

The main difficulty encountered was that of extracting the beetles without damage from the holes. The use of a wad of cotton wool soaked in chloroform was found to be ineffective, and a measure of success was only achieved by offering 5 cents reward to the searchers for every beetle recovered intact, to ensure care when prising them out with a piece of wire. Even then a damage rate of 9% occurred over the total occasions of capture/recapture.

In addition to marking and locating the beetles, an assessment of their age since emergence was made by observation of the condition of the abdominal hairs. Since this method can only be approximate, the classifications young, intermediate and old were used.

Results. It is known that the beetle flies from dusk to dawn and most activity takes place in the early evening, so any beetle captured once will have been in position for approximately 12 hours. Similarly it was assumed to remain for 12 hours after its final capture. One capture, with no recapture, thus indicates about 24 hours feeding; two captures, 48 hours and so on.

Very occasionally a newly deserted feeding hole was found in a palm with no capture record on previous days. It was assumed that a beetle had fed during one night only, and was not at any stage captured. Separate records were kept for males and females. Daily recaptures were analysed according to days of initial marking, and expressed as percentages of the total number of undamaged beetles released on days of marking. Allowance was made for damaged individuals.

and the figures shown in *Table 4* were derived by subtraction of the overall averages. The figures for the later returns are inevitably slightly distorted, since the chance of a beetle being damaged on multiple recaptures is clearly higher than on one capture only. A total of 9 beetles were damaged after initial marking in this way.

Table 4. Average percentages of beetles feeding in palms for varying periods

	Percentage of beetles at each length of stay (Note 1)						*Total number recorded*
	24 h	*48 h*	*72 h*	*96 h*	*120 h*	*144 h*	
Male	51	20	15	6	8	0	61
Female	44	28	18	0	5	5	59

Note 1. These figures exclude 3 beetles which fed for less than 24 hours and were consequently not marked.

It would appear that the females on average spend slightly longer feeding than the males. The percentages feeding for 120 hours or longer cannot be regarded as significant in view of the small numbers involved. However, it is possible that this represents residual feeding activity by insects which have completed their reproductive cycle. During the experiment 5 males, obviously old, returned to the palms and fed weakly, until they eventually died in their feeding holes. In any future work on these lines it would be desirable to search the stumps after marking of the adults has been completed in order to observe their subsequent behaviour.

Marked beetles returning to feed for a second time were more uncommon and no clear pattern emerged. Of the 80 beetles marked and left in their feeding holes, 6 males and 4 females returned at a later date. Although a watch was kept for marked beetles for 3 months after marking ceased, no beetle returned more than 22 days after initial marking, and no beetle was found more than 200 yards from the palm where it was initially marked. Results of observations on the condition of the abdominal bristles were unsatisfactory, although it was clear that the majority of beetles feeding had only just emerged. There appeared to be little correlation between the state of the bristles and age as deduced from the general condition of the beetles.

Mite counts. During the course of the above experiment, a count was made of the number of mites (*Hypoaspis* sp.) found on the beetles. The numbers found varied from 0–32, primarily on the underside of the thorax, and sometimes round the mouth parts. The numbers tended to fluctuate from day to day on individual beetles. *Table 5* shows some larger fluctuations observed on certain individuals seen several times. These fluctuations are probably due to mites becoming detached from the beetle when it was extracted from the hole. The mites are frequently found in the beetle breeding sites, and it is clear that they depend for their dispersal on being carried by the beetles. We believe they may be instrumental in the spread of *R. oryctes*.

Table 5. Fluctuations in numbers of mites (Hypoaspis *sp.*) *found on beetles feeding in oil palms.*

Sex	Number of mites found on beetle: *1st capture*	*1st recapture*	*2nd recapture*	*3rd or subsequent recapture*
Female	0	8	2	—
Female	0	1	3	6
Female	1	3	0	—
Female	0	12	10	—
Female	0	10	0	—
Female	4	6	0	—
Male	1	0	15	3
Male	0	12	3	—
Male	32	2	12	—

A final point worthy of mention is the frequency of cases where either two or more beetles were found feeding together in the same hole, or a new beetle came to a hole which had been deserted the previous night. Sixteen beetles were caught in this way, of which nine were males. The occurrence of two or more beetles of the same sex at the same hole indicated that no sexual attraction was involved. On two occasions three beetles were found in the same hole. No clear pattern could be detected in the times of arrival or departure of the extra beetles at the holes. These observations perhaps indicate a highly developed sense of smell for the sap of the palms.

INFESTATION LEVELS

Fig. 1 shows the overall infestation by adult beetles in the experimental area. A larval search undertaken in October 1969 is reflected in the much lower figures for October and November that year. However, the rapid build-up in numbers thereafter suggests that a large proportion, especially of younger stages, escaped detection in the course of the search. The results of a second search, completed in mid-April 1970, show a similar effect, with a recovery towards earlier levels in the immediately succeeding months.

Two censuses were taken of beetle damage, as outlined by Wood (1968). The results are shown in *Table 6*. The absence in the second census of heavily damaged palms (levels 3 and 4) indicates that the area is now recovering.

Fig. 1. Monthly collections of adult beetles from young palms planted at 60/acre in an area of 105 acres.

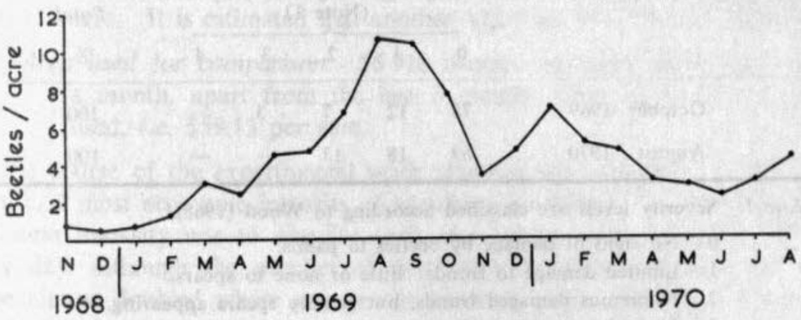

Fig. 2. Monthly collection of adult beetles from rotting rubber stumps (up to July 69) and young palms (August 69 onwards) in an area of 117 acres.

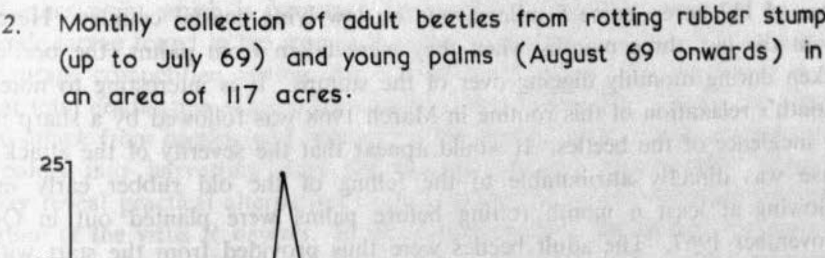

Table 6. Results of census of damage by Oryctes rhinoceros *in the experimental area*

	Percentage according to severity level (Note 1)					*Total*
	0	1	2	3	4	%
October 1969	78	12	7	3	—	100
August 1970	69	18	13	—	—	100

Note 1. Severity levels are classified according to Wood (1968):

0. No signs of damage by beetles to palms.
1. Limited damage to fronds: little or none to spears.
2. Numerous damaged fronds, but healthy spears appearing.
3. Many fronds damaged, spears shortened and distorted. Some spear rot.
4. Fronds severely damaged, all spears absent or rotting.

Fig. 2 shows the number of adult beetles collected monthly from an area of 117 acres, some 5 miles away, on low lying coastal country. Here, apart from the last three months when they were taken from palms, the beetles were taken during monthly digging over of the stumps. It is interesting to note that 1 month's relaxation of this routine in March 1968 was followed by a sharp increase in incidence of the beetles. It would appear that the severity of the attack in this case was directly attributable to the felling of the old rubber early in 1967, allowing at least 6 month rotting before palms were planted out in October–November 1967. The adult beetles were thus provided from the start with what must have been ideal breeding grounds.

EFFECTS OF RAINFALL

The fluctuation in the number of beetles caught daily in the palms was compared with the rainfall in inches for the 24 hours up to 09.00 hrs on the day the beetles were taken. The number of beetles attacking palms is generally lower in wet weather, supporting Cumber's (1957) findings in Samoa. No correlation was found between the moon's phases and beetle activity, although beetles are more commonly taken at light traps on moonless nights (Wood, pers. comm.).

ECONOMICS OF CONTROL

Two basic control measures have been considered: the searching of breeding sites for larvae, and "beetle patrols" daily over the young palm areas to collect the feeding adults from the palms. The comparative costs of complete sanitation at the time of replanting have not been included, since the high water table on the coastal soils would have precluded the use of heavy bulldozing equipment to remove stumps in any but the longest droughts.

The overall costs of the two measures were as follows:

Experimental area. Approx. $5 600 till 31st August 1970, using daily beetle rounds, and including 2 searches for larvae, *i.e.* $53.33 per acre. It is estimated that another $2.00 per acre will be required.

Area used for comparison. $6 918 overall, searching the stumps once a month, apart from the last 3 months when beetle patrols were used, *i.e.* $59.13 per acre.

In the course of the experimental work attempts were made to discover the optimum and most economic intensity of searching for larvae. It was found that the optimum intensity was to aim for each searcher to cover between ¾ and 1 acre per day, although the number of *O. rhinoceros* larvae collected per acre could be almost doubled where one person covered ⅓ acre per day. The costs of this highly intensive search approach $15.00 per acre, but this could well prove economic if adopted shortly after planting, with a view to destroying as much as possible of the breeding areas.

A further point which is frequently overlooked is the importance of leaving other beetle larvae found in the stumps in order to hasten the decay of the stumps and encourage competition against the *O. rhinoceros* larvae. In conclusion it is clear that total eradication is quite uneconomic, even if possible. Palms can stand a limited attack from beetles, and only where the attack results in delay in bringing young palms into harvesting does the damage become unacceptable. Future work may reveal practical alternatives such as biological control through artificial propagation of the virus *R. oryctes*. In the present state of knowledge, the correct approach is complete sanitation of young areas, combined with regular searches of decaying stumps, which should be broken up as much as possible as they rot, to destroy breeding sites.

There is evidence (Wood, 1969) to show that activity of beetles may be considerably reduced if a dense vegetation cover is maintained. A combination of these measures should provide adequate control, although complete sanitation is expensive, until the efficacy of cheaper measures has been proved. We believe that only if these measures fail, should it be necessary to revert to daily and laborious "beetle patrols".

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DISCUSSION

Chairman: P.D. Turner

Chairman: This was a pleasing paper—the prospect of drastically curtailing *Oryctes* damage is very exciting, and if it really got going, would please many oil palm planters on the coastal estates, where the pest seems to be especially severe. That it will be totally effective is, of course, unlikely because a few individuals always escape and survive.

Cates: I am familiar with the Pacific area and would like to observe that the increase in coconut planting in Samoa in the last year has been spectacular, because of the effect of the virus on *O. rhinoceros*. Disappointingly, in Tonga, where the virus and fungus were recently introduced, the effect has been less dramatic. This may relate to the author's statement that climatic conditions play a part. Observation suggests good results in one of the Fiji islands too, but unfortunately no expert assessment is being done at present.

Chairman: One of the interesting points in the paper concerned the suppressive effect of ground cover over the breeding places (including *Mikania*, not such a good thing perhaps!)

Wood: I have a comment on Mr. Barlow's point about changing the standards of damage assessment to take into account the greater susceptibility of younger palms. I would suggest retaining a common standard but lowering the level of alert for the younger palms.

Ground cover, when heavy, leads to almost total economic control. I cannot say this applies in all circumstances, but it is true of all those I have seen.

I am concerned that in Malaysia, the virus can co-exist with severe economic outbreaks. This tends to confirm the author's point that either genetic or climatic factors can prevent it from giving a total control—what one has to look for is some means of manipulation. Decoy breeding sites, like rotten sawdust inoculated with virus, might perhaps propagate the disease and add to the control given by ground cover. For the coconut smallholder, fighting influx from breeding sites he cannot control, the idea is especially attractive. The recent reduction in infestation in Samoa owes much to the virus, but what will be the situation when everything settles down remains to be seen. There is a degree of pessimism in some circles.

Barlow: We have the impression that right on the coast the beetle problem is more severe. Does Mr. Wood feel that ground cover is effective within two miles of the coast?

Wood: I cannot say—I would certainly recommend that you establish trials on the coast.

Owen Jones: I was recently associated with an estate which had a heavy *Ischaemum muticum* cover (if you can call it cover!), but little beetle attack. This was eradicated. Now there is no *Ischaemum* but plenty of beetle!

Johari: An area on an estate near ours has very heavy cover, but also plenty of beetle attack. It is in a peat area.

Hew: Two of our agronomic trials contained plots with different densities of cover. The experiments primarily assessed the effect of a leguminous cover, and the best age for planting out, but showed incidentally far higher attack in the bare or sparsely covered plots. This tends to bear out Mr. Wood's theory.

Wood: Don't call the cover effect Mr. Wood's theory! He has merely provided objective evidence to back up something that many planters have long known about.

Chairman: There is a statement in the paper that if the collection were held up for a month then considerably more damage results. This would emphasize the need for regular maintenance, but I wonder why it happened, since the life-cycle of the grub is about 3 months?

Barlow: I cannot give a complete answer. I can only confirm that this is what happened. Perhaps it is connected with the time spent in (and relative ease of finding) the various instars.

SOURCES OF REINFESTATION OF OIL PALMS BY THE WOOD RAT (*RATTUS TIOMANICUS*)

by

Brian J. Wood

SUMMARY

Previous studies on *R. tiomanicus* in oil palms show that virtually complete elimination can be achieved by proper baiting. Reinfestation is by reproduction, and invasion from still-infested palms and surrounding vegetation. Various studies have a bearing on the latter subject. They are described, and practical conclusions are derived.

Rats in climax population (steady density) had small home ranges, males averaging a maximum diameter 96 ft (from 0–260) and females 80 ft (30–270). Occasionally a rat moves further afield and appears to change its home range. This tendency markedly increases, after a time, when a population is depleted by trapping out, but rats do not rapidly flow into a baited area and the border between baited and unbaited blocks remains distinct for some time. Rats, after removal to nearby plots, tend to leave the place where they are released and will return home if the distance is not too great. This tendency breaks down only partially when the release site has a depleted population.

R. tiomanicus exists up to the border of estates with all other vegetation types sampled. It exists independently in lallang and perhaps in towns but not commonly in jungle or rubber. Other rats, rare even just inside estates, occupy these vegetation types, especially *R. exulans* in lallang and rubber and *R. rajah* in jungle.

Because of the mode of action of chronic poisons, it is best to bait manageable-sized blocks on frequent replacement rounds. Oil palms are the main source of reinfestation and it seems most advantageous to bait through a whole estate block by block. Roads and rivers cannot be considered inviolable demarcating lines. A practical baiting procedure is suggested. Special watch is then needed at fields bordering lallang or any oil palms over which no control can be exercised.

By using a sufficiently attractive bait in a systematic manner rats may be virtually eliminated from oil palms (Wood, 1969a). Reinfestation gradually occurs, partly through invasion from outside and partly through reproduction from any survivors and from the early invaders. Reproduction is of major importance, but where near-elimination takes place, there are strong indications that the early nucleus of a new infestation comes mainly from outside, so that if this reinvasion can be restrained or halted, the build up of a new population should be substantially delayed. The main sources are contiguous or nearby still-infested oil palms, and surrounding vegetation. Various studies on the biology of the wood rat, *Rattus tiomanicus*, are being continued, and a preliminary account is given here of data which may have a bearing on the question of reinvasion.

Methods

Populations are studied by catch, mark, release and recapture (CMR) methods. Rats are toe and ear clipped for individual recognition at later capture. They may also be caught by hunting and in spring-traps, as supplementary techniques. The studies were carried out on an estate complex in Central Johore with undulating but not markedly hilly terrain, where a number of areas were left out of routine estate control practice and set aside for the trials. Palms are planted on the triangular pattern, at either 30 or 33 ft spacing, which provides a convenient trapping grid (it should be noted that on triangular planting, distance between parallel rows is less than the distance between palms). Usually 2 or 3 traps per point (palm) are set. Population study methods are explained more fully in Wood (1969a). It has been noted in several trials that rat populations in oil palms, in the absence of control, occur at a certain level, which is generally from 100–200 rats per acre, with limited fluctuations. Without speculating on the mechanisms which bring this about, it may be called a "climax" population.

MOVEMENT OF RATS IN OIL PALMS

Home range

The area in which an animal normally spends its time is called its home range. The concept of home range is quite distinct from that of "territory", which refers to an area established by an animal for its living and which it guards against intruders, particularly during a breeding season (Burt, 1943). Various ways of assessing home range exist, such as radio tracking and marker dyes but the most commonly used, for practical reasons, is based on the distances apart of trapping, for animals caught several times in live traps. Where the last mentioned method is used, home range can be calculated from the available data in various ways. The simplest is to plot successive trapping points, enclose the outer ones and use maximum diameter as the home range index (*see* Fig. 2). This method appears to be adequate for the present purposes to illustrate the nature of the movement of the rats in the palms and compare it in various circumstances. A typical example of this home range may be taken from an experimental plot in an area with a climax population. The plot is 5 by 20 palms and trapping is done for four nights in every four week period. It has continued for 20 months and many rats have been recorded. In the first month, 202 rats were captured; 151 of them were still known to be present the following month. There was a gradual drop-out, but 2 of them were still present at 20 months. One hundred and twenty five of the rats were present over at least 3 months, and excluding a few which were only captured 3 or less times in this period, their average home range diameter was, for males, 96 ft (about 3 palm spaces), the smallest being 0 ft (same palm—6 captures over 6 months) and the largest 260 ft, and a rather smaller average of 80 ft (30–270) for females. The home range diameter for all these rats is depicted in the histogram (*Fig. 1*), grouped in successive 30 ft (1 palm space) distances. The trapping patterns of a few individuals exemplifying various kinds of home range are illustrated in the plan in *Fig. 2*. It is probable that the average diameters given, and the impression from these diagrams, somewhat underestimate the real range

Fig I Home range of multiple recaptured rats in a 630 x 130 ft plot as shown by percentage of total in each maximum diameter class.

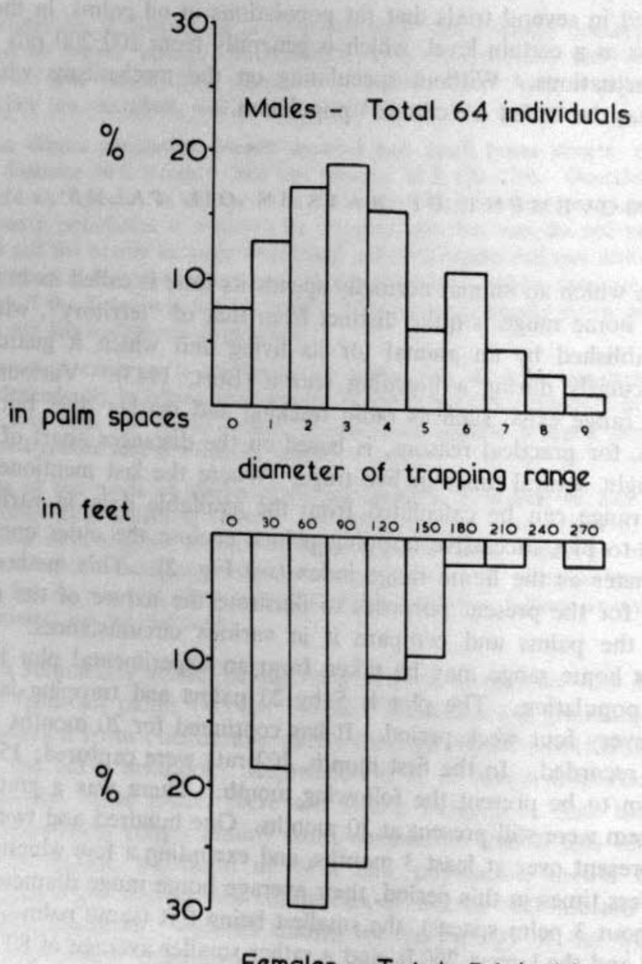
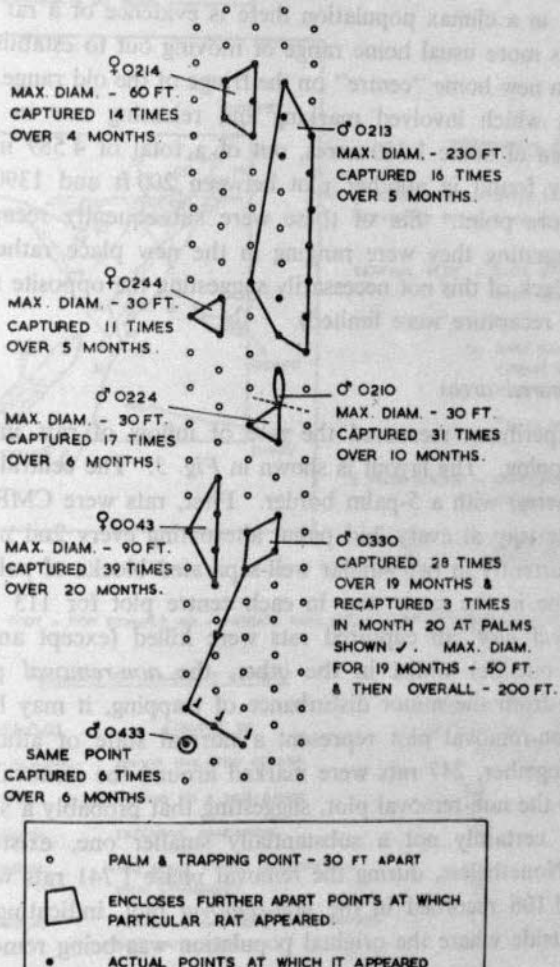


Fig 2 Home ranges of some sample rats in oil palms – illustrated by range of multiple recaptures in a long term trapping experiment.



because some rats will be coming into plots only as part of their home range. Thus rat ♂0213 probably moves out of the trapping plot and might go further afield than the indicated maximum diameter, and ♂0433 is caught at a single palm which may be near the edge of the range. Nonetheless they are a fair guide to the rather restricted areas occupied by individuals, and some rats were multiple-recaptured at a single palm within the plot, not on its edge.

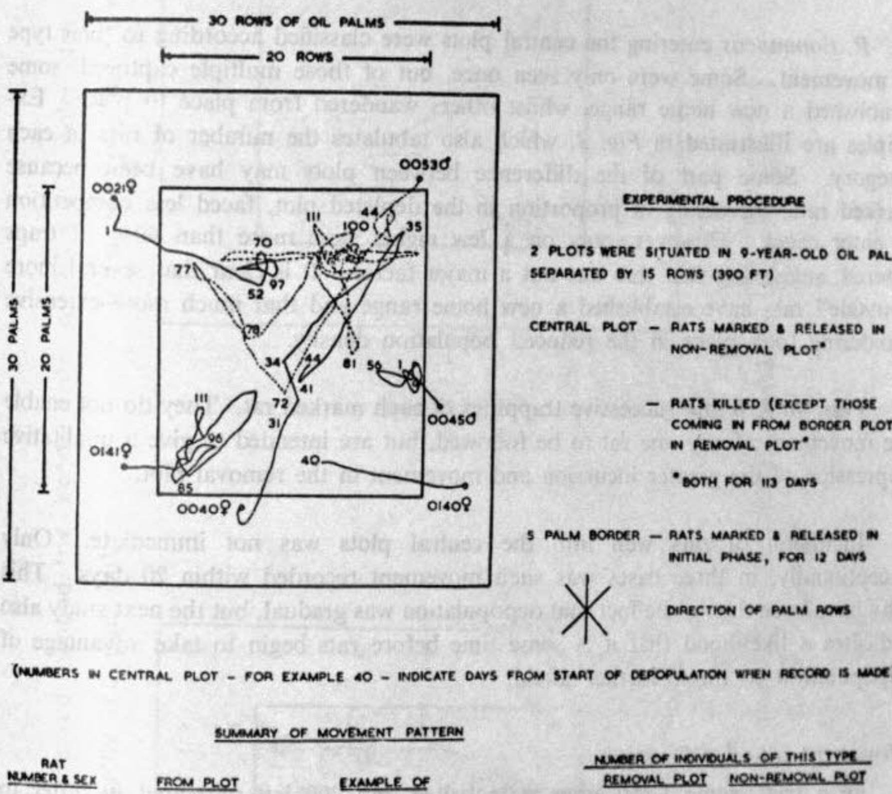
Occasionally, in a climax population there is evidence of a rat making a long journey outside its more usual home range or moving out to establish a new home range or perhaps a new home "centre" on the fringe of the old range. For example, in an experiment which involved marking and releasing rats in plots scattered throughout an area of some 1 350 acres, out of a total of 4 589 marked rats, 16 were subsequently found in another plot between 200 ft and 1390 ft away from the original capture point. Six of these were subsequently recaptured near to the new site, suggesting they were ranging in the new place rather than making an isolated visit (lack of this not necessarily suggesting the opposite since in general opportunities for recapture were limited).

Reinvasion of cleared areas

An early experiment measured the rate of inflow of rats into an area depopulated by trapping. The layout is shown in *Fig. 3*. The central plot is 20 × 20 palms (about 7 acres) with a 5-palm border. First, rats were CMR in this border for 12 nights, one trap at every 2nd palm, alternating every 2nd night. This was carried out concurrently in two similar well-separated blocks of palms. After this, trapping was done in the same way in each centre plot for 113 nights. In one block, the *removal plot*, all captured rats were killed (except any marked ones appearing from outside) whilst in the other, the *non-removal* plot, they were released. Apart from the minor disturbance of trapping, it may be assumed that events in the non-removal plot represent a normal state of affairs in a climax population. Altogether, 247 rats were marked around the removal plot compared with 368 outside the non-removal plot, suggesting that probably a somewhat denser population, and certainly not a substantially smaller one, existed in the non-removal area. Nonetheless, during the removal phase 1 741 rats were killed, 57% more than the 1 106 recorded in the *non-removal* plot, indicating that rats were coming from outside where the original population was being removed.

Further evidence of this came with the appearance of more marked rats in the central plots. Omitting rats still operating in their original home range (arbitrarily considered to be within 180 ft of the original capture point), only 12 marked rats entered the non-removal plot against 37 into the removal plot. In each case, about twice as many males as females entered. Similar results were

Fig. 3 Layout of an experiment to compare movement of rats in dense climax and declining populations, showing some typical movement patterns, with a summary of the various types of pattern.



(NUMBERS IN CENTRAL PLOT – FOR EXAMPLE 40 – INDICATE DAYS FROM START OF DEPOPULATION WHEN RECORD IS MADE)

SUMMARY OF MOVEMENT PATTERN

RAT NUMBER & SEX	FROM PLOT	EXAMPLE OF	NUMBER OF INDIVIDUALS OF THIS TYPE: REMOVAL PLOT	NON-REMOVAL PLOT
♀ 0140	NON-REMOVAL	SINGLE ISOLATED RECORD	7	4
♀ 0021	REMOVAL	MOVING TO A NEW RANGE	14	4
♀ 0040	REMOVAL	EXTENSIVE WANDERING	6	4
♂ 0053	REMOVAL	NEW HOME RANGE INTERSPERSED WITH WANDERINGS	8	0
♀ 0141	REMOVAL	FORMER HOME RANGE INTERSPERSED WITH WANDERINGS	2	0
		TOTAL	37	12
(♂ 0045	NON-REMOVAL	REMAINING WITHIN ORIGINAL HOME RANGE	NOT INCLUDED IN ASSESSMENTS)	

obtained by Stickel (1946) working in a forest in Maryland, who found that wood mice (*Peromyscus leucopus*) entered a depopulated plot, moving beyond their normal home range. She too found that males outnumbered females about 2 to 1, evidence that greater movement by males might well be a regular feature of field rodent populations.

R. tiomanicus entering the central plots were classified according to their type of movement. Some were only seen once, but of those multiple captured, some established a new home range, whilst others wandered from place to place. Examples are illustrated in *Fig. 3*, which also tabulates the number of rats in each category. Some part of the difference between plots may have been because marked rats, increasing in proportion in the depleted plot, faced less competition to enter cages. However, only on a few nights were more than 40% of traps entered, suggesting that this was not a major factor. It is clear that several more "outside" rats have established a new home range and that much more extensive wandering took place in the reduced population density.

Figs. 4a & *b* link successive trappings of each marked rat. They do not enable the movement of any one rat to be followed, but are intended to give a qualitative impression of the greater incursion and movement in the removal plot.

Incursion of rats well into the central plots was not immediate. Only exceptionally, in three cases was such movement recorded within 20 days. This may have been due to the fact that depopulation was gradual, but the next study also indicates a likelihood that it is some time before rats begin to take advantage of depopulation to move further afield.

Movement into baited areas

In a trial, some 1 150 acres were baited and 200 left untreated in order to compare an increasing population with a climax one. In addition to the main studies (Wood, 1969a) a transect of traps was run at right angles to the border between baited and unbaited areas, extending across 25 palm rows (650 ft) each side. Traps were set for a four-night period in every 4 weeks, 3 traps/palm, along the transect line.

In *Table 1*, individuals caught in each period are totalled for groups of 5 palms, No. 25 to 21, 20 to 15, and so on downwards to represent increasing distance away from the border into the unbaited half, and No. 26 to 30, 31 to 35 upwards into the baited half.

Fig. 4 Movement of rats marked around the border into a 20 x 20 palm plot,
a. existing population gradually trapped out b. dense population remaining

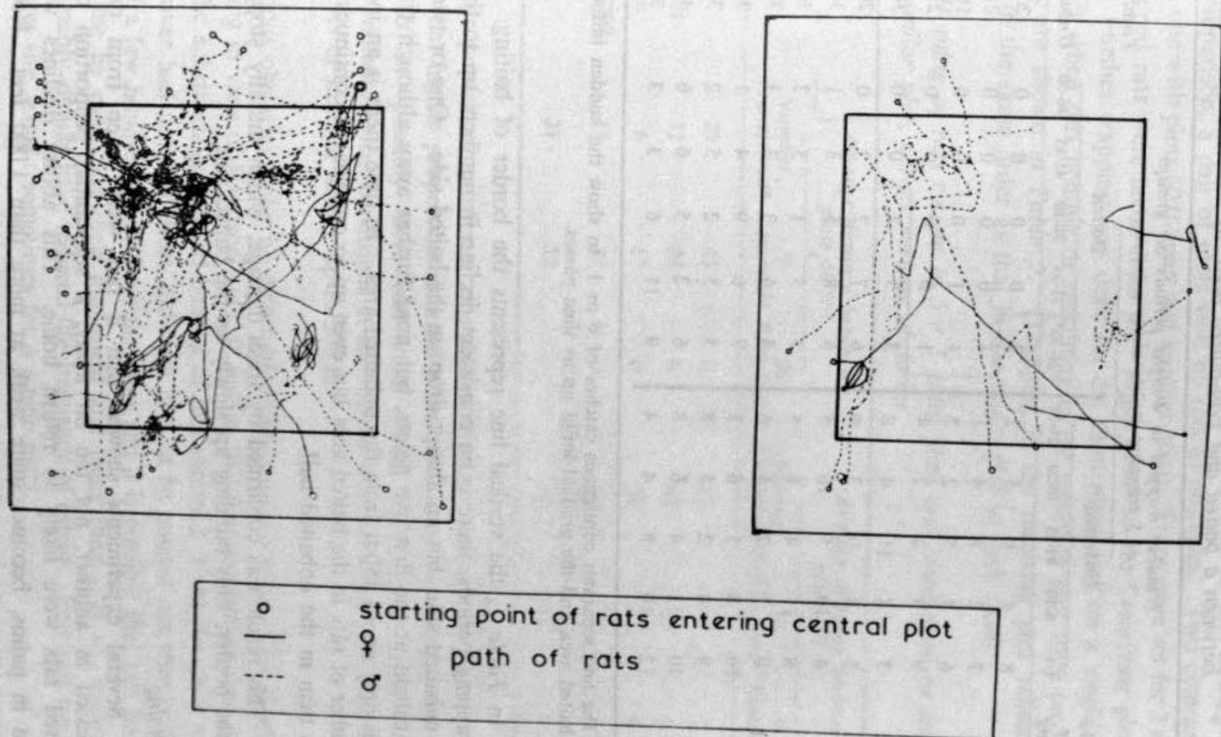


Table 1. Number of rats caught at increasing distances either side of the border between a baited and non-baited area, at intervals after baiting

Weeks after baiting	Number trapped in 4-night periods on groups of 5 trapping points along a transect: *Unbaited* 1-5	6-10	11-15	16-20	21-25	*Baited* 26-30*	31-35	36-40	41-45	46-50	Total on each side of border: *Unbaited*	*Baited*
4	8	4	1	5	2	2	0	0	0	0	20	2
8	7	2	7	4	1	1	0	0	0	0	21	1
12	6	4	5	2	2	1	1	0	0	0	19	2
16	9	4	2	2	4	1	0	0	0	0	21	1
20	3	8	11	4	8	3	3	2	0	0	34	8
24	5	8	0	3	4	6	7	2	2	0	20	17
28	4	10	5	10	5	6	8	5	3	1	34	23
32	8	11	4	8	5	3	5	1	5	3	36	17
36	8	7	7	5	6	4	6	3	3	3	33	19
40	10	8	5	6	5	7	6	9	4	1	34	27
44	8	8	2	8	8	5	5	2	5	2	34	19
48	10	12	4	6	8	6	2	5	6	6	40	26
52	12	10	8	4	4	9	11	6	3	3	38	32

* The line separates contiguous catches of 0 or 1, to show the sudden initial drop in the baited area and the gradual build up as time passes.

In *Table 1*, the vertical line represents the border of baiting. In the first 4 trapping periods, there is no consistent decline in numbers up to the border on the unbaited side, but an abrupt drop on the baited side. One or two individuals are caught at the first five points, but none further away although trapping point 31 is only about 150 ft from the unbaited area. In time there is an increase in the number of rats in the baited area but even up to one year it continues to be rather less than in the unbaited half.

This result was confirmed by fresh damage, which initially stopped abruptly at the border, only building up slowly on the baited side.

Homing

Several experiments showed that if rats were taken from one area and released in another, not too far away, a substantial proportion of the transferred rats were likely to return home. This ability declines with distance, and in palms, becomes quite weak at more than 1 000 feet. Notwithstanding return, disappearance from the release site generally occurs, irrespective of distance. Homing is illustrated in a trial investigating the influence of obstacles. Pairs of 5 × 5 palm trapping plots were established, one of each pair either side of a narrow estate road (about 15 ft wide), a wider and much busier laterite road (about 20 ft), a narrow stream (8 ft), and a rather wider (30 ft) fast-flowing river, plus, for comparison, a pair of plots with no special obstacles. Two comparisons were made, one with plots 60 ft apart and another 300 ft. Traps were set for 2 nights and all trapped rats were taken from the "origin plot" to the "receiving plot" of each pair. Further trapping was done on the third night and on a single night 10 days later when rats homing or remaining in the receiving plot were recorded. The results are shown in *Table 2*. (Trapping in the receiving plot reflected a population in the same order as that in the origin plot in each case).

Table 2. Homing of rats caught in 5 × 5 palm plots and transferred to another similar plot, across various obstacles

Obstacle	*Average distance between plots 60 ft*			*Average distance between plots 300 ft*		
	*Number Transferred**	*% Returned†*	*% Remained†*	*Number Transferred**	*% Returned†*	*% Remained†*
Narrow road	29	45	0	15	47	0
Wide busy road	32	25	0	42	43	0
Narrow stream	6	17	0	21	62	0
Wide fast flowing river	19	37	0	16	44	0
No obstacle	21	52	5	12	92	0

A large proportion of transferred rats always returned. There is no clear reason why a somewhat higher proportion returned where the inter-plot distance was 300 rather than 60 ft—possibly there was some subtle variation in experimental technique or meteorological conditions at the second trial. It is anyway clear that there is no loss of homing ability up to 300 ft.

The various obstacles make no detectable difference to homing. This is somewhat surprising in view of Harrison's (1958) finding that a macadamized road with frequent traffic substantially reduced homing of this species.‡ Even the quite wide fast-flowing river had no such effect, although it must be pointed out that bridges were situated a few hundred yards from the plots and it is possible that rats found their way home by extending their movement and using them. If so, however, chance presumably should have reduced the frequency of return. Few rats remain at the receiving site, except sometimes for a single night.

* Caught in nights 1 and 2.

† Recorded on nights 3 and 13.

‡ Then referred to as *R. jalorensis*.

Speculating on reasons for homing, it appeared that the "stranger rats" may be under social pressure from those well-established, and be forced to move, continuing under such pressure until they return to their home range. Harrison (*loc. cit.*) reached this conclusion. He also concluded that return home indicated no special directional ability, since the probability of a rat happening upon the fringes of its home range by chance about agreed with the actual return frequency. An alternative explanation of homing is that individual rats, upon release in unfamiliar surroundings, set off in search of the familiar. A further trial appeared to indicate an actuality somewhere between the two.

Homing was compared in two pairs of 5 × 10 palm plots, the members of each pair situated some 416 ft (16 palm rows) apart. Each pair comprised a 5 × 10 palm origin plot and a similar size receiving plot. First, rats were transferred for 5 nights followed by two trapping nights after 10 days to check returns. After this a plot of 21 × 21 palms centred on the receiving plot of one pair was baited using anticoagulant rat baits† at one per palm, replacing taken baits at 3-day intervals for 4 rounds. The homing experiment was then repeated. The baiting evidently substantially reduced the population—45 rats were captured in the receiving plot in the first period against 5 after baiting, whilst in the other pair figures were 47 and 41 respectively. The homing results are shown in *Table 3*. In both plot pairs on both occasions a large number of rats were transferred (between 54 & 75). In the conditions of climax population, that is in both plot pairs before baiting and in the non-baited pair afterwards, results were rather similar, 35–66% of rats returning, and only 7–11% remaining. Where the receiving plot was cleared of rats, only 27% returned, against 25% remaining. No "learning" appeared to be involved because rats which had homed at the first occasion and been retransferred were in about the same proportion among those homing and those remaining as rats captured for the first time in this phase.

Table 3. Effect on the homing of rats of depopulating the receiving plot by baiting

Pairs to plots	*Before baiting*			*After baiting*		
	*No. of rats transferred**	*% rats returning*	*% rats remaining*	*No. of rats transferred**	*% rats returning*	*% rats remaining*
Receiving plot depopulated	67	66%	9%	75	27%	25%
Climax population	54	50%	11%	57	35%	7%

† KG22—*see* Wood, 1969a.

* Transferred between plots 16 rows (= 416 ft) apart.

Movement of rats—discussion

It is apparent that *R. tiomanicus* in a climax population in oil palms has a generally quite closely circumscribed home range. Harrison (1958) found an average standard diameter of 240 ft (73 m) to 330 ft (100 m) for the species in some grassland scrub environments in 3 different localities. This means that an individual rat would spend 2/3 of its time (and thus 2/3 of all trapping would be) within the standard diameter. With an average maximum diameter of 80–100 ft it is clear that in oil palms the home range is smaller. This may be due to the more favourable oil palm environment, involving less need for the rats to move far in search of necessities. Harrison's speculations on the reasons for the variation in his 3 environments would favour such a conclusion. An alternative explanation is that in the denser population in oil palms, more intense social pressures restrict movement. The more frequent entry of rats and increase in the distances travelled in the depopulated plot favour this explanation. Brant (1962) reached similar conclusions about two species of rodents (the white-footed mouse, *Peromyscus maniculatus* and the harvest mouse, *Reithrodontomys megalotis*) in a scrub environment in California. Subject to massive seasonal fluctuations in numbers, there was a distinct increase in home range of these mice at low population and *vice versa*.

It is apparent that the home range restrictions affecting *R. tiomanicus* tend to weaken when depopulation occurs and there is movement into an area cleared of rats. The homing trials show that breakdown of home range ties is not complete, and a rat put into a "population vacuum" by no means certainly stays there. Presumably this also applies to one that wanders into a depopulated area. Home range ties still apparently remain to some extent and the occupation of vacant living space is relatively slow.

A feature noticed in these studies (particularly that described under the section *Reinvasion of cleared areas*) is that not all of the rats which change their home range are young. A high proportion were sexually mature at the first capture and weights ranged up to that of good sized adults. It might be thought that pressures to move in order to find an accepted place in a community would be stronger in young rats, but this work appears to confirm Brant's (*loc. cit.*) observation that a mammal may take part in dispersal movement at almost any time in its life.

SURROUNDING VEGETATION AS A SOURCE OF PEST RATS

Several kinds of vegetation may surround oil palm estates and act as a habitat for various species of rats. The aim of this project was primarily to determine whether any are able to support a substantial population of *R. tiomanicus* and thus act as sources of reinfestation.

The environments—In the study area, and commonly around Malaysian oil palm estates, 4 types of vegetation may be recognized, viz: —

Grassland/scrub—thatch or lallang grass (*Imperata cylindrica*) colonizes a cleared area, initially in almost pure sheets, perpetuated by burning, or alternating with rotating cultivation. It is later invaded by bushes such as straits rhododendron (*Melastoma malabathricum*) and Siam weed (*Eupatorium odoratum*). Brackens and other ferns, grasses, creepers and other plants come in and young trees begin to appear. The progress of the habitat, failing periodic destruction, is on to secondary forest.

Town—in small towns, houses tend to be widely spread, each with a cultivated plot of vegetables and fruit trees. Softer grasses than lallang predominate and most of the bushes of the natural scrub are kept absent or scarce, except in isolated patches.

Rubber estates—are very common, with various kinds of ground vegetation.

Jungle—Dipterocarp forest with an upper storey of big trees and a lower shrub layer is the natural inland climax vegetation other than in swamps and on very high ground. It is usually reduced from its primary state by more or less intensive logging.

Trials—two main techniques are used. In the first, 5 × 10 palm trapping plots (300 ft × 130 ft) are laid out in the oil palms, adjacent to the surrounding vegetation, contiguous with a plot on a similar grid outside. Another such plot is located 600–1 000 ft away from the border and a fourth in the same vegetation type but at least a mile away from any oil palms. In the second technique, two transect lines about 52 ft (equivalent to two palm rows) apart are run out from inside the oil palms up to 1 500 ft outside, with a trapping point every 30 ft (*i.e.* at palm spacing). A plot is also laid at more than a mile away, (*see* footnotes to *Table 4* for trapping procedures in individual trials). More than one trial has been done in 3 of the 4 types, at different times and sites, to take account of any local or seasonal variations. Baits were varied in case of differing preferences among the rat species likely to be found.

Identification was done by means of Harrison's (1966) keys, and the species of rats and other small mammals and their numbers trapped in the different environments are shown in *Table 4*. The intention is to give a mainly qualitative impression of species composition, and the rats trapped live and taken in spring traps are grouped together. Dissection of dead rats from spring traps was done to examine stomach contents, which gives an important clue to their food source. Results, according to the amount of oil palm fruit, are shown in *Table 5*.

Table 4. Rats and other small mammals trapped at the border between an oil palm estate and various other vegetation types, and at distance of a mile or more in the same vegetation types. Central Johore.

	Number of rats etc. in each location						
	R. tiomanicus				*Other species*		
Date of trial†	*Just inside palms*	*Within 1 500 ft*	*>1 mile away*	*Name*	*Just inside palms*	*Within 1 500 ft*	*>1 mile away*
				GRASSLAND/SCRUB			
Mar '69(1)	57	78	20	*R. exulans*	0	8	not investigated
Sept '70(3)	30	99	29	,,	1	5	9
Jan '70(3)	8	61	3	,,	0	3	2
May '70(3)	0	13	9	,,	0	4	5
Total	95	251	61	*R. exulans*	1	20	16
				TOWN			
Aug '69(2)	20	14	0	*R. exulans*	0	6	9
				R.r. diardii	0	0	2
				RUBBER			
May '69(2)	44	8	0	*R. exulans*	0	12	3*
Aug '69(4)	41	2	0	,,	0	2	0
May '70(3)	13	0	0	,,	0	1	0
Total	98	10	0	*R. exulans*	0	15	3
				JUNGLE			
Oct '69(3)	12	0	1	*R. rajah*	0	9	15
				R. sabanus	0	1	0
				Tupaia glis	2	17	14
				Lariscus insignis	0	6	12
Apr '70(3)	46	0	1	*R. rajah*	0	14	4
				R. whiteheadi	0	1	0
				R. sabanus	0	0	1
				Tupaia glis	0	18	8
				Lariscus insignis	0	0	1
Total	58	0	2	*R. rajah*	0	23	19

† Layouts as follows:—

(1) Just inside palms a plot of 5 × 10 points, 3 traps/point; 2 such plots within 1 500 ft and 1 at > 1 mile. 4 nights CMR, 1 night spring trapping.

(2) As (1), but 3 nights CMR.

(3) 2 parallel transects of 60 points at 30 ft space, 10 inside and 50 outside palms. 2 traps/point. In jungle 2 × 12 point transects and in other vegetation a plot as in (1) as > 1 mile. 3 nights prebaiting, 3 nights CMR, 2 nights spring trapping.

(4) Plot layout as 3, but 5 nights prebaiting, 5 nights spring trapping.

* + 1 *R. rajah* (near a patch of advanced secondary jungle in an unplanted ravine).

Table 5. Dependence by R. tiomanicus *on oil palm fruit (as shown by stomach contents) in different environments around estates just inside and just outside palms, and some distance away. Summary of various trials.*

Habitat border	*Position in relation to palm estate*	*Number of rats examined*	*% rats with various stomach contents*			
			Entirely oil palm	*Part oil palm*	*No oil palm**	*No indication†*
Lallang	Just inside	46	89	2	2	7
	Just outside	96	33	23	32	12
	Distant	25	0	0	60	40
Rubber	Just inside	60	96	2	0	2
	Just outside	8	63	0	0	37
	Distant	0				
Small town	Just inside	4	100	0	0	0
	Just outside	2	0	0	50	50
	Distant	0				

* *No oil palm*—entirely other materials.

† *No indication* (of food source)—empty stomach, mothers' milk, or trap bait.

Results—Comparison of the palms column under *R. tiomanicus* (*Table 4*) with that column under *other species* clearly shows the former to be the dominant rat of mature oil palms, with virtually no influx of other species even right at the estate border. Only one *R. exulans* (the Polynesian or little house rat) was trapped in palms, on one occasion bordering lallang.

Lallang had numerous *R. tiomanicus* together with *R. exulans*. Several dissected wood rats had fed entirely on substances other than oil palm (*see* Table 5). Stomach contents commonly included insects, especially termites, soft flesh—probably of snails or slugs, seeds, fruit, and various mixed and indeterminate vegetable materials. These match the diets found by Harrison (1954) under similar conditions. Rats were able to remove the baits from some traps without springing them, hence several had bait materials in their stomachs. Both species of rats just outside the border of the palms clearly moved in to take oil palm fruit, and one or two were live captured both inside and outside the palms.

Several wood rats were trapped in the small *town* but numbers fell away as the distance from palms increased, whilst *R. exulans* became more common. The Malayan house rat, *R. rattus diardii*, also occurred at the distant site. Spring trapping had to be curtailed or abandoned because of chickens, and live trapping is of little value to indicate natural food sources. On the evidence of only one spring-trapped rat, it appeared that they can find food other than oil palm. No attempt was made to get further evidence because of the difficulties involved and the relatively small amount of estate border occupied by towns.

The *rubber* in the study area had few *R. tiomanicus*. Those in the adjacent areas were all found at trapping points close to the palms, and in all cases where any conclusions could be drawn they had been primarily feeding on oil palm fruit. The rubber was in the main well tended and free of ground debris or very dense vegetation. Possibly the position could differ where this was not the case. Rao (1965) lists the wood rat as an occasional pest of young rubber. *R. exulans* also occurs.

There is an abrupt and striking change at the *jungle* border. *R. tiomanicus* was trapped right up to the last palm, and the rajah spiny rat, *R. rajah**, from the first point inside the forest. There was no evidence of any movement or foraging between the two habitats by any rat species, and stomach contents are not shown in *Table 5*. Only two isolated *R. tiomanicus* were taken, at points within the distant plots. As expected, a greater diversity of species was found in the jungle, with two other rats occasionally trapped and a tree shrew, *Tupaia glis*, and a ground squirrel, *Lariscus insignis*, common. Tree shrews (which are not pests) were also found in oil palms, in which they often occur, especially in older stands.

Discussion of rats and surrounding vegetation—The species found in surrounding vegetation are those which have been recorded in numerous other studies, particularly those of Harrison (*e.g.* 1957). Only lallang/scrub is likely to act as a serious source of infestation of oil palms by *R. tiomanicus*. The rats near to palms take advantage of it as a food source but clearly are not dependent on it. Towns, a relatively common environment, may act as a minor source. *R. tiomanicus* may occasionally exist in rubber estates, but in this study, appeared only near oil palms, which formed the major part of their diet. Neither this environment nor jungle appear likely to serve as a source of substantial reinfestation.

OTHER STUDIES

Two other studies are worthy of mention. One was carried out to investigate the build up of *R. tiomanicus* in oil palms planted after rubber, on the border of a long-standing oil palm estate. The young palms had been planted just 3 years and had been fruiting for about 6–9 months. Standard 300 × 130 ft plots were established, with trapping points on a 30 ft triangular grid, 3 traps/point, 3 nights prebaiting, 5 nights trapping, at varying distance away from the old palms. Twenty-six *R. tiomanicus* were captured at about 150 ft away, but only 13 at 1 000 ft and 2 at 1 900 ft. This indicates the relatively slow ingress, establishment and build-up of *R. tiomanicus* in such circumstances.

* *R. rajah* is a group containing two morphologically rather indistinct forms or species (Harrison, 1966). No attempt was made to separate them, if indeed they were both present, and it is a matter of no great relevance to this study.

The other study was done in the coastal area of Selangor, in lallang adjacent to an estate where *R. argentiventer* was a potentially severe problem in young palms (Wood, 1969b). On this occasion, a 5 × 10 point 35 ft square grid was used, 3 cages/point, CMR for 3 nights followed by 1 night of spring trapping. Using the final night of spring trapping to obtain a Lincoln index, populations of 48 (± 16) *R. argentiventer* and 21 (± 8) *R. tiomanicus* per acre were estimated. The plot was near to the oil palms and most spring-trapped rats had some oil palm in their stomach, but a few of each species had solely other material. This evidence, and the fact that *R. argentiventer* is a common species of lallang in some areas away from oil palms (Harrison, 1957) shows that lallang could be a potent source of reinfestation in a locality suitable for the species.

ESTATE RAT CONTROL — PRACTICAL CONSIDERATIONS

What is the practical significance of these studies to the operation of rat control programmes? Before discussing that, it is necessary to briefly consider the baiting technique in use, which employs a chronic anticoagulant poison such as warfarin. Little is known about the toxicology of this class of poisons to *R. tiomanicus*, but rats in general may succumb either to a massive single dose or to the regular ingestion of small amounts until a lethal dose is accumulated. It is characteristic that the acute dose may be many times greater than the total amount that needs to be ingested over a period (Ministry of Agriculture, Fisheries and Food, 1958). On the other hand, if at any time less than a lethal dose has been taken, the rat will become gradually detoxified and recover completely, in the absence of further doses.

Cage trials with *R. tiomanicus* have shown that some will succumb to a single bait but others will survive. In the field, not all rats have access to a bait on the first round. A single round leads to some reduction, but not enough to eliminate damage nor below a level where recovery to former population size would be very rapid (Wood, 1969a). Thus in baiting it is necessary to apply replacement rounds, and these must be at relatively short intervals, to avoid either detoxification, or recovery of population numbers. If resources, particularly labour, are limiting, it is thus necessary to complete small blocks rather than cover a whole estate on extended rounds.

These trials show that still-infested oil palms are the major source of reinvasion, but that movement out of an adjacent unbaited block into a freshly controlled one is not in any sense an immediate inundation, but occurs only slowly. It is thus preferable that a baited area is not adjacent to an unbaited one for too long a time, but a brief interval is acceptable. At present I have no positive evidence how long a discrete area of oil palms might remain relatively free of rats after overall control, but such information as there is suggests it could be very long. There is a strong impression from trial work and field practice, that the bigger the baited area, the slower the re-infestation, but no specific studies have yet been reported following the baiting of whole estates. The following policy appears best to maximise prospects of long term freedom from the pests: —

Determine what labour can be spared for the job. Suppose on a 6 000 acre estate, 10 persons can be made available and each can bait 30 acres/day, the estate can be split into 300 acre (10 × 30) blocks, giving 20 such blocks. These of course will be approximate sizes, delimited by convenient boundaries such as field borders, estate roads and rivers. These boundaries should not be relied on to prevent spread back of rats, so permitting long intervals in baiting programmes, because homing trials show the rats to be perfectly capable of crossing them. The first baiting round in blocks 1–4 can be done on days 1–4 respectively, the second round on days 5–8 and so on. Weekly rest days and other holidays can be omitted from the reckoning since extension of some rounds to 5 days or even more occasionally is not likely to have an adverse effect. As blocks 1–4 are completed then further blocks can be progressively worked over, across the estate. Replacement rounds should be carried on to bring bait acceptance below 20–30% to minimise survivors, so a degree of flexibility about the starting of new blocks is necessary.

This leaves three possible sources of reinfestation, *viz* reproduction from survivors of the baiting programme, rats from surrounding vegetation, and rats from adjacent oil palm estates.

Little can be done about survivors, but their number is likely to be very few when replacement rounds are followed through properly. Most surrounding vegetation, in particular jungle and rubber, is not likely to be a source of massive reinvasion by *R. tiomanicus*. Only lallang and scrub and to a lesser extent towns may support significant populations. In fields bordering these, special control rounds may be needed. Evidence of populations building up will lie in a periodic census. Various methods exist for this (Wood, 1969a) but perhaps most convenient is the placement of 50 baits, 1 per palm in representative plots. This can be done at 3–6 month intervals and if 20 or more are taken by rats within four days, control is required.

In the case that a recalcitrant neighbour's palms are the potential source of reinfestation, the same procedure will have to be adopted in fields adjacent to his. It is perhaps some small consolation in this case that, because of the limited ranging of the pests, one is unlikely to be losing many baits to kill his rats!

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DISCUSSION

Chairman: B.S. Gray

Chairman: The paper represents a major contribution and has confounded a lot of our old ideas on rat movement. We can no longer blame our neighbours for our own infestations. The results are encouraging for the practical planter.

Sankar: Does the density of ground cover affect rat populations or damage? I have found less damage where there is dense cover, but more where it is sparse. I cannot comment on population size.

Wood: I have no objective data. I had always assumed it would be the reverse—the more cover, the more rats.

Sankar: No, I didn't mean the population size, I meant the damage.

Wood: I can offer objective evidence that these two are related!

Hutauruk: In one of our Sumatra estates, despite very good cover, there was still heavy rat damage on young palms.

Gillbanks: Do rats live entirely on oil palm fruit or do they need a protein supplement?

Wood: We ran laboratory trials with rats on a diet of oil palm only (either mesocarp alone or whole fruit), on a varied diet, and on oil palm plus limited protein material. On oil palm only they soon fell to about 50% of their original weight and died. On a mixed diet they remained healthy for a year, and did virtually as well on the fruit plus supplement. Presumably, in the field, the supplement is from insects, slugs, snails, etc.

Nowak: I read that in South Africa the possibility of releasing cats for rat control was being considered.

Wood: The problem seems to be that they do not get enough energy from one rat to find the next, therefore additional feeding is needed. This could be more expensive than poison baiting.

Wycherley: Use of acute poisons on small mammals must have an effect up the food chain, and could be drastic on migrant raptors. Does secondary poisoning occur with anticoagulants? Cats, hawks, snakes and various other predators might be affected. I am told that there are snake-infested estates with no rat problems. Would the author like to comment?

Wood: The breakdown of the anticoagulants is quite rapid, and secondary poisoning probably does not occur. For example, in oil palm estates I have never heard of a cat suspected of having died in this way, nor of any more remote side-effects.

Regarding snakes as rat predators, I do not think there is any level of balance that is economically favourable. The rats do balance at some point (the "climax" population) but due to what factor is not known. Clearly they have the reproductive capacity to increase further; perhaps the governing factor is a social one, with reproduction slowing down at high population numbers. Predators do not seem to be involved and snakes are common in the experimental areas where the rat populations are high.

Owen Jones: Rats were common on our estates although KG22 has been effective in eliminating them. Now there are few snakes, although when rats were common, snakes appeared to be common as well. Does the author agree that as the rats decrease the snakes may emigrate?

Wood: Probably, for having less to feed on, they go away. This does not mean that when rats are there, they are controlled by snakes. Information on such points is accumulating in our research programme.

SOME NOTES ON THE CONTROL OF THE BAGWORM, *METISA PLANA* WALK., IN NORTH SUMATRA

by

Ch. Hutauruk and H.S. Situmorang

INTRODUCTION

Infestation of oil palms in North Sumatra by the bagworm, *Metisa plana*, has been known for a long time. Since 1958 the problem has become more serious and thousands of hectares have been affected. The infestation was initially controlled by DDT 10% dust (at about 20 kg/ha). "Operation PADAMA" carried out between 1961 and 1963 on oil palm plantations of PNP VII (formerly PPN ANTAN III) was so successful that other plantations followed suit with their own regular dusting programme. Unfortunately, with repeated treatment, DDT tended to become less effective. For instance, it was found that later treatments required 3 to 4 successive applications in order to produce the same result as the initial treatment. Within a month, re-infestation builds up and recurrent outbreaks occur producing very severe damage. There seem to be two possible reasons for this: that resistance to DDT is building up in the bagworm population, or that the DDT has disturbed natural balance so that the bagworms are no longer kept in check by their natural enemies.

Pest resistance to insecticides is a well-known phenomenon. One example is the resistance to DDT of diamond-back moth, *Plutella maculipennis*, on cabbages in Lembang near Bandung (Ankarmist, 1953). It occurs because repeated applications of any one insecticide on any particular pest cause the death of non-resistant insects while not affecting resistant ones who thus reproduce. Metcalf (1955) has pointed out that development of resistance to insecticides could be reduced by alternating different insecticides.

Natural enemies play an important role in regulating many potential insect pests. According to Carman & DeBach (1967) only 1 or 2 out of every 100 species of plant-eating insects become pests, the remainder being suppressed by their natural enemies.

Conway & Wood (1964) and Wood (1968), discussing these problems in a local context, suggested that broad-spectrum persistent contact insecticides may affect the natural equilibrium adversely, especially in perennial tropical crops, for parasites and predators being generally more active are much more affected by such insecticides. As a result of the use of persistent insecticides the natural equilibrium may be disturbed and could give rise to chronic pest problems. On the other hand, in areas where insecticides were not used, infestation could decline naturally. It is not always clear in such cases how the infestation started in the first place. Of course, pest infestation has to be eradicated, in order to ensure full production of palm oil, and when an attack is occurring insecticides provide the most effective weapon. The choice of the right insecticide is important in order to minimise the effect of insecticides on beneficial insect species.

The above-mentioned authors have pointed out that the use of selective insecticides, tending relatively to favour natural enemies rather than pests, would be helpful in restoring natural balance.

In order to discover alternatives for DDT for use on Sumatran oil palms, the following trials were carried out. Special emphasis was placed on assessing for selectivity, for only by field experiment can it be determined if a chemical is selective in a particular situation.

EXPERIMENTAL PROGRAMME

Methods and Materials

Replicated trials were carried out to compare DDT 10% with dicarbam (50% WP) and trichlorphon (Dipterex 80% SP) applied as dusts. The latter has been suggested as being selective against bagworms under Malaysian plantation conditions (Conway & Wood, 1964; Wood, 1968) and has been used successfully as a spray against bagworms on oil palms (Wood, 1967). Talc or powdered limestone of local origin were used as carriers. Application was by means of tractor-drawn engine-powered dusters.

Bagworms were counted on 5 sample fronds per plot in all trials. Immediate effects were determined by the percentage dead, and longer term effects by the continuing live population.

Results—Expt. 1

On 20-yr-old palms at Gunong Baju estate. Randomised block design with 4 replicates of 5 treatments on 10 ha plots. Mortality was assessed at intervals after application. The treatments and results are shown in *Table 1*.

Table 1. Mortality of bagworms after various treatments—Expt. 1

Treatment			*% mortality at days after application*		
Chemical	*Carrier*	*a.i./20 kg/ha*	*3*	*6*	*12*
Dicarbam	limestone	1.0	79	58	84
Trichlorphon	limestone	1.0	84	94	93
Trichlorphon	talc	1.0	78	93	94
DDT	—	2.0	70	62	85
Untreated check			50	53	42
		L.S.D. .05	4	4	2

The result at 12 days shows a substantial kill for the insecticide treatments. All others are at least equal to DDT and there is an indication that both trichlorphon treatments are the best. A good deal of mortality occurs in the untreated check, illustrating the difficulties of obtaining clear-cut results in this type of experiment.

Expt. 2

On 7-yr-old palms at Bah Djambi estate. Randomised block design with 4 replicates of 6 treatments on 5 ha plots. The treatments were repeated 4 times at 7-day intervals and they and the results are shown in *Table 2*. The treatments included different periods of storage for the Dipterex 80 SP/limestone mixture to determine if its effect was decreased or if phytotoxicity developed in longer storage, for we had noticed that the stored mixture appeared to be phytotoxic to tea plants.

Table 2. Mortality of bagworms after various treatments—Expt. 2

Chemical	Treatment a.i./20 kg/ha	Days stored	% mortality at days after the final of 4 successive applications			
			3	6	9	14
Trichlorphon	0.5	4	49	82	56	93
"	0.5	2	39	53	46	54
"	1.0	4	76	57	84	85
"	1.0	2	77	60	80	100
DDT	2.0	—	45	53	68	55
	L.S.D. .05		6	7	7	5

These results indicate no deterioration in effectiveness with a storage up to 4 days and there is no evidence of phytotoxicity. The results confirm that trichlorphon gives a good kill. *Fig. 1* shows a graph of continuing populations in these treatments, combining the two storage periods for each trichlorphon level. It is interesting to note that after the main treatments in November 1968, neither the trichlorphon nor control plots have needed retreatment, whereas this was required in the DDT plots in January 1969.

From observation in the whole experimental area there were signs that the decline in population was associated with attack by a parasitic wasp.

Expt. 3

On 14-yr-old palms at Marihat estate. Randomised block design with 4 replicates of 5 treatments on 5 ha plots. Mortality was assessed at intervals after application. Inadequate control was obtained at the first dusting, and treatments were repeated. The treatments and results are shown in *Table 3*, and the continuing population trends can be seen in *Fig. 2*.

Fig. 1 Effect of various treatments on bagworm populations. Oct 68 — Nov 69. Expt. 2

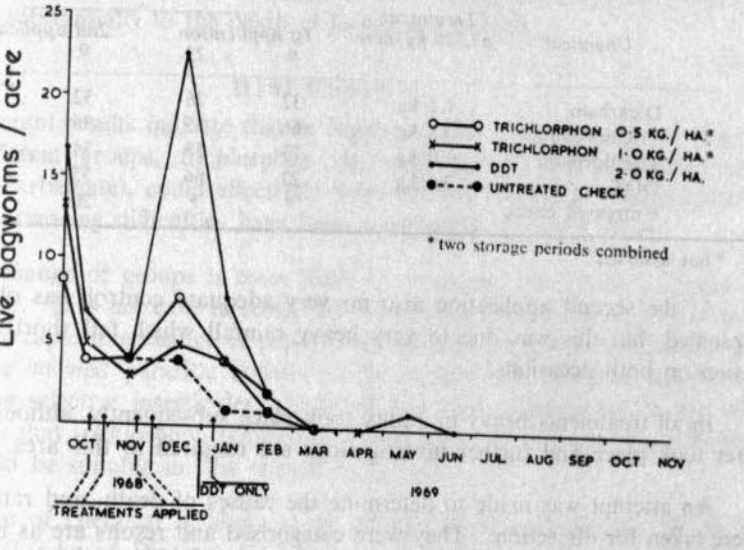

Fig. 2 Effect of various treatments on bagworm populations. Apr 69 — Apr 70. Expt. 3

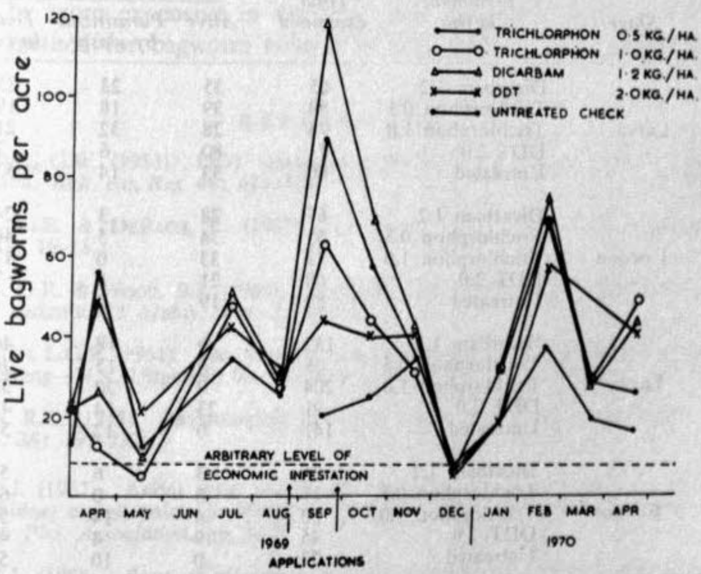

Table 3. Mortality of bagworms after various treatments—Expt. 3

Chemical	Treatment a.i./20 kg/acre	% mortality at days after application			
		1st application		2nd application	
		9	23	9	23
Dicarbam	1.2 kg	32	26	32	27
Trichlorphon	0.5 kg	66	35	36	32
Trichlorphon	1.0 kg	73	78	34	29
DDT	2.0 kg	22	66	35	33
Untreated check		*	*	20	31

* not assessed

At the second application also no very adequate control was obtained—it is presumed that this was due to very heavy rainfall which fell shortly after application on both occasions.

In all treatments heavy mortality took place subsequently, although a rebound later took place and further investigations are required in this area.

An attempt was made to determine the causes of death, and random samples were taken for dissection. They were categorised and results are as in *Table 4*.

Table 4. Mortality of bagworms in samples from oil palms given various treatments

Date of sample	Stage	Treatment kg/ha	Total examined	% in each category			
				Alive	Parasitized by wasp	Dead in case	Empty case
Nov 69	Larva	Dicarbam 1.2	65	35	23	23	19
		Trichlorphon 0.5	89	39	18	19	24
		Trichlorphon 1.0	78	28	32	21	19
		DDT 2.0	71	80	6	7	7
		Untreated	66	33	14	53	0
	Cocoon	Dicarbam 1.2	67	28	3	24	45
		Trichlorphon 0.5	65	34	5	46	15
		Trichlorphon 1.0	72	33	0	17	50
		DDT 2.0	60	21	2	7	70
		Untreated	89	19	0	1	80
Dec 69	Larva	Dicarbam 1.2	133	0	18	40	42
		Trichlorphon 0.5	46	0	15	70	15
		Trichlorphon 1.0	204	0	20	38	42
		DDT 2.0	91	23	14	42	21
		Untreated	141	0	12	53	35
	Cocoon	Dicarbam 1.2	36	3	6	58	33
		Trichlorphon 0.5	11	0	0	64	36
		Trichlorphon 1.0	50	4	14	56	26
		DDT 2.0	45	9	4	49	38
		Untreated	73	0	10	59	31

It is apparent that parasitic wasps of the super-families Ichneumonoidea and Chalcidoidea, similar to those described by Kalshoven (1951) and Wood (1968) as attacking the species (the latter referring to West Malaysia), are present and are contributing substantially to the death of larvae and cocoons.

DISCUSSION

The experimental results indicate that in bagworm control by dusting, two insecticides of different groups, trichlorphon (an organophosphorus compound) and dicarbam (a carbamate), could effectively substitute for DDT (an organochlorine), with which increasing difficulties have been experienced in recent years.

Such a change of groups is most likely to overcome any problem connected with resistance. It is not easy in small plot trials to gather evidence on selectivity because of the rapid interchange of populations between them, but such indications as there were showed parasitic activity to be of sufficient potential importance to merit using selective insecticides. None of the trials contradicted in any way the possibility that trichlorphon (Dipterex), known to be selective in other circumstances, would be suitable in this respect in Sumatra.

A change of chemical is likely to be advantageous, and the use of 0.8 kg trichlorphon (1.0 kg of Dipterex 80 SP) is now recommended for practical use; 1.2 kg dicarbam also kills the pest, although it is less suitable theoretically to be selective (Wood, 1968). The cost of a single trichlorphon treatment at this rate is more than that of the standard DDT application (Rp 1295/ha against Rp 675), but if it results in less frequent application through restoration of natural balance, it will not be more expensive in the long run. Dusting is still an economical application method for bagworm control on oil palms in North Sumatra.

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DISCUSSION

Chairman: B.S. Gray

Chairman: This paper appears to confirm our ideas on bagworm control in Malaysia. What are the results of the trichlorphon application now being recommended, and why do you dust rather than spray?

Hutauruk: At one kilo Dipterex per hectare on Tindjoan estate, we got good results, but further treatment may be necessary. The use of dusting is a matter of past preference and availability of equipment. We intend to change to spraying.

Chairman: Would Mr. Wood comment on the upset ecology in oil palm plantations in Sumatra?

Wood: The situation substantiates our view here that chemicals, wrongly used, can upset biological balance. Certainly I would say this is the main reason why the bagworm problem in Sumatra recurs. I believe that as more selective methods are introduced, the infestations may decline.

COCKCHAFERS AS PLANTATION PESTS IN MALAYSIA AND THEIR CONTROL

by

B. Sripathi Rao and K. Suppiah

SUMMARY

Cockchafers are an important group of crop pests, as grubs destructive to the roots and, as beetles, to the foliage. The grubs have been sporadic pests of rubber plantations since 1930, and recently also in oil palm. Beetles of other species frequently cause much damage to leaves of oil palm and cocoa.

Species known to cause economic damage to the above three crops are briefly described, together with an outline of their bionomics. Recommended control measures are discussed with relevance to the stage of the crop and of the pest.

Cockchafers are night flying beetles belonging to the families Melolonthidae and Rutelidae. They are familiar to everyone—stoutly-built, horny beetles with a smooth, often shiny appearance, flying to light during certain times of the year.

Both families include a number of well-known pests of crops all over the world. The adults are destructive to the foliage, while the soil-inhabiting grubs feed on living roots and decaying organic matter. The destructive role of the adults is more commonly encountered in the form of lace-like perforations on the leaves of a number of cultivated and wild plants. Root consumption by the grubs, on the other hand, is more insidious, and is revealed only when more or less serious damage has been done to the plant.

Two of the major plantation crops of Malaysia—rubber and oil palm—and a third, cocoa, which is currently being emphasised in the crop diversification programme of the country, are frequently subject to depradations of cockchafers. The grubs are troublesome in rubber; oil palm is attacked by both stages, by different species, while leaf feeders are important on cocoa.

COCKCHAFERS AS ROOT-FEEDING PESTS

Grubs of a number of Melolonthid beetles are sporadic pests of plantations in Malaysia (*Fig. 1*). They have an annual life-cycle (Rao, 1965). The white grubs hatch out of eggs laid in clusters in the soil in March/April and feed for about six months, mainly on living roots. When fully grown they burrow deeper and pupate. The adults emerge from the soil in large numbers just after dusk in February/March, with the advent of wet weather after a period of drought (*Fig. 2*). The beetles do not feed on any of the plants in the plantation, but fly to forests in swarms to feed and mate. This restricts infestations to plantations close to primary

Fig. 1. Grub of Psilopholis vestita

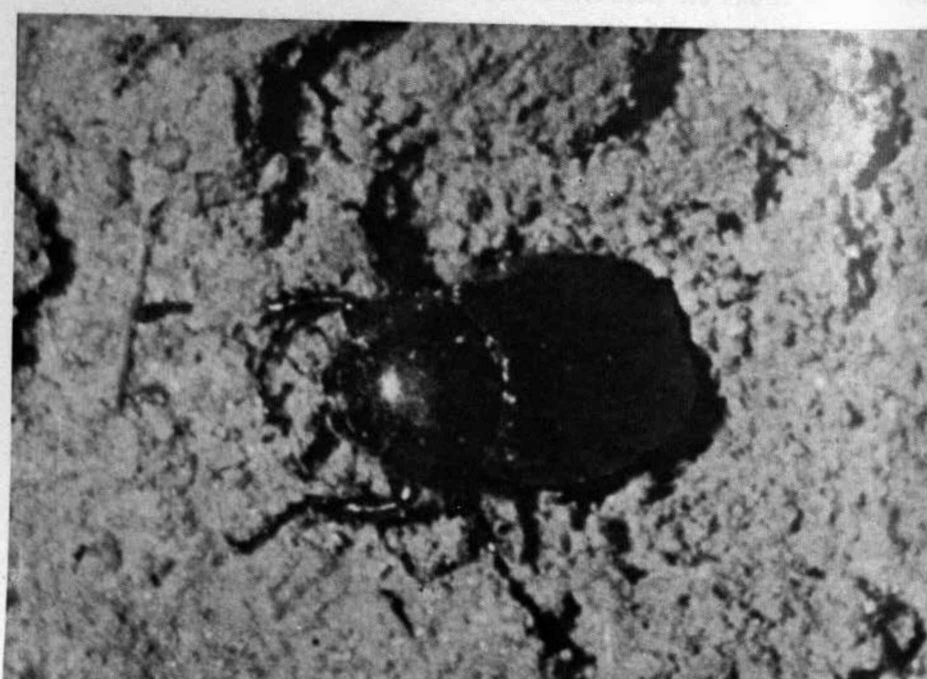

Fig. 2. Lachnosterna bidentata *emerging from the soil after completing life-cycle*

or secondary jungle. A second factor limiting widespread outbreaks is that areas with friable soil, in which the grubs can move easily, are preferred.

Rubber

Cockchafers are the most important pests of rubber plantations today; grubs of a number of species have been destructive in certain areas since 1930 (Anon., 1968). Areas under attack increased year after year, until in 1938 about 3 400 acres were known to be infested (Newsam, 1953); the dominant species was *Psilopholis vestita* Sharp. There was a decline thereafter, and by 1947 the pests had largely disappeared. However, since 1955 there has been an increase in activity, mainly by *P. vestita* and *Lachnosterna bidentata* Burm., and to a lesser extent by *Leucopholis rorida* Fabr. and *Lepidiota stigma* F. Two other species, *Leucopholis nummicudens* Newm. and *Leucopholis tristis* Brnsk. were occasionally troublesome, and *Exopholis hypoleuca* Wied. rarely so. About 2 000 acres were reported to be attacked in West Malaysia in 1968 (Rao, 1969) (*Fig. 3*).

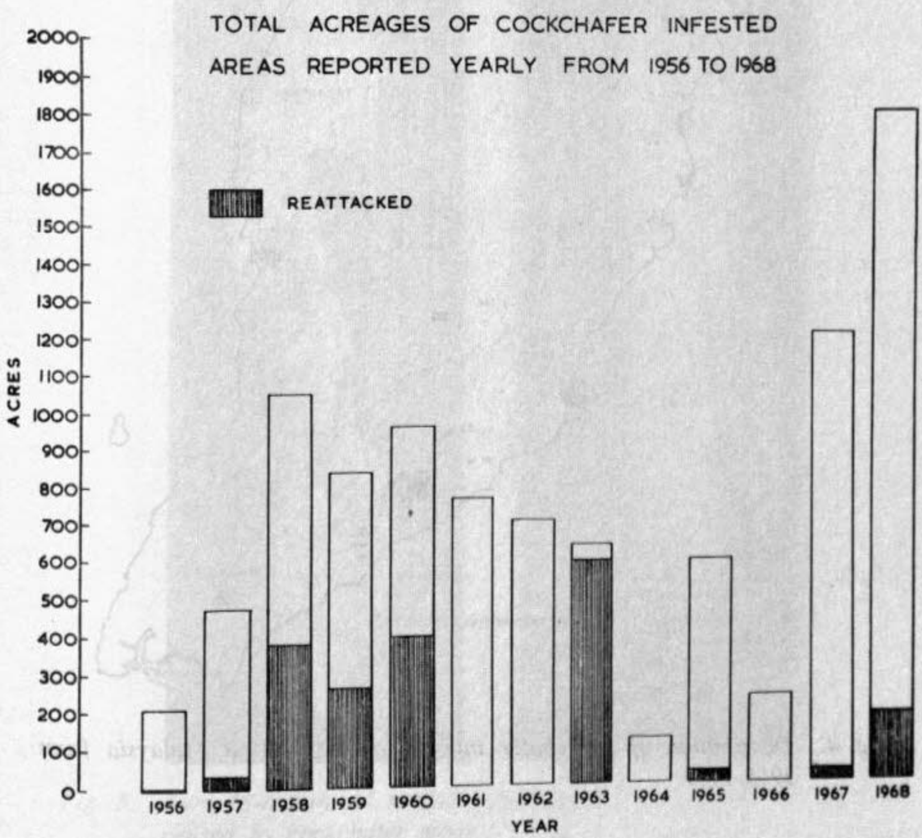

Fig. 3. Acreage attacked by cockchafer grubs in West Malaysia from 1956–1968

The pests have been largely confined to four centres of infestation—one comprising parts of the States of Malacca, Negri Sembilan and north Johore, the second in south Kedah and central Perak, the third in Pahang near Kuantan, the fourth in south Johore (*Fig. 4*). Smaller centres exist in north Kedah (including Pulau Langkawi), west Pahang near Bentong and west Negri Sembilan.

Fig. 4. Distribution of cockchafer infested areas in West Malaysia from 1956–1969

The grubs feed voraciously on roots, the extent of damage depending upon the age of the trees and the density of the grub population, which in a heavy infestation may be as many as a quarter million per acre. The first overt signs of attack are the rapid killing of legume covers, grasses or other undergrowth, as though a herbicide had been sprayed. The soil, loosened by the movement of the grubs, feels spongy to walk on; combined with root destruction, this may result in soil erosion and collapse of terraces, and subsequent tree falls in hilly areas.

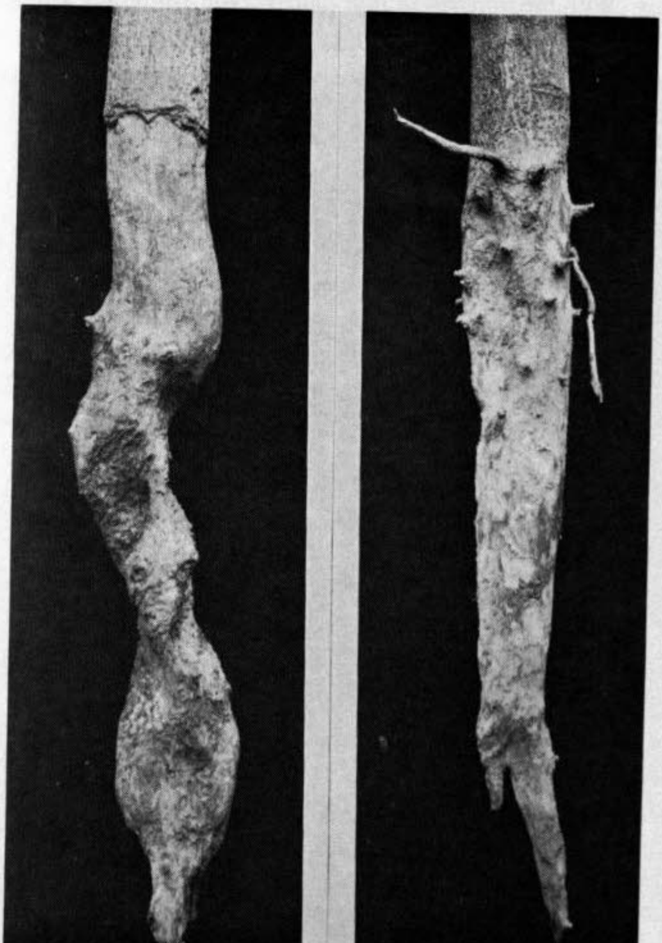

Fig. 5. Two 18-month-old rubber seedlings showing severe root damage caused by cockchafer grubs

In nurseries or first year field plantings established on land in which the grubs are already present, persisting from the old stand, even a small number can quickly destroy many plants. A single grub can consume the entire root system and then pull the plant down to feed on the stem (*Fig. 5*). Plantings with a well-established cover of legumes are prone to attack by *L. bidentata*, which is primarily attracted to the cover. Between 1957 and 1964 most of the serious outbreaks in the first region mentioned (central coastal districts) were by this species. The covers are first destroyed in extending patches; the grubs then proceed to feed on rubber roots, finally concentrating around the tap root and the base of the laterals. With the progress of root damage, the symptoms are leaf discolora-

Fig. 6. A 25-year-old tree killed by recurring cockchafer attacks

tion followed by dieback and finally, death of the whole tree. The extensive root system in mature rubber, on the other hand, can only be partially consumed during one season, and generally only the feeding roots and other small roots in the inter-rows are destroyed, but the infested area suffers a drop in yield. Re-attacks, which are not uncommon, greatly weaken the trees, but rarely kill them (*Fig. 6*).

A feature of cockchafer outbreaks during the last 3–4 years has been that they have become more widespread; more areas of high yielding modern clones between six and ten years old have been attacked, generally by *P. vestita*. When the pest is present in large numbers even fallen twigs and branches are consumed. The area suffers a heavy drop in yield and retardation of growth and if the attack is repeated many trees die in the absence of control measures. Such attacks should therefore be considered in the same category as attacks in immature rubber, when considering control measures.

Oil palm

Cockchafer grubs have only recently become important pests of oil palm as well. Serious damage by *P. vestita* has been experienced on two estates in south Johore close to areas planted with rubber; in one instance both crops adjoining each other were attacked (Wood & Ng, 1969). The affected areas had the same features with respect to topography, soil and nearness to jungle as rubber areas generally attacked. The pattern of damage too is similar—covers and other ground vegetation quickly destroyed and the foliage of the main crop turning yellow as a result of extensive root damage. In a field of 4-yr-old palms repeated attacks for three successive years retarded the trees to the extent of about two years' growth. In an 8-month-old planting several palms died. Grubs of *L. rorida* have occasionally been troublesome in oil palm nurseries, inflicting heavy casualties (Wood, 1968).

COCKCHAFERS AS FOLIAGE PESTS

The beetles of the group (Scarabaeidae) that feed on the foliage of crop plants are commonly referred to as chafers. A number of species exist in Malaysia, of which those of the genera *Apogonia* (Melolonthidae) and *Adoretus* (Rutelidae) are the commonest and the most important. They feed at night and shelter during the day in the top layers of the soil or mulch. They are much smaller than the root-feeding cockchafers discussed earlier. *Apogonia* spp. are shiny black, whereas *Adoretus* spp. are dull brown. The two are also distinguishable by the pattern of feeding—the former eat large areas of tissue mainly from the edge of the leaf, not unlike the damage done by grasshoppers; the latter make numerous small perforations. In both cases the leaf is finally skeletonised, often by both feeding on the same plant (*Fig. 7*).

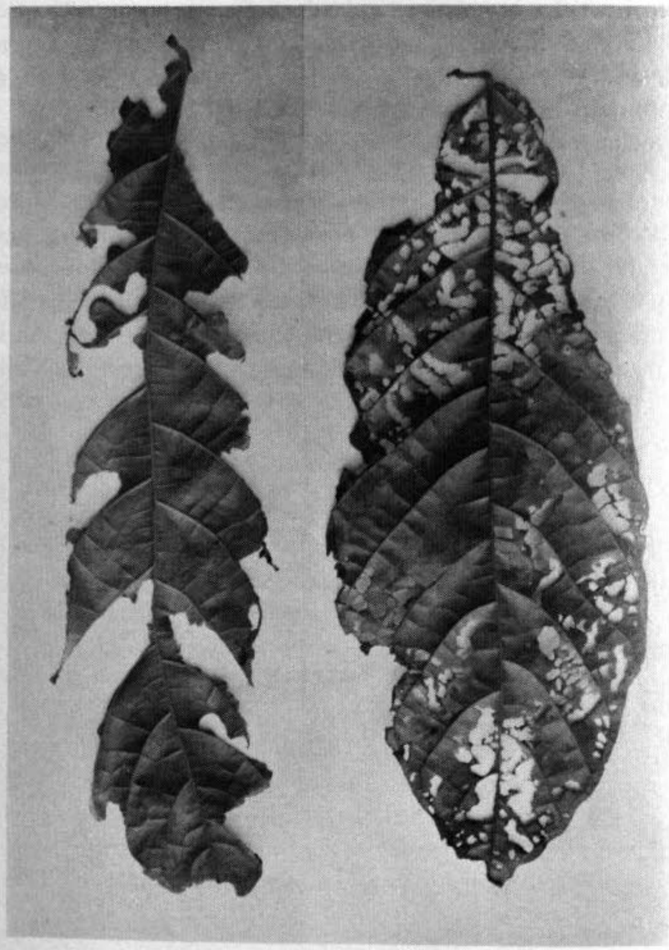

Fig. 7. Cocoa leaves damaged by Apogonia *sp.*

Lever (1953) worked out the life-cycle of these beetles in the insectary and found the immature stages in the soil to last three to four months. The normal food of the grubs consists of roots of grasses and other weeds and decaying organic matter. Duration of the adult stage varies with species. There is no evidence of any periodicity in the life-cycle or in the activity of the beetles, breeding probably taking place continuously. *Apogonia* spp. are strongly attracted to light, while *Adoretus* spp. are less so.

Oil palm and Cocoa

Two species of *Apogonia—A. cribricollis* Burm. and *A. expeditionis* Rits.— and two species of *Adoretus—A. compressus* Web. and *A. borneensis* Kr. also attack oil palm and cocoa. The latter is in addition attacked by a few other chafers, but to a much less extent, the two *Apogonia* spp. being the worst of the leaf feeders on this crop. The beetles cause considerable damage in nurseries and young plantings, which can suffer severe setbacks in heavy infestations. Though larger trees are also attacked, the overall effect of leaf destruction on them is not significant.

Rubber

Leaf damage by chafers has only occasionally been seen on rubber. *A. compressus* has been recorded as feeding in large numbers on mature leaflets of the lowermost storey of six-month-old seedlings (Rao, 1965) (*Fig. 8*). A Melolonthid *Maladera* sp. sometimes perforates the edges of mature leaflets.

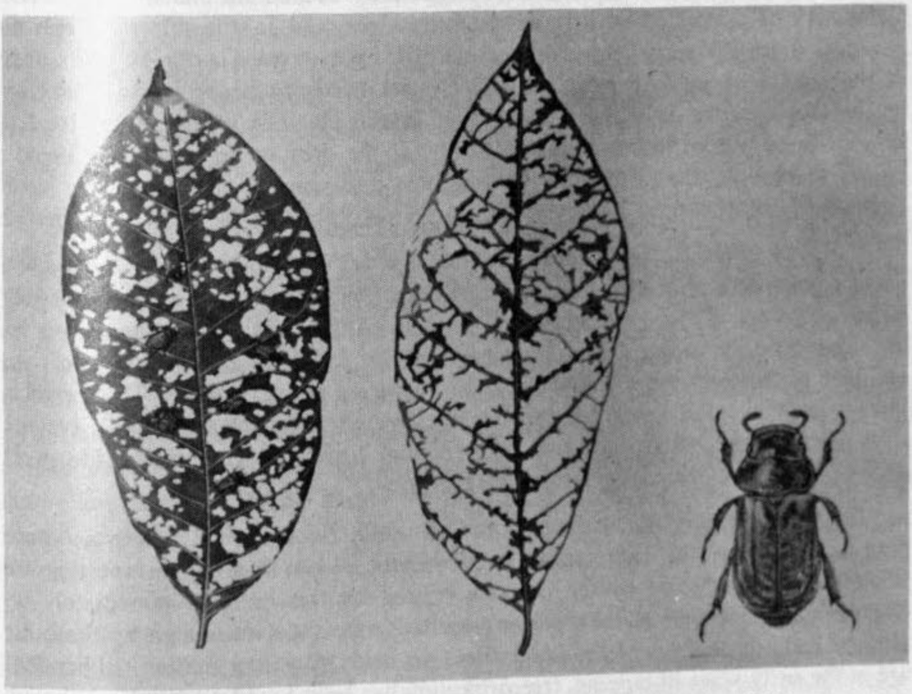

Fig. 8. Rubber leaves perforated by Adoretus compressus

CONTROL

Attempts to control cockchafer grubs in rubber started from the time the pests became a serious problem in the early thirties. Hand-digging to collect the grubs was the only method available for a long time. In addition to being laborious and only partially effective, this disturbs the soil and accelerates erosion. Soil insecticides that kill the grubs are readily available today. The problem however, is to make them reach the pest in the soil, without resorting to the expensive procedure of soil injection. A suitable insecticide applied on the surface and rotovated into the soil is an effective prophylactic treatment at the time of cultivating the land prior to planting, ensuring freedom from attack for about three years, but this cannot be recommended against the pests that are so sporadic and unpredictable in their choice of site to breed. For already established plantations experiencing an infestation, applying an insecticide to the soil surface is feasible only in flat areas where mechanical equipment can be operated. Unfortunately a large proporton of the cockchafer-attacked areas known are either hilly or undulating to various degrees.

The small areas of nurseries makes them easy to treat. The insecticides recommended—0.1% heptachlor or aldrin emulsion—are poured into holes spaced 18 in. apart and 6 in. deep. No special tool is generally needed for making the holes; a crowbar or a pointed stick would suffice as the soil in the affected areas is generally loose. Young field plantings are also easily treated since only the area of the soil immediately around the root system needs to be protected; this can be done by pouring two pints of the same insecticide into similar holes located in a circle of 6–8 in. radius from the plant. If the area to be planted is already known to harbour the grubs, the planting hole itself can be treated by the same quantity of the chemical; basket seedlings can be dipped in the insecticide before planting.

Larger trees can also be protected in the same way, but applying progressively larger quantities of the insecticide with the size of the trees, up to one gallon, at the same time increasing the number of circles of holes around the bole to two, and then to three, to cover an area of about two to three feet radius. This protects the tap root and the base of laterals in the treated zone and serves to save the trees from severe injury. Further, the residual toxicity of the insecticide gives protection against three generations of the pest.

Treatment around the bole is of limited value for old trees, where no more than a fraction of the root system is protected. While it is important that all immature areas affected by the pest are treated by this method immediately on discovering an infestation, the decision whether to treat a mature area by the same method rests on the age of the plantation. In fields of young mature rubber that are in the early years of tapping, tree protection has been found essential. Although the boles are then protected, the treatment does not prevent smaller roots in the inter-rows being affected, for tree protection leaves the bulk of the grub population in the inter-rows to complete their growth by feeding on the covers or roots of the rubber beyond the treated zone. Grubs of *P. vestita* feed extensively on the underside of fallen twigs and branches after consuming all the roots in the inter-rows. On the other hand, in heavy infestations of *L. bidentata*, especially in areas of moderate to poor cover, the grubs die of starvation once the trees are protected and there is nothing more in the inter-rows to feed on.

If both the trees and the cover are to be protected in an immature planting and, in older plantings, the extensive root system of the trees in the inter-rows is also to be saved and the pest eradicated completely, the whole area of the infested field requires treatment. Good results have been obtained with 2 lb heptachlor/200 gal/acre poured as described into holes spaced 3′ × 3′. The treatment however is prohibitively costly, about $90/- per acre, as there is no mechanical equipment available for soil injection of high volumes of the insecticide. On the other hand, the insecticide in the form of 10% granules, broadcast on the soil surface at the rate of 20–25 lb per acre, achieves some control of the grubs, especially if its incorporation into the soil is assisted by heavy rains after the treatment. This costs less than a third of the overall soil injection treatment.

An alternative method of ensuring freedom from re-attack is the destruction of the pest during its adult stage, during emergence from the soil or flighting. The above treatment with granules kills the bulk of the pests surviving to complete their life-cycle as the beetles emerge through the treated soil surface. Further, if a fresh batch of beetles attempts to start an infestation in that soil, either they or the young grubs that hatch from their eggs are killed.

Some species can be caught in large numbers in light traps with a 15-watt blacklight fluorescent tube as the light source. They are most easily caught when they emerge from the soil and fly towards the jungle. Mass flighting takes place for less than an hour, soon after dusk, and is restricted to a short season of about six weeks in February/March, which makes trapping easy. The method has proved successful for *L. bidentata* (Rao, 1964) with a trap design comprising a 24 in. diameter funnel and three vanes 10½ in. wide. The catch is collected in a polythene bag tied to the end of the funnel (*Fig. 9*). A possible approach to controlling this species, by integrating the use of insecticide and light traps, has been described by Rao (1969). Other species of cockchafers, particularly *P. vestita*, have also been caught in this trap.

Leaf-eating chafers are controlled by spraying a stomach poison such as lead arsenate, applied at 0.4% (Lever, 1953). Excellent control of the pests is also obtained with 0.1% trichlorphon (Wood, 1968), an insecticide of much lower mammalian toxicity than lead arsenate. Both are sprayed high-volume on the foliage at monthly intervals; the interval should be shortened in wet weather.

Hand collection at night with the help of a torch has been attempted, but apart from being laborious for large areas, has not given any significant reduction in numbers of the pests. *Apogonia* spp., though attracted to light, are caught only in small numbers in light traps.

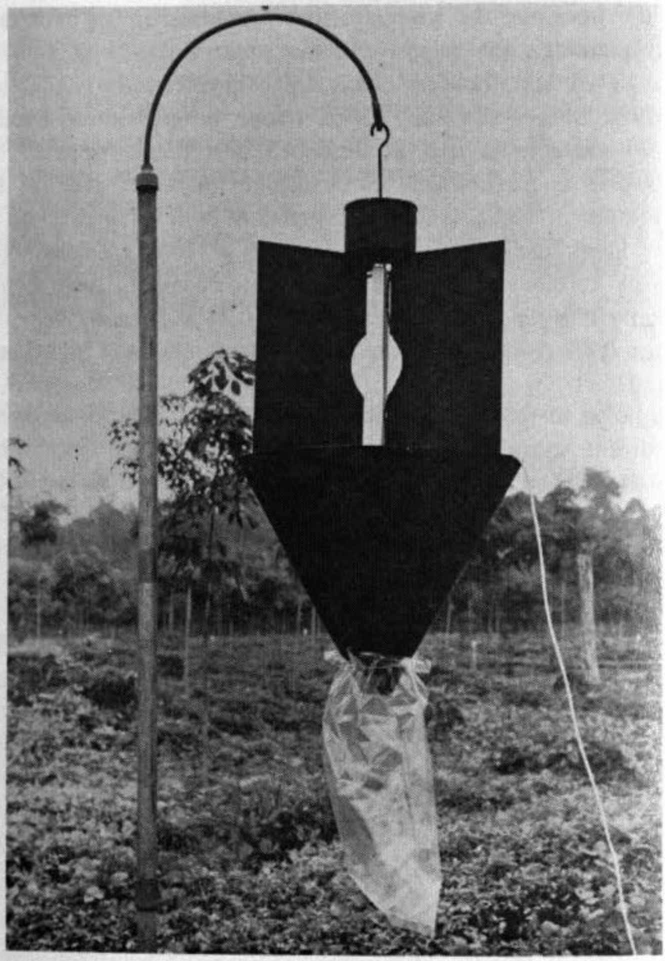

Fig. 9. A light trap for Lachnosterna bidentata

CONCLUSIONS

Cockchafer grubs have for many years been serious pests of rubber plantations, occurring sporadically in certain areas of the country. Though the adult beetles have a limited range of food plants, generally in the forest, the grubs feed indiscriminately on the roots of almost any vegetation that exists in the ground. Hence, it is not surprising that, with the recent rapid increase in the planting of oil palm, they are starting to become important pests of this crop also.

The pests are particularly damaging to young plantations. Though adequate control measures are known, an infestation may not be detected until considerable root destruction has taken place, when symptoms appear above ground. When the grubs have completed much of their feeding and are preparing to pupate, they are resistant to insecticidal treatment. Early detection and rapid implementation of control measures are therefore essential. Estates in areas that have a history of past outbreaks should routinely check their fields close to primary or secondary jungle, by sample diggings at random to reveal the grubs, during early June when significant root feeding commences. Symptoms on the covers are a good reason to suspect an infestation in young plantings, while in older areas, grasses and other undergrowth come off the ground without any effort when pulled.

Leaf-feeding chafers are troublesome everywhere, almost throughout the year. They are however easy to control by spraying a suitable insecticide, required more or less routinely in nurseries and young plantings of oil palm and cocoa.

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DISCUSSION

Chairman: B.S. Gray

Gillbanks: When feeding in the jungle, do the cockchafers concentrate in small areas, or spread over large areas?

Suppiah: They remain fairly localised along a narrow belt of jungle, up to about 100 yards deep.

Chakrabarty: Has any experiment been done to spray the jungle with insecticides to kill the adults prior to any new reinfestation of the plantation?

Suppiah: No experiments have been done. The number of species of plants that they will feed on is limited; in the case of *Lachnosterna bidentata* we have recorded about 12, and for *Psilopholis vestita*, 6. These are scattered and such spraying might well be impracticable.

Chairman: You mention that root-feeding cockchafers are becoming oil palm pests. Could you elaborate on that?

Suppiah: A recent paper by Wood and Ng (*see references above*) describes attacks in two localities.

Nowak: In the case of a leaf-eating cockchafer like *Apogonia* spp. can one deal with it at the grub stage instead of spraying the palms being attacked?

Suppiah: We have no practical experience. Would Mr. Wood comment?

Wood: Mr. Hew made the point yesterday, that if you put a polybag nursery on a clean-weeded area, few cockchafer attacks occur. In a sense, removing the food source is controlling the cockchafer grubs and would appear to be a feasible method.

Hew: Control of grubs in the soil by chemical application is very expensive, so spraying of the palms is more suitable.

Is anything known about any connection between cultural practices, in so far as they affect soil structure, and cockchafer breeding? We got the impression that where the soil is ploughed to improve the tilth, conditions become more suitable for cockchafer breeding.

Suppiah: I have no evidence on that.

THE IMPORTANCE OF ECOLOGICAL STUDIES TO PEST CONTROL IN MALAYSIAN PLANTATIONS

by

Brian J. Wood

SUMMARY

Ecology is the study of the relationships of communities of living organisms with their environments and each other, in particular the factors affecting their numbers. Pest control is, essentially, modification by man of these numbers in an agricultural environment, and it is argued that investigations of and a general awareness concerning ecological factors are essential prerequisites for proper effectiveness. Examples from Malaysian plantations are given of major outbreaks and great expense arising from failure to observe these principles and, on the other hand, of ecological studies forming the basis of successful and cheap control procedures. Plantations exhibit a high degree of biological stability, especially in the continually warm and humid climate of Malaysia, so that many pests are of only potential severity, breaking out spasmodically, but conditions are also ideal for the existence of pests and for their rapid increase if this stability is upset.

Malaysia is predominantly agricultural and much dependent on efficient plantation production. Pests menace efficiency, but the insurance of continually increasing ecological knowledge will keep to a minimum both the economic impact of pests and the considerable risk of severely aggravating pest problems by unsuitable control measures.

Some consideration is given to relating pest control practice in Malaysian plantations with modern thinking on environmental problems.

Ecology is the study of the relationships of communities of living organisms (populations) with their environments, in particular of the factors which affect their numbers. An area devoted to a crop plant forms an environment, often called an agroecosystem, in which a regime of plants and animals exists, all of which are directly or indirectly influenced both by one another, thus forming the biological environment, and by soil, weather and so on, the physical environment. Pests are those members of this regime which may compete with or feed on the crop plant, and their numbers are governed in intricate ways. These intricacies are perhaps particularly marked with animal pests where long chains of interdependence develop, through primary plant feeding, predation, parasitization, hyperparasitization, social interactions, diseases, competition, and many other influences.

Research on the control of pests has many aspects, including identification work, studies of their biology, their direct relationship with the crop plant and, obviously, discovering techniques to kill them. All are extremely important, but they are not in themselves complete. Pest control is essentially a practice by man of modifying the numbers of a particular population, hence it is a practice of ecology. Those concerned with growing crops are usually primarily familiar with plant science, and perhaps less so with the ways in which animal numbers are influenced. My aim is to illustrate the importance in pest control of this kind of knowledge by examples, taken from Malaysian plantation crops, where ecological studies have formed the background for sound practice and where lack of information has resulted in unnecessary expense, failure of control, or worse.

Pest control practice which accepts and utilises environmental factors and looks for compatibility in control measures, rather than simply considering a pest and a means of killing it in isolation, has acquired various names. "Integrated control", originally coined to define the supplementing of biological with compatible chemical control (Stern *et al.*, 1959) has now assumed wider meaning, and Geier (1966) has used the term "Pest Management".

The most dramatic illustrations of the adverse consequences that can arise from a lack of ecological awareness are insect outbreaks which have been caused through upset to natural balance by insecticides. A good deal has already been written about these incidents (*e.g.* Conway, 1968; Wood, 1968) but some of the more salient points are reiterated here to illustrate the principles involved. The Malaysian plantation presents a very stable environment, both because of the continuity of the crop and the perpetually warm and humid climate. Many insect pests can find a complete existence within the plantation, and reproduce continuously, but despite a high increase potential they rarely become numerous because various insect-eating insects, the parasites and predators (natural enemies) hold them in check. Once this constraint is removed, "explosions" can take place, as the pests reproduce at something approaching their full potential. Insecticides, by differentially favouring the pests, even though they may initially kill a high percentage of them, can in certain circumstances cause just this to happen. For example, in oil palms in West Malaysia severe outbreaks of caterpillar pests began to occur in the late nineteen-fifties and early sixties. These caterpillars, which had previously been innocuous, primarily included the bagworms *Metisa plana* and *Cremastopsyche pendula* (Psychidae) and to a lesser extent various nettle caterpillars, in particular *Setora nitens* (Cochlidiidae). In all cases where any deduction at all could be made, it transpired that the worst trouble originated *after* the application of chemicals. No other common factor could account for the outbreaks, which occurred in various parts of the country, at different times of the year in different years. The sprays were in some cases initially used against other far less serious pests, such as cockchafers, and sometimes against minor outbreaks of the pests which themselves later became serious. Large acreages were entirely defoliated, and although sprays gave control, they also often again set the stage for rebound, and recurrent spraying became necessary.

There is more to the recurrent outbreaks than the simple fact that parasites were killed in the early stages. The reverberations of a disturbance can continue in both space and time. Good biological control, as DeBach (1964) has observed in the introduction to the classic work on the subject, comprises a rare pest being controlled by a rare enemy. Once the pest achieves its full increase capacity for a generation or two it is no longer rare, but its enemy can only begin to build up after the pest has increased. The enemy may lag for a few generations and in the meantime the pest in a certain area has met the next natural check on its increase—the food is completely eaten up—in this case the oil palm leaves. Bagworms spread to new areas, both gradually outwards and by "seeding" of sites some little distance away. The "rare" pest became locally more common, putting the still "rare" enemy at a disadvantage there too. This continued long after the use of any of the insecticides associated with the original disturbance.

Another complication may be the breakdown in the co-ordination of the life cycles of pests and their enemies. If, as commonly happens in the non-seasonal climate, all stages of a pest are regularly present in small numbers, newly emerging enemies, parasites in particular, can always find a host in the right stage to ensure a continued existence, so there has never been any pressure for close synchrony to evolve. When a disturbance occurs, not only are the enemies differentially affected but so too may be pests of various ages. Thus the particular stage that is spared will precede the explosion, which then occurs in simultaneous jumps. A parasite population may build up but then, although numerous hosts are present, the parasites can find few suitable to feed on or lay eggs in so must die or migrate. Bagworm outbreaks recurred several generations after parasites seemed to have re-established control (bagworms complete a generation in about 3 months so this can be some years afterwards). Even now attacks build up in some of the original upset localities, but scarcely ever elsewhere, although the frequency declines as years pass.

The insecticides which set off these events had characteristics predisposing them to favour pests over enemies in the long run. They had a broad spectrum (killed a wide range of insects, including natural enemy groups) and were contact acting with long lasting residues, thus being disadvantageous to enemies exploring over the area after the main effects had dissipated. It might now be reasonably asked—how does an ecological awareness, an appreciation of the kind of events discussed above, help in practice? Clearly, the ecologist can recommend avoidance of insecticides which might be likely to have major repercussions, and he can help in defining such insecticides and circumstances, but insecticidal upsets are not the only cause of pest attack, and the planter with an outbreak, however caused, needs to end it rapidly without substantial loss. The most immediate weapon at this stage is the insecticide. Some insecticides are more selective in action. Bartlett (1964) outlines characteristics leading to selectivity and he assesses some of the commoner chemicals from this aspect. Briefly, requisite attributes are the opposite of those given above, involving narrow spectrum (more specific to the pests), acting only on being eaten (stomach poisons), or having fast-fading residues. Most of these characters are relative; possession of favourable attributes predisposes to selectivity, but whether a chemical is actually selective or not will influenced. My aim is to illustrate the importance in pest control of this kind of knowledge by examples, taken from Malaysian plantation crops, where ecological studies have formed the background for sound practice and where lack of information has resulted in unnecessary expense, failure of control, or worse.

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In the oil palm situation, nettle caterpillars cleared up rapidly after the use of non-selective chemicals stopped, but bagworms continued. Trials were carried out with various chemicals likely to be selective and two, lead arsenate, a stomach poison and trichlorphon, which has a fast-fading contact residue, but remains longer as a stomach poison, showed initial promise. Further field studies showed the ideal time to spray; this was when young bagworms were emerging and before maximum parasite activity developed. Several aerial spray campaigns have been carried out, mostly with trichlorphon, and only in two instances has any further control action been necessary—the sprays reduced the pest and although they never eliminated it, parasites took care of survivors.

So far, I have illustrated this point with an oil palm story, but similar events occurred on cocoa in new ventures in Sabah (Conway, 1969). The cocoa was planted in forest clearings and some of the understorey trees and saplings were left as shade. Bark borers, especially a caterpillar ring-bark borer of the hepialiid family, became pests, leading to dieback and death. Dieldrin sprays were applied and reduction was obtained, but leaf-eating caterpillars then became troublesome. This led to more spraying with a whole range of non-selective insecticides, followed by more pests, until defoliation by several species of bagworms, which had by this time appeared, was severe. Conway, with knowledge of the probable ecological factors, suggested that spraying be stopped. This was done, and some of the pests began to disappear, more or less rapidly, with obvious parasite activity involved. Bagworms remained, and a programme of trichlorphon spraying led to their gradual control. In the meantime field investigations showed that a particular species of shade tree, *Trema cannabina*, was also a host to the borer which, although lethal to cocoa, was relatively harmless to this tree. Simply by removing this plant, the source of all the trouble was eliminated. But for some ecological consideration there might have been repercussions for the cocoa-growing industry even worse than the expense and loss which occurred.

Sometimes the original cause of an outbreak remains uncertain, but the need to avoid non-selective insecticides is still present, both to minimise the risk of further repercussions and to allow maximum chance for natural enemies to gain control. In oil palms in Sabah major outbreaks have occurred of another more voracious and potentially prolific bagworm, *Mahasena corbetti*. This was followed by nettle caterpillar (*Darna trima*) attacks. No reason was readily apparent for the original bagworm attacks, but they appeared to be continuing for reasons similar to those affecting the bagworm species in West Malaysia. Acting on an assessment of the ecology of the latter situation (Wood & Nesbit, 1969), trichlorphon was applied in the hope that it would reduce the bagworms and allow the then rare parasites to build up so that sooner or later the usual almost total freedom from this pest could be restored. It was moderately effective in control and although it was some time before parasites appeared in any numbers the intended result of the policy appears to be achievable. Control by the aerial spray technique has improved with better timing, and parasites are now common (Sankaran, 1970). In several cases, what appeared to be incipient outbreaks have declined of their own accord, and others cleared up completely after inclusion in one of the limited number of spray campaigns which have been needed, despite survivors being left. *Darna trima* built up originally perhaps as a result of a trichlorphon spray, but this is not clear. Several outbreaks have occurred. Immediate control is easy by a spray but the pest is something of an enigma, in that a new numerous generation may follow a previous one, or there may be a sudden termination of outbreak after one generation matures or dies, in both cases irrespective of whether or not spraying was done. Only more detailed ecological studies are going to help elucidate this problem. The work of the CIBC* station in Sabah is providing an invaluable ecological background on oil palm pests there, especially on the natural enemy fauna and diseases, and Syed (these *Proceedings*) speculates that the natural control of *D. trima* may be weak so that importation of enemies could be of value. He also discusses a virus disease which attacks it and suggests disseminating this like an insecticide, a measure that would assuredly be highly specific and hence unlikely to have side-effects.

Rao (1969) describes a programme of ecological research which resulted in the control of cockchafers, potentially severe pests of rubber along certain jungle margins. The cockchafers come into the rubber from the nearby forest and lay their eggs in the soil. The grubs feed on roots, and can kill or severely harm the trees, and completely destroy leguminous and any other ground vegetation. The cockchafers have an annual life-cycle. Control takes into account the requirements of the crop and the habits of the beetle, and is organised to have no side-effects. Soil insecticides are used to protect young rubber in its most vulnerable first two years of life. Then cover assumes its importance and the measure becomes unsatisfactory both because of the expense of treating the whole area and because it can disturb biological balance, the consequence of which is destruction of the cover (which was supposedly being protected) by leaf-eating insects. At this time light-traps are used to capture adults and thus reduce the infestation. The well-defined and restricted annual and daily flying times permit minimal cost on trap operation. In later years, when tree girth obscures the light, cover is no longer important, so broadcasting of soil insecticides is practised.

Rhinoceros beetle is an important pest of young oil palm replants when it breeds in the rotting logs of older felled stands. Control by killing, either of adults in the young palms or destruction of breeding sites and removal of grubs, may be practised, but neither method is fully satisfactory. Adult collection means

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* Commonwealth Institute of Biological Control.

the beetle does its damage before it is killed, and it is doubtful if it makes much difference to the overall population size. Grub and breeding site destruction is far from fully effective, usually, and is quite expensive. A programme of research was set up to examine various aspects of control (Wood, 1966). It included advanced methods to totally destroy breeding sites soon after felling as well as possible means of speeding their rotting down by the use of arboricides, acids and other chemicals, and by increasing the exposed injured surface. Other trials examined the possibility of reducing the suitability of logs for breeding by injecting insecticides, or by a cover of ground vegetation. The last had occasionally been suggested by planters as depressing infestation, but it had not been confirmed or quantified objectively. In fact, it was found that this measure markedly reduced breeding. Moreover, it greatly lessened attack on young palms irrespective of breeding in the vicinity (Wood, 1969a), so much so that simply by ensuring the early and dense growth of natural or leguminous cover, something not agronomically undesirable anyway, complete economic control of the beetle is usually obtained. This fully justified expenditure on the original research programme.

Rats have long been a serious chronic pest in oil palm estates. South (1931) considered their control, and other workers subsequently discussed the problem, but as Gillbanks *et al.* (1967) pointed out, there existed a lack of objective standard for determining the effects of techniques of rat control. Since then a programme of research on rat populations in oil palms has been pursued, applying and developing for the specific situation, ecological techniques designed for the study of populations of small mammals. The number of rats in oil palms can now be assessed with reasonable accuracy and linked to the damage that is occurring. It has been clearly demonstrated that such measures as hunting and trapping can have little effect on population size except at impossible cost, and similarly that many measures, although undoubtedly they produce dead rats, do not control the population. As a result of this study, a suitable bait formulation has been developed and baiting technique has been improved so that rats can demonstrably be virtually eliminated for a period of several months (Wood, 1969b).

In these examples, my theme has been the study of pest populations in relation to their environment—"applied ecology"—as a basis for sound pest control strategy. No one method is universally applicable—killing an animal is not necessarily controlling it—and altering one element in a dynamic balance is bound to have repercussions which may or may not be harmful, but which must be thought about. The interpretation of a situation such as that involved in biological imbalance must often, perforce, be speculative, dependent on circumstantial evidence and deduction. Nonetheless, lack of detailed information is no excuse for abandoning all attempt at rational control which initially may have to be based on no more than an awareness of ecological principles. This was shown at its simplest by a case in tea: an estate in West Malaysia had an outbreak of leaf roller, with other caterpillars building up. I was asked to comment and it transpired D.D.T. had been recently sprayed a few times. Simply on the basis of inference, I suggested all spraying be stopped immediately. Within a very short time the outbreak had cleared up with no repercussion. This contrasts with the situation in parts of some tea estates in Sumatra, where regular D.D.T. dusting is carried out against these pests, which continue so severe that harvestable crop is markedly reduced. Developments in Malaysia could easily have followed another course, as they could in oil palms and cocoa, early attention being devoted to selecting chemicals with the highest kill and perfecting application techniques so that regular rounds of pest outbreak, control and later re-outbreak became established. Apart from the expense, other dangers are attendant; among the more obvious are recurrent loss of crop before the control measure becomes justifiable, the frequent very great difficulty of applying pesticides in plantation conditions, and the development of pest-resistance to the chemicals in use. Gordon Conway (pers. comm.) has suggested that pest management is rather akin to business management—decisions have to be reached on the basis of whatever information is to hand. The situation, the measures and the outcome are themselves important sources of information for the future to supplement findings from more formal experimentation. Of course, more sophisticated techniques will be brought to bear in reaching decisions—systems analysis using the computer is likely to play an increasing part in interpreting available data, although it is not expected to substitute for knowledge from careful field observation and experimentation.

Malaysia is predominantly an agricultural country, much dependent on maximum high quality production. Harvest is commonly reduced and defiled by pests, some chronic, some spasmodic but still severe or even catastrophic at times. A flow of graduates from agricultural college who will become involved in all aspects of agriculture is certain, and apart from obvious conclusions about the training of those to be primarily concerned with pest control, it is to be hoped that all will be equipped with a knowledge of ecological principles. Although some success has been achieved by ecologically based approaches, we are only beginning to build up the fund of necessary knowledge. Some of our control efforts are less effective than we would like, or carry incompletely understood risk of side effects. There is, too, always the chance that some pests will overcome control measures which are currently effective; *e.g.* rats may evolve either resistance to the poisons used or avoidance behaviour and thus escape the baiting technique, or another less susceptible pest may fill the niche that is left by their control. We have to endeavour to be one jump ahead. Research must go on irrespective of the crisis of the moment, for the insurance of knowledge is worth far more, in the long run, than *ad hoc* measures to deal with problems as they become pressing, even though it may be more difficult to show its value on a conventional balance sheet. Perhaps the ideal is for the field man (backed by specialist research) to concentrate on the whole pest complex of a crop for a period, rather than on a particular type of pest, for then he cannot afford to develop partisan attitudes for any one method of control, be it chemical or biological, nor can he afford to treat problems in isolation, for the responsibility of repercussions is his. Much of the work done in Malaysia, happily, is being orientated along these lines, and as manpower increases it will be possible to reinforce this approach. It is encouraging to note the stress on pest ecology and the integrated approach in some of the papers presented in this session of the conference.

More needs to be known about the effect of damage, too, for this constitutes a major part of integrated control (Smith, 1968). There is little point in merely allowing a pest to reach its low point of natural balance if it is still harmful. For example, in the cocoa story already recounted, after the cessation of spraying and the restoration of balance, two species of mirid bugs appeared which punctured and destroyed pods so that even very low level attacks caused serious damage. In this case, Conway (1969) showed that lindane, used sparingly at low dosage, would control the pest with no marked side-effects. On the other hand, many pests which cause noticeable damage do little real harm at low numbers; *e.g.* occasional rhinoceros beetle attack is only marginally detrimental to young palms and there is no point in spending a lot of money in an effort to eliminate every beetle.

In recent years there has been a revolution in thinking about the environment. A major turning point was the publication of Rachel Carson's (1963) *Silent Spring*, a work which awoke the popular imagination to the unthinking and unnecessary use of insecticides and other chemicals in sledgehammer-like blows to subvert subtle nature. I hope I have not created the impression here of being against the use of insecticides. Rather am I, together with the colleagues I have quoted and many others, opposed to their "unthinking and unnecessary" use as a substitute for understanding the natural forces we are dealing with. Conservation and pollution are words now in common coinage. Paradoxically, especially so far as tropical perennial crops are concerned, the economic entomologist or zoologist—"applied ecologist" is my preferred term for obvious reasons—should have much in common with the conservationist. Both of them realise the long-term importance of maintaining as natural and diverse a situation as possible, and both aim to manage the numbers of organisms. Whilst their intentions about ideal levels may differ, the conservationist does not want to be overrun by any one species, any more than the applied ecologist can hope for complete permanent elimination except in very rare instances. Both in fact are ecological regulators and the more they understand of the complexities at work, the better they are likely to succeed. Pollution occurs because it has been assumed that products such as insecticides once used or dispersed, are thus disposed of. Unfortunately this is not always true—increasingly they are coming back to haunt us because the earth, "Spaceship Earth" it is sometimes graphically called, is a closed system. If we continue our efforts to develop pest control methods based on maximum possible understanding of ecological principles, using available chemicals wisely, as far as possible applying those which degrade rapidly, we shall be doing our small part to keep our world inhabitable and our pest control cheap, effective and sound in the long term.

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DISCUSSION

Chairman: B.S. Gray

Turner: Many chemicals seem to carry risks of affecting the biological balance. Could Mr. Wood suggest how long a chemical ought to be tested before it is released on the local market?

Wood: There is no simple answer, although theoretical considerations can help. A study of the recorded effects of the chemicals against the major natural enemy groups is valuable. The way in which the chemical acts should be considered; in general, primarily stomach-acting poisons, or those with short-lived residues, are likely to be most favourable. If on *a priori* grounds a chemical seems suitable, then it must be used in practice before any hidden drawbacks can show up. If it starts to have repercussions, then changes have to be made. More detailed studies will reduce the need for such an empirical approach, but as yet we lack the manpower to directly assess selectivity against the specific natural enemies in a particular situation.

Wycherley: As chairman of the conservation section of the International Biological Programme in Malaysia, I would say the paper is of great service in trying to put pest control problems into perspective. As development goes on in Malaysia, the residuum of natural conditions, which is to provide resilience for recovery, declines. If we are to have anything left to conserve, agriculture must be very efficient. Efficient pest and disease control therefore contributes to conservation. We create an artificial situation by using land for agriculture, and to some extent create conditions predisposing to pest attack, but we must make use of all the natural regulating factors. We must cease to think of chemicals as a cure at one stroke. They are something that can be used at times to tilt the balance back in our favour. Would Mr. Wood like to comment on that?

Wood: Only to agree! It is important to bear in mind that the pest outbreaks to which I referred specifically are unique occurrences, not something we are constantly battling against. The aim of control was therefore to restore the natural situation without excessive crop loss.

Yeow: A point which has not been touched upon regarding insecticide use is risks to the consumer. Insecticides are sprayed on some vegetables regularly right up to harvest. Even chemicals banned in Malaysia are sometimes smuggled in and used.

Van: To remove any misunderstanding on this aspect I would like to confirm that legislation exists on pesticide importation and use in Malaysia.

Varghese: I wonder if the possibility of microbial pesticides such as *Bacillus thuringiensis*, or the *Metarrhizium* disease of beetle grubs, has been considered?

Syed: At the CIBC station in Sabah we are looking into such possibilities, with a fungus of bagworm for instance. A lot of work is needed and we are in the early stages, but perhaps something of value will emerge.

THE CONTROL OF SECONDARY LEAF FALL OF *HEVEA BRASILIENSIS*

by

R. L. Wastie

SUMMARY

Secondary leaf fall (SLF) caused by *Oidium heveae* can be satisfactorily controlled with sulphur dust. An economically feasible fungicidal treatment for Gloeosporium SLF (caused by *Colletotrichum gloeosporioides*) is not yet available, although defoliation can be reduced with prophylactic fungicides. Among a variety of effective products, captafol, tetrachloroisophthalonitrile and benomyl are the most promising.

Both Oidium and Gloeosporium SLF can be avoided by hastening the onset of wintering with an aerial application of cacodylic acid in January. This rapidly defoliates the trees, with the result that refoliation is accelerated and a disease-free canopy results.

The disease of Hevea known as secondary leaf fall describes the defoliation of young leaf that commonly occurs in March and April as the tree is refoliating after its annual wintering. Of the four parasites associated with defoliation, the most important sole causes are the fungi *Colletotrichum gloeosporioides* Penz. and *Oidium heveae* Steinm., which cause Gloeosporium and Oidium secondary leaf fall (SLF) respectively. The other two associated causes of leaf fall, the mite *Hemitarsonemus latus* and thrips *Scirtothrips dorsalis*, rarely cause defoliation on their own.

The importance of SLF lies in its weakening effect on the tree. Repeated attempts at refoliation divert metabolites from latex production, and the depression in yield which normally occurs after wintering is excessively prolonged. Artificial defoliation of mature trees, by applying a defoliant from the air, has also confirmed that removing 80–90% of the canopy and maintaining this state for several months results in a drop in yield of the order of 15–25% (Rao, pers. comm.). In addition, a reduction in the rate of girthing and of bark renewal is also to be expected from repeated SLF.

The severity of SLF depends on the weather, the speed of wintering and refoliation, and the innate susceptibility of the planting material. Wastie (1971) has recently reviewed these predisposing factors, which are closely inter-related. The disease only occurs if sufficient fungal inoculum (i.e. spores) is present on leaf of a susceptible age, and if suitable weather follows. The extent of the resulting defoliation depends directly on the weather: long periods of high humidity and frequent rainfall favour Gloeosporium SLF, whereas Oidium SLF is more severe in drier weather, with infrequent showers of short duration (Anon., 1970).

An important characteristic of the fungi causing SLF is that they are able to attack only immature leaf; the large amounts of susceptible leaf that develop during the refoliation season therefore enable the diseases, particularly Gloeosporium, to build up to epidemic proportions extremely rapidly. Therapeutic treatment of SLF with fungicides currently available is therefore ineffective, and only under certain well-defined circumstances has chemical intervention with prophylactic fungicides proved rewarding.

Although SLF has been of annual occurrence since at least 1928 (Weir, 1929) it appears to have become more common, and its effects more severe, in recent post-war years. This is because modern clones, with a few notable exceptions, have tended to be more susceptible to SLF than pre-war selections.

The most effective long-term means of avoiding SLF is by planting resistant or partly resistant cultivars. Resistance to Oidium is independent of resistance to Gloeosporium, and *vice versa* (Wastie, 1971), and disease severity differs markedly between regions of West Malaysia. Careful choice of the cultivars most suitable for each region must therefore be made (Ho *et al.*, 1969). However, cultivars planted in the last 10–20 years without the benefit of this more recent information frequently suffer severely from defoliation, and in this situation more direct methods of disease control are required.

OIDIUM

Oidium SLF is of widespread occurrence over the whole of West Malaysia, but reaches its peak severity in drier districts in the shadow of the north-east monsoon, particularly coastal Negri Sembilan and Malacca. It is invariably the first cause of SLF, because it develops most freely in the drier weather which usually occurs in February and early March while refoliation is beginning. The most susceptible commonly-planted clone is PB 5/51; also of above-average susceptibility are RRIM 501, 605, 614, 615, 628, 701, PB 28/59 and Tjir 1. If left untreated, extensive and repeated defoliation may take place until wetter weather intervenes and insufficient susceptible leaf remains to support the disease. Even a moderately heavy attack of SLF in the most susceptible clones results in a poor canopy, thereby reducing the vigour of growth and increasing weeding costs.

Sulphur, a common mildewcide, is highly effective against Oidium, but only when prophylactic applications are made at the onset of refoliation. The progress of the disease on already-infected leaves cannot be slowed down by sulphur dusting to a sufficient extent to prevent leaf fall. Sulphur is easily and relatively cheaply applied to even the tallest trees as a dust; suitable machinery and the method of operation have recently been described (Wastie, 1969a). Treatment, with either portable or tractor-mounted machines, should begin when the first few mildew spots are seen on the lower leaves and about 15% of the leaf is in a susceptible condition—i.e. just bursting from the bud—and should be repeated at intervals of 5–7 days until the majority of the leaves are more than 10 days old—fully expanded but still limp—by which time they will not fall even if attacked. The period for which protection is necessary depends on the rapidity of refoliation, and usually varies between 3–6 weeks. Dusting at intervals of 5–7 days, again depending on the rapidity with which the new foliage develops, thus usually necessitates 4–6 rounds of treatment, at a recommended application rate of 8 lb per acre/round.

Local knowledge of the severity of defoliation in the absence of treatment should govern the extent to which it is carried out. In general, only a large improvement in the canopy will justify annual treatment. Clone PB 5/51 is most likely to benefit from dusting, not only because of its high susceptibility to the disease, but also because it is highly wind-fast and no trunk snap or branch breakage is likely to result from the retention of a heavy canopy. Wind-susceptible clones such as PB 5/63, RRIM 501 and RRIM 614 should be dusted cautiously, if at all, particularly in areas prone to wind damage. The retention of a heavy canopy often results in natural defoliation of lower leaves, due to shading. This is particularly common in PB 5/51, when whole branches may be shed in this way.

Among other fungicides tested, the systemic fungicide benomyl (Benlate) is active against Oidium, both when applied as a spray and as a dust (Shepherd, pers. comm.). It is unfortunately not absorbed by the leaves except to a very local extent, and its effect is therefore mainly as a surface fungicide. Other systemic fungicides, which hitherto have been developed mainly as mildewcides for horticultural crops, may also be expected to be effective against Oidium SLF: among them two methylpyrimidines have been tested, but unfortunately with inconclusive results. But unless systemic products can be applied to the lower leaves by spraying, or to the bark by painting or injection, dusting remains the most attractive method of applying foliage fungicides, since the best coverage is obtained thereby.

In so far as the economics of sulphur dusting have been investigated, they appear favourable for PB 5/51 in central coastal districts, where yield increases more than sufficient to cover the cost of treatment may be expected (Wastie & Mainstone, 1969). However, the variability in severity of Oidium SLF from clone to clone, between districts, and from one year to the next, suggests that the treatment should be applied with due regard to the intensity of attack experienced in neighbouring untreated fields. In a year in which wintering and refoliation are early, as in 1968 or 1970, Oidium SLF may be escaped altogether.

The severity of Oidium SLF alters as the tree ages; it is insignificant before about the fifth year when the wintering cycle becomes established, and even for the first year or so of tapping yields may be satisfactory in spite of a somewhat depleted canopy. Thereafter susceptibility, and the effects of defoliation, are greater, although they eventually fall again as growth and yield decline and the canopy becomes higher and thinner with age. The peak years for dusting are therefore approximately the 8th–15th years of the tree's life.

It seems unlikely that forecasting outbreaks of Oidium SLF will be possible to any practicably useful extent. Although weather conditions favourable to the disease are known in outline (Wastie, 1971), they must be considered in relation to the stage of maturity of the new canopy. The disease builds up rapidly—i.e. within a few days—once favourable weather coincides with susceptible leaf, and dusting must therefore begin when the leaf is at the appropriate stage of susceptibility (and if the first few mildew spots are present), irrespective of the weather. Only if continuous wet weather is experienced can Oidium safely be ignored, for under these conditions Gloeosporium SLF is likely to be of greater importance.

GLOEOSPORIUM

Whereas Oidium is confined to the immediate post-wintering period, Gloeosporium leaf disease, as well as being an important cause of SLF, occurs throughout the year, particularly in the south of the country. Only the states of Kedah and Penang regularly escape Gloeosporium SLF, because of the earlier wintering; over the rest of the country the disease is most severe in south Johore and south Perak, and to a somewhat lesser extent in Selangor and inland Negri Sembilan also (Wastie, 1971). Gloeosporium is more common than Oidium, not only because the disease is more widespread and persistent but also because almost any clone may be defoliated if weather conditions are favourable—even normally reasonably resistant clones such as PR 107 and Tjir 1. Common clones of above-average susceptibility to Gloeosporium include PB 5/63, 86, 28/59, RRIM 526, 623 and 513. Of these the first is the most susceptible, and the worst cases of defoliation may result in extensive dieback and even complete death of the tree.

The control of Gloeosporium is of potentially more widespread application than that of Oidium, but is unfortunately considerably more difficult. Prospects for the control of Gloeosporium SLF have been recently reviewed (Wastie, 1969b). Although fungicides effective against the disease are currently available, the difficulty of applying them effectively and economically militates against treatment of all but the potentially most severe defoliation. An additional difficulty lies in the fact that the period of susceptibility to Gloeosporium begins as soon as the buds begin to burst, and before individual leaflets can be clearly seen from the ground with the naked eye. Thus by the time the leaves have developed appreciably they are often too severely infected for prophylactic spraying to be effective.

Of the wide range of fungicides showing activity against Gloeosporium, the most effective are Daconil (tetrachloroisophthalonitrile) and Difolatan (captafol), though the latter is somewhat phytotoxic. The systemic fungicide Benlate (benomyl) has been found to be systemically active against Gloeosporium in nursery plants, but only when applied in large volumes of water to the soil. Bark injection is ineffective (Shepherd, pers. comm.). Watering is not feasible on a field scale and, as against Oidium, Benlate is not systemic when applied to the leaves, and acts only as a surface fungicide.

Applying low-volume spraying techniques, as used successfully in Malaysia against Phytophthora leaf fall (Wastie & Chee, 1969) has shown promise as a means of controlling Gloeosporium SLF. An aqueous suspension of the fungicide emulsified with 40% of a light spraying oil and applied with an ultra low volume sprayer has reduced the intensity of the disease on nursery plants. The phytotoxicity of the formulation necessitates a very light coverage, but makes it possible to apply quite low volumes per acre. Nevertheless, several applications throughout the period of susceptibility are necessary to obtain worthwhile control, and the method has not yet been used successfully on a field scale because of the difficulty of obtaining adequate coverage of the foliage of the whole tree.

Because of its high cost, direct control of Gloeosporium SLF cannot in general be recommended, for it is unlikely that economically worthwhile benefits will be obtained. An exception lies in severe cases of defoliation of clone PB 5/63, where dieback is likely in the absence of the expensive treatment that effective control implies. A means of ameliorating the worst effects of severe defoliation has already been recommended (Anon., 1968)—to apply a high-nitrogen fertiliser to trees with a poor canopy in order to encourage further refoliation later in the year, and to maintain growing conditions as favourable as possible.

CONTROLLED WINTERING

It has frequently been observed that in years or districts where wintering is early, or among early-wintering individual trees and clones where wintering is otherwise normal, refoliation proceeds to completion without the intervention of secondary leaf fall. This is because of the absence of inoculation at the beginning of the season, or because of weather conditions unfavourable to the fungi concerned. Rao, (these *Proceedings*) has recently indicated that an aerial application of cacodylic acid (dimethylarsinic acid) to the foliage of mature trees in January, just before wintering, induces rapid defoliation within two weeks, and is followed by an earlier refoliation than would otherwise occur. Leaf diseases are thereby largely avoided. Rao's technique was used with considerable success on several sites in Johore and Negeri Sembilan in January 1970, although the necessity of repeating at the end of the month an ineffective application made at the beginning resulted in a later refoliation than was intended. Nevertheless, Gloeosporium SLF was avoided in 1951 Tjir 1 and considerably reduced in 1959 PB 5/63, both in Johore; in Negri Sembilan Oidium SLF was considered less severe in a defoliated area of 1959 PB 5/51, although the degree of control was less than that obtained by sulphur dusting in another part of the same field.

The success of the new technique depends on several factors: the skill and experience of the aircraft pilot, the clarity with which the ground marking is carried out, the age of the trees, and the weather at the time of and immediately after spraying. Defoliation appears to be more successful with some clones than with others, and is more easily achieved in older trees, which already have a well-marked wintering cycle, than in younger, recently mature fields. As with all aerial spraying, clear marking is essential; sets of three umbrellas painted yellow and tied to the tip of bamboo poles on the flight path make suitable beacons, but have to be placed in position before the operation begins. A high wind makes spraying hazardous, and rain within a few hours of the application largely negates its effect (Rao, pers. comm.). Finally, unless complete or near complete defoliation is achieved, refoliation occurs no earlier. Partial defoliation is ineffective at hastening natural wintering.

Compared with direct treatment of SLF, avoiding it by hastening the onset of refoliation has several advantages. The technique is particularly useful for fields susceptible to Gloeosporium SLF, for which no easy alternative treatment is yet available. Since Gloeosporium SLF does not usually occur until after mid-March, defoliating in early January allows ample time for healthy refoliation to take place. Oidium, since it occurs earlier, may not be so easily avoided. The quantity of cacodylic acid which has been used—1.3 lb per acre applied as 4 gallons per acre of 10% Phytar 560—cost \$7.20 per acre in 1970. The cost of application varies with the distance of the sprayed site from the loading point, but approximates to \$5/- per acre (excluding the cost of the initial positioning of the aircraft). The overall cost of the operation therefore lies between \$12–18 per acre, which is competitive with 5–6 rounds of sulphur dusting and probably cheaper than several rounds of prophylactic spraying against Gloeosporium. The disadvantages of artificial defoliation, as presently practised, are that the defoliant must be applied from the air during a very short period of the year, and that a large measure of ground support and co-ordination must be provided. These disadvantages could be overcome if ground-based methods of application were available, although coverage, and hence defoliation, are likely to be insufficient with one application unless a systemic defoliant were used. The effects of such a product, however, might be too drastic—as is, for example, the n-butyl ester of 2,4,5-T, which has been used in the past for defoliating rubber trees (Hutchison, 1958).

CONCLUSIONS

The flexibility and cheapness of sulphur dusting make it likely to remain the preferred method of controlling Oidium SLF where relatively small acreages are involved. Gloeosporium SLF cannot be similarly prevented as easily and economically, for dusting is ineffective and more sophisticated and expensive fungicides and carriers are needed to obtain satisfactory coverage and control.

Hastening the onset of refoliation by defoliating the old leaves with an aerially-applied contact herbicide in January is a promising means of avoiding secondary leaf fall. Further research on the optimum time of treatment and alternative methods of application are needed.

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DISCUSSION

Chairman: P. de Jonge

Chandapillai: We have tried Benlate for the control of Gloeosporium secondary leaf fall, and it shows some promise. Virgin bark thickness was appreciably better in the two 5-acre treated plots than the control.

Locke: With regard to the water/oil emulsion to which you referred, have you found all oils phytotoxic?

Wastie: In our experience all oils are phytotoxic to some extent, as are emulsifiers used to prepare oil/water suspensions.

Chairman: What is the explanation of the yield falling to below control level after dusting the PB 5/51 block?

Mainstone: The refoliation after dusting was excellent, but untreated plots suffered firstly from *Oidium* and subsequently from *Gloeosporium*, mites and thrips, and did not develop a satisfactory canopy until September. At this time he dusted trees carried very heavy canopies, and went into a period of secondary wintering. I think the improved canopy towards the end of the year in the control plots and the secondary wintering of the dusted trees accounts for the difference in yield pattern.

I would like to make another comment in relation to the pattern of wintering. If the trees have a uniformly good refoliation they will invariably carry through to the next wintering with a fairly uniform canopy. If, on the other hand, wintering is irregular, the early-wintering trees will refoliate without disease, whereas late-wintering trees will become heavily infected. The result is that in a normal commercial area a rather irregular wintering occurs when the next wintering falls due; once this irregular pattern is established it tends to be maintained for a number of years. Perhaps artificial defoliation could be used to even-up refoliation in such a situation.

CONTROLLED WINTERING OF *HEVEA BRASILIENSIS* FOR AVOIDING SECONDARY LEAF FALL

by

B. Sripathi Rao

(Presented by R. L. Wastie)

SUMMARY

The observation that early wintering clones, and areas where an early dry period triggers early wintering, generally escape secondary leaf fall suggested an indirect approach to control of this disease—inducing early and uniform wintering by artificial defoliation.

Trials conducted during three seasons showed that a correctly timed application of 1½ lb cacodylic acid per acre from the air achieves this. The refoliation that follows is consequently brought forward to coincide with the dry period, and is completed before the onset of wet weather favourable to the two fungi mainly responsible for the disease—*Oidium heveae* and *Colletotrichum gloeosporioides.*

The natural defoliation of senescent leaves taking place annually in the rubber tree, *Hevea brasiliensis*, from about the fifth year of growth is commonly referred to as wintering. Occurring during dry weather that generally prevails in most parts of West Malaysia in February, its exact period and intensity vary between different clones, and between different regions, being a little earlier in the north and a little later in the south.

Depending upon the speed and completeness of wintering, the pattern of refoliation that follows may vary considerably—early or late, rapid or gradual, complete or incomplete. The young leaves that unfold are highly susceptible to attack by two fungi, *Colletotrichum gloeosporioides* Penz. and *Oidium heveae* Steinm., the yellow mite *Hemitarsonemus latus* Banks and the thrips *Scirtothrips dorsalis* Hood, which cause defoliation, either alone or in combination. The large amount of susceptible foliage which develops during refoliation enables the pathogens to build up to epidemic proportions, and to cause a rapid and extensive defoliation of developing leaflets. Known as secondary leaf fall (SLF), this is the most important leaf disease complex of *Hevea* in Malaysia (Anon., 1970). It is particularly severe on certain high-yielding modern clones with a high susceptibility to one or other of the two fungi chiefly responsible for the disease.

Infrequent showers of short duration during otherwise dry weather favour *O. heveae;* it is therefore the first disease to develop and is the main cause of leaf fall during the immediate post-wintering period (Anon., 1966). *C. gloeosporioides*, on the other hand, is favoured by long periods of high humidity, and usually develops during the wetter weather which commences in mid-March or April (Anon., 1968). The malady therefore acquires importance when wintering is gradual or late.

Secondary leaf fall is difficult to control, because the trees on which it occurs are 30–100 ft. tall. The repeated application of prophylactic pesticides during the susceptible stage of the foliage is a difficult and expensive undertaking. Treatment has proved economically beneficial only with *O. heveae*, which can be controlled by four or five applications of sulphur dust from power dusters (Wastie & Mainstone, 1969). Fungicides effective against *C. gloeosporioides*, on the other hand, have to be sprayed; unfortunately no suitable ground equipment with sufficient manoevrability in the uneven terrain of our plantations, and at the same time able to spray to sufficient height, is available. Aerial spraying has proved uneconomic because of the need for repeated applications.

Early-wintering clones and areas where wintering occurs early generally escape severe SLF (Ho *et al.*, 1969). If the onset of wintering could be hastened by spraying a chemical defoliant, an earlier refoliation, avoiding SLF, is possible.

CHOICE OF DEFOLIANT

Two types of chemical are available for inducing artificial defoliation—the synthetic auxins such as 2, 4, 5-T, which are absorbed and translocated in the leaf tissues to bring about premature abscission, and the contact toxicants or desiccants that act by causing rapid loss of water by evaporation (Osborne, 1968). Defoliants of the first type have the disadvantage of moving beyond the leaves to the bud and shoots, causing dieback. This is undesirable where the aim is to prevent damage to buds and twigs; therefore only desiccants were considered.

Three herbicides in common use in rubber cultivation—sodium chlorate, paraquat and monsodium acid methanearsonate (MSMA)—and a compound closely related to the last, dimethylarsinic acid or cacodylic acid, were chosen for initial trials on six-month old potted rubber seedlings with fully matured leaves. The foliage was sprayed with a hand sprayer, either at high-volume until run-off occurred (50 gal/acre), or low-volume (10 gal/acre), using 10 plants per treatment. Concentrations of the defoliants for high volume and low volume respectively were 2% and 10% for sodium chlorate, 0.2% and 1.0% for paraquat, 0.66% and 3.3% for MSMA and 0.33% and 1.65% for cacodylic acid. A wetting agent (0.1% Teepol) was incorporated with the first chemical. All the treatments gave complete defoliation in a week, but severe scorching of green shoots occurred with high volume applications of all the chemicals. Slight to moderate shoot damage was also observed on some of the plants sprayed at the lower rate with sodium chlorate and paraquat. Low volume applications of MSMA and cacodylic acid caused no damage to the seedlings apart from the foliage.

A growth regulating substance, 2-chloroethyl phosphonic acid (ethephon), was also tested for its defoliant action on *Hevea*, spraying 0.25%, 0.5%, 0.75% and 1.0% concentrations at low volume on the foliage of two-year-old plants in a nursery, treating five plants with each dosage. Complete defoliation was only achieved with the highest concentration, but was accompanied by some slight dieback of green shoots.

Cacodylic acid and MSMA were chosen for aerial spraying trials in the field.

AERIAL SPRAYING TRIALS

The trials were conducted in a field of 20-year-old trees on the Institute's Experiment Station, spraying the defoliants from a Piper Pawnee–235 just prior to wintering in January 1968, 1969 and 1970. Two adjacent tree rows, 60 ft apart and 1 200 ft long, separated from the next treatment by a guard row, were sprayed with a concentration double that used for low volume spraying in the screening tests, at the rate of 4 gal per acre. Spraying was done between 7 and 8 a.m. to prevent any loss due to drift or evaporation.

Trial 1 Two plots were spıayed respectively with $1\frac{1}{3}$ lb cacodylic acid and $2\frac{2}{3}$ lb MSMA per acre on 21st January 1968. The percentage defoliation was assessed separately on the five clones planted in the field, by making visual observations at twenty points at random while walking along the interrows between the treated rows. Observations were made one and two weeks after the treatments. The results are illustrated in *Fig. 1*.

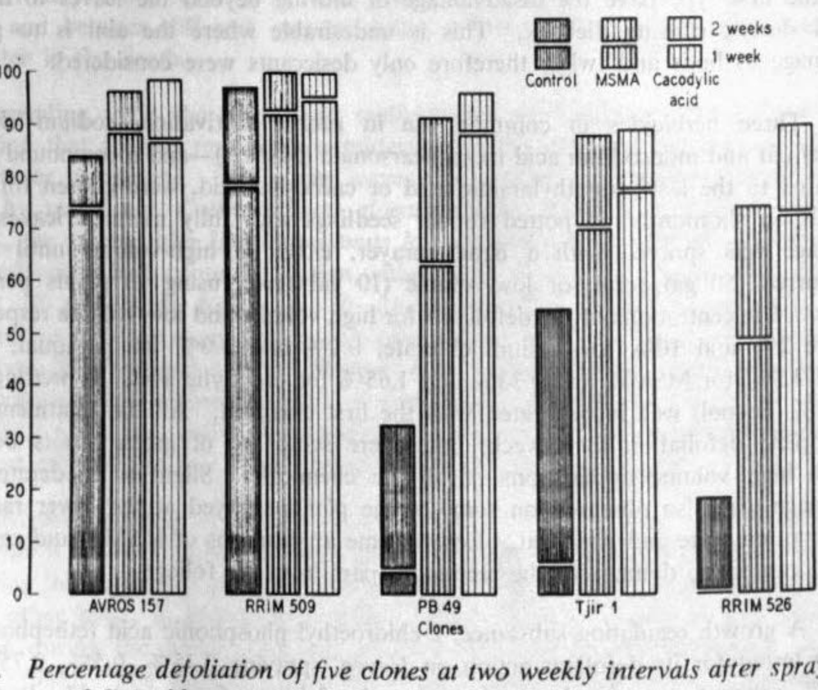

Fig. 1. Percentage defoliation of five clones at two weekly intervals after spraying cacodylic acid

The extent of leaf fall in the untreated control rows indicated that wintering was already in progress in AVROS 157 and RRIM 509 at the time of spraying, the treatments helping but little to complete the process. The effect of the defoliants was very marked, however, on PB 49 and RRIM 526, and slightly less so on Tjir 1; the superiority of cacodylic acid over MSMA was clearly evident, especially in the first week's results. Subsequent leaf fall was somewhat confounded with natural wintering. There were no signs of twig dieback in either treatment.

Trial 2 In 1969 the trees were sprayed on 4th January, well before any signs of wintering became evident. Three doses of cacodylic acid were applied in four treatments—$1\frac{1}{3}$ lb per acre in two plots, 1 lb in the third, and $\frac{2}{3}$ lb in the fourth, followed in the last two and one of the first two plots by a second application of $\frac{2}{3}$ lb after two weeks. Defoliation was estimated from the number of fallen leaves collected in five 4 sq. yd wire-net enclosures placed at random in the interrows between each pair of treated rows. Leaves were collected two weeks after the first application and at fortnightly intervals subsequently.

All three rates of application resulted in extensive defoliation two weeks after the treatment, becoming almost complete after a further two weeks (*Figs. 2 & 3*); only on a few lower shoots and small trees shaded by large ones was some foliage retained. There was no significant difference between the effects of the three dosage rates; the slight superiority of the double treatments disappeared before the third sampling (*Fig. 4*).

Fig. 2. Aerial view of pairs of treated rows, separated by guard rows, ten days after spraying cacodylic acid

Fig. 3. A defoliated row in contrast to the guard row four weeks after spraying cacodylic acid

Refoliation commenced at the end of January on scattered trees in the treated plots, becoming more widespread and general during early February, when trees in the control plot were only starting to show scattered patches of leaf discoloration on exposed shoots. Refoliation was complete, with the foliage hardened beyond the stage of susceptibility to the two leaf diseases, by mid-February, when the untreated plot showed sparse and uneven wintering which extended, together with refoliation, into March.

Leaf counts were continued at weekly intervals during March and April, when the slowly-refoliating untreated plot suffered a fairly severe attack of *C. gloeosporioides*, resulting in moderate leaf fall. The foliage in the treated rows was by then resistant to the disease. This was confirmed by the striking difference in the number of diseased leaflets falling into the cages (*Fig. 4*).

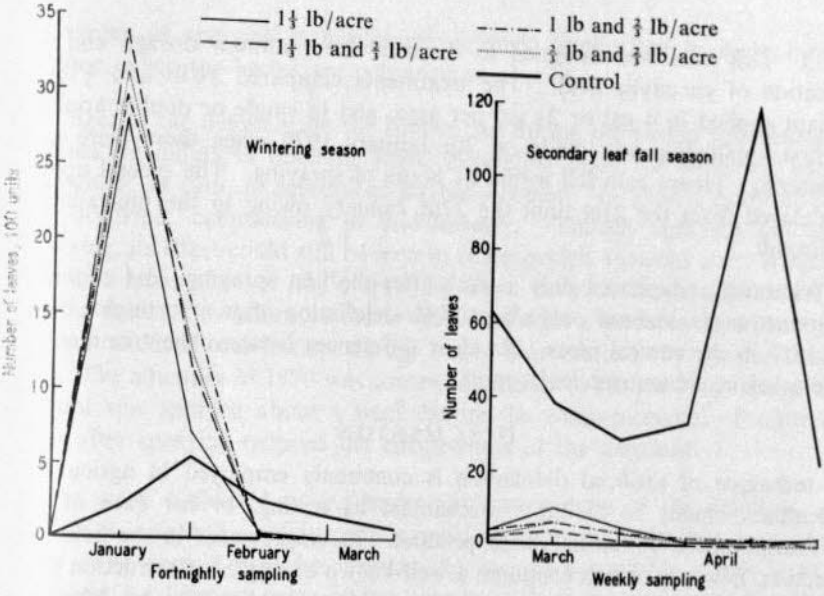

Fig. 4. Average leaf count in 4 sq. yd quadrats under trees sprayed with cacodylic acid

The marked difference in the thickness and colour of the canopy between the artificially defoliated and control plots persisted throughout the year (*Fig. 5*).

Fig. 5. Two artificially defoliated tree rows, each adjacent to a guard row, showing the difference in canopy density after refoliation

Trial 3 This trial was designed to discover the optimum dosage and rate of application of cacodylic acid. The treatments compared $1\frac{1}{3}$ lb and $\frac{2}{3}$ lb of the defoliant applied in 4 gal or $2\frac{1}{2}$ gal per acre, and in single or double applications. The first application was made on 7th January 1970 when there were no signs of wintering. Heavy rain fell within 24 hours of spraying. The second application was delayed from the 21st until the 27th January owing to the unavailability of the aircraft.

Wintering commenced only a week after the first spraying; leaf counts, made in wire-net cages, showed only about 60% defoliation after a fortnight, compared with 15% in the control plots. No clear differences between the treatments could be detected in subsequent leaf counts.

DISCUSSION

The technique of artificial defoliation is commonly employed in agriculture and horticulture, chiefly to facilitate mechanical harvesting, or for ease of packing and transportation of the harvested product. Its employment in the field of plant protection, however, is less common; a well-known example is destruction of potato haulms just prior to harvesting to prevent infection of tubers by *Phytophthora infestans* (Wilson *et al.*, 1947). Contact desiccants are preferred, as it is undesirable to have the chemical translocated and accumulated in the harvested product.

Artificial defoliation by chemicals was first considered for plant protection in rubber in Malaysia when Altson (1950) drew attention to the serious consequences which would result if South American leaf blight, caused by *Microcyclus* (*Dothidella*) *ulei* P. Henn. were to spread out of the neotropics where it is at present confined. Should measures to keep out the disease fail, Altson suggested eradicating it by a rapid and complete defoliation of trees within and surrounding the outbreak area, thus destroying the disease with the foliage. Hutchison (1958) found 5% n-butyl ester of 2,4,5-T, aerially sprayed in three gallons of gas oil per acre, to result in rapid defoliation.

The idea of using a similar technique for disease avoidance in *Hevea* was prompted by the desirability of manipulating the time of the natural wintering process of the tree, which is closely associated with the occurrence and intensity of SLF. Inducement of an earlier and more complete wintering by artificial means, so that the refoliation that follows is brought forward to coincide with dry weather when the two fungi mainly responsible for the disease are not active, appeared attractive. The disease is avoided if refoliation is completed before the onset of the wetter weather.

Cacodylic acid has proved to be an effective and safe defoliant for use on *Hevea*. Defoliated trees showed no evidence of twig dieback. Further, its low mammalian toxicity—1 350 mg/kg acute oral LD 50 to rats—makes it suitable for aerial application. Applied at the rate of $1\frac{1}{3}$ lb/acre in 4 gal of water, the treatment is inexpensive, the chemical costing about $8/- per acre.

The timing of spraying is important: a single application in early January would suffice, when the leaves are preparing to absciss.

The effect of the defoliant on the rubber tree during the period just before the wintering season differs in different years, depending upon the wintering pattern that year which, in turn, is determined by the weather. In 1968 a fairly uniform wintering occurred, commencing in mid-January. Though spraying was done after wintering, its effect could still be seen in clones which wintered late. Wintering was slow and incomplete in 1969; spraying done early in January benefited all clones in the field. This indicated that even clones with a tendency to winter early benefit from artificial defoliation during years characterised by partial uneven wintering. The situation in 1970 was somewhat similar to that in 1968, except that the defoliant was sprayed about a week before the commencement of wintering. Rain soon after spraying reduced the effectiveness of the defoliant.

Further work is needed to test lower application rates of the defoliant, and to determine if a second application is needed in fields with the tree rows closer than 60 ft. The correct time for treating the various susceptible clones is likely to be different in different parts of the country. A thorough knowledge of the local climate and wintering behaviour of these clones is therefore a prerequisite for successful use of the technique.

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DISCUSSION

Chairman: P. de Jonge

Chairman: Are the hormone-type defoliants safe for use at low concentrations?

Wastie: Although a hormone-type herbicide might well work there are certainly hazards attached to their application.

Chairman: In Hutchison's defoliation experiments the concentrations used were 2½% and 5% of 2,4,5-T in diesel fuel. That indeed looks a pretty harsh treatment.

Wastie: It might be possible to mix 2,4,5-T with a contact herbicide like potassium iodide or Phytar 560. More work needs to be done to find the best defoliant.

Chairman: A low concentration of either 2,4-D or 2,4,5-T might both assist defoliation and also, by its stimulating effect, increase yield.

Cates: Why was there no drift of defoliant from sprayed to unsprayed tree rows?

Wastie: The rows were 60 ft apart so it was easy to spray only one tree row at a time. The application was made fairly early in the morning, when there was very little danger of drift.

Gillbanks: I am interested in the side-effects of this accelerated wintering. As well as a better canopy in the following year, an increased bark thickness and possibly increased girthing were mentioned. How large would you expect these side effects to be? They would presumably have long-term beneficial effects on the trees.

Wastie: This is best answered by analogy with the side-benefits derived from the better canopy obtained in a sulphur dusting experiment we carried out in co-operation with Dunlop.

Mainstone: We have been carrying out sulphur dusting now for a number of years commercially and we are finding that the yield trends in our PB 5/51 areas are becoming very much more akin to the type of yields that one gets in clone trials where, because of small plot size, *Oidium* does not build up. Yields have improved from 1 500 lb/acre to over 2 000 lb/acre, and bark renewal is also better.

Nowak: How does defoliation affect yield? I presume it drops rapidly with the fall of leaves, but how is the normal increase in yield following wintering affected?

Wastie: Since the sudden enforced wintering hastens refoliation, the yield picks up again that much quicker; overall it is likely that a slightly higher yield will be obtained compared with normal wintering fields.

Chairman: The effects on yield are rather difficult to measure in aerial spraying experiments. Plot sizes are very large and experimentation is therefore difficult.

CHEMICAL CONTROL OF PANEL DISEASES OF *HEVEA BRASILIENSIS*

by

K.H. Chee

SUMMARY

In a rapid and simple screening test of fungicides for the control of black stripe of *Hevea brasiliensis*, trees were inoculated by stapling to the tapping panel a polythene sleeve containing the pathogen grown on polyurethane foam.

Among 20 fungicides tested, organo-mercurials (0.5% Antimucin WBR, 0.5% LPF XXI and 5% Kroma-clor), captafol (2% Difolatan), drazoxolon (1.0% Mil-col) and cycloheximide (0.5% Acti-dione) were effective against black stripe when applied after every tapping.

Mouldy rot was controlled with two weekly applications of benomyl (0.5% Benlate), 0.5% Acti-dione and 2% Difolatan. Antimucin WBR and Fylomac 90 (tetradecyl pyridinium bromide) at 0.25% and 0.28% concentrations respectively were only effective with more frequent applications. Antimucin WBR gave somewhat better control of mouldy rot than Fylomac 90.

Mineral oils, vegetable oils, sticking agents and a detergent used as adjuvants to the fungicides had little beneficial effect.

INTRODUCTION

The two tapping panel diseases of *Hevea brasiliensis*, mouldy rot (*Fig. 1*) caused by *Ceratocystis fimbriata* Ell. & Halst and black stripe (*Figs. 2 & 3*) caused by *Phytophthora palmivora* (Butl.) Butl., damage the tapping panel during wet weather or periods of prolonged high humidity. The diseases are economically important because they invade bark exposed by tapping and kill the cambium. A slight infection may heal with no ill effects, but a heavy infection prevents normal bark regeneration; at best the renewing bark is then rough and gnarled and difficult to re-tap; at worst, big wounds exposing the wood render subsequent tapping impossible.

Mouldy rot was a problem during the period of rehabilitation after the war, but is less important now that undergrowth is controlled, stands are properly thinned, and effective fungicides used. The disease is now generally confined to shaded or swampy ravines and low-lying areas. Black stripe, on the other hand, was until recently rarely encountered, but with the planting of large acreages of high yielding susceptible clones it appears to be on the increase, particularly during the rainy season, in the states of Perak, Kelantan and Kedah. Outbreaks of Phytophthora leaf fall in the latter two states have also resulted in severe black stripe, for the spores of the fungus wash down the trunk from the canopy and infect the panel.

MATERIALS AND METHODS

More than 60 fungicides have been screened in the laboratory to assess their inhibition of *P. palmivora* and *C. fimbriata* in agar culture. Those which showed promise were tested under field conditions.

Black stripe

Naturally infected trees of the highly susceptible clones PB 86, PR 107, RRIM 600 and RRIM 605 were used for the experiments; to accelerate screening tests artificially inoculated trees in the Institute's experiment station were also utilised. A rapid method of artificial inoculation was developed in which the fungus was grown in a 6 cm square polyurethane foam pad impregnated with pea extract agar. After incubation at 27°C for two weeks, the pad was inserted in a flattened 5 cm diameter polythene sleeve 15 cm long, with an opening 4 cm square cut in the centre on one side to expose the fungal colony (*Fig. 4*). The polythene cover was then stapled at each end just above the upper end of the tapping cut (*Fig. 5*). Infection of the entire panel by sporangia released from the inoculum took place after three to four weeks.

This method of inoculation has the advantages that the sleeve can be labelled before taking it into the field, thus obviating the necessity of marking the trees; it does not obstruct the tapping operation, the inoculum is light and easily portable, and can rapidly be fixed in place by one man. Stapling has no harmful effect on the bark.

Under natural conditions, or even with artificial inoculation, uniform infections of black stripe seldom occur; diseased trees were therefore allotted at random to the various fungicidal treatments. Fungicides were brushed on the tapping panel in a band 3 in. above and 1 in. below the tapping cut, at either alternate-daily or at weekly intervals, allowing about 18 applications in the alternate-daily treatments and 6 applications in the weekly treatments. Each treatment consisted of not less than 20 trees and was repeated at least once. Assessments of the progress of infection were made once before treatment and then weekly for six weeks, the final results being the means of the weekly scores. Trees no longer infected were scored 0, slightly infected (few small shallow depressions) 1, moderately infected (one to five distinct stripes) 2, severely infected (>five stripes) 3, and very severely infected (fissures coalesced, bark rotting) 4. The number of trees in each infection category was multiplied by its score; the difference before and after treatment allowed the percentage reduction in disease severity to be calculated and compared with untreated trees.

Mouldy rot

The method of screening fungicides against mouldy rot was essentially the same as that for black stripe, but only naturally infected trees were used, and the

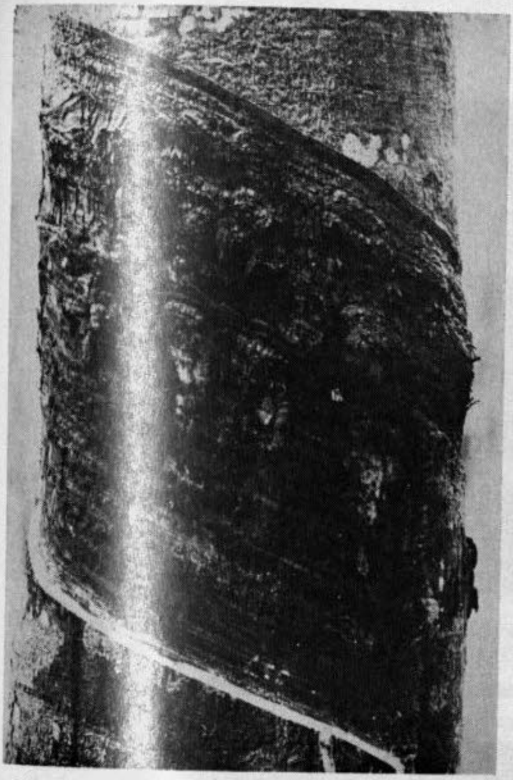

Fig. 1. Mouldy rot, showing big wounds exposing the wood

Fig. 2. A severe infection of black stripe, showing vertical fissures and bleeding

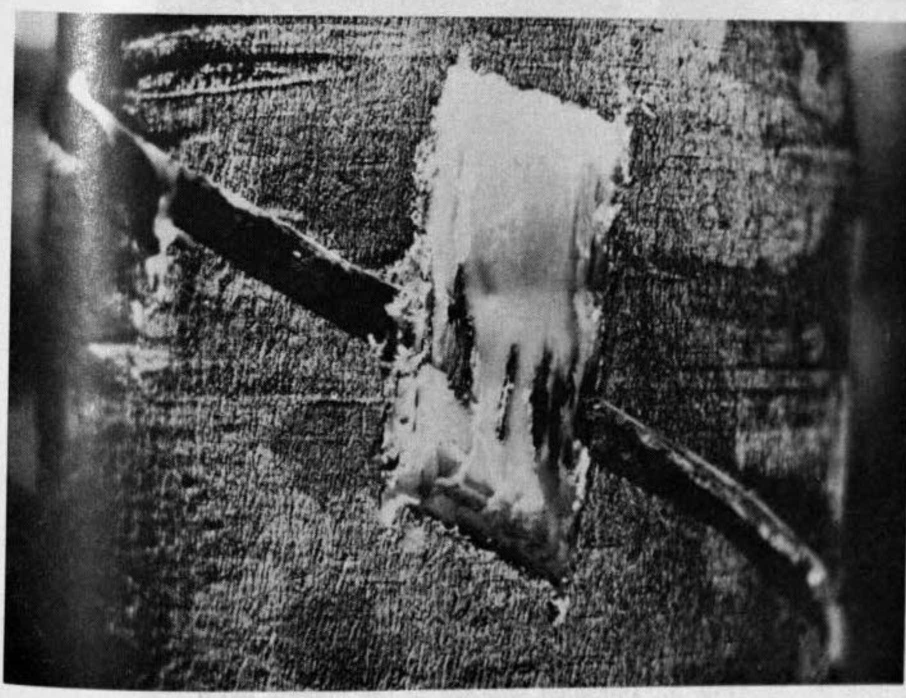

Fig. 3. Black stripe on a newly opened panel. A piece of bark has been removed to show the stripes on the wood

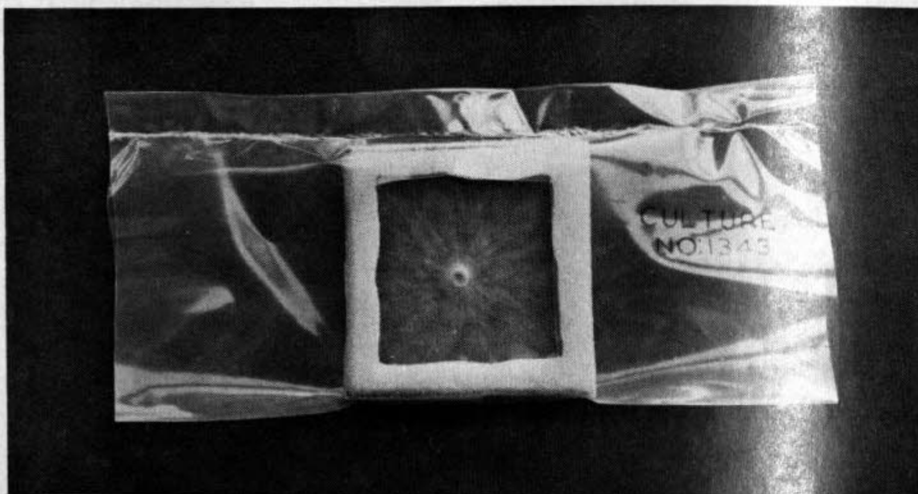

Fig. 4. Fungal inoculum growing on a polyurethane foam rubber pad inside a polythene sleeve

Fig. 5. Inoculum attached to the tapping panel

treatments continued for only two weeks, allowing six applications in the alternate-daily treatments and two applications in the weekly treatments. The results were assessed as with black stripe, by scoring on individual trees the degree of control as shown by the severity of the residual infection.

Adjuvants were added to some fungicides in an attempt to facilitate penetration and retention of the active ingredients in the bark. Products tested included a detergent (Nonidet P. 40), mineral oils (Prorex, BP 85 spraying oil) vegetable oils (palm oil, coconut oil) and sticking agents (Shell panel dressing, Flintkote type 3, Otina C, Mobilcer A and M, Stikvel).

RESULTS AND DISCUSSION

It is apparent from Table 1 that 0.5% dilutions of the organo-mercurial fungicides Antimucin WBR, LPF XXI and 5% Kroma-clor were effective in controlling black stripe when applied after every tapping. Other effective fungicides were captafol (2% Difolatan), drazoxolon (1.0% Mil-col) and cycloheximide (0.5% Acti-dione). Complete control of the disease seldom occurred and a maximum 65% reduction in severity was the best that could be achieved with severe infection.

None of the adjuvants significantly improved the degree of control. No systemic action was noticed with any of the fungicides. In general it appears that a liquid formulation is more suitable against black stripe than a wettable powder: Antimucin WBR and LPF XXI (liquid) were effective but not Verdasan (a wettable powder organo-mercurial). Kroma-clor, however, is a wettable powder containing, apart from an organo-mercurial compound, four other active ingredients, which may give it additional potency. Its effectiveness could also be due to the higher concentration used. The 'flowable' formulation of Difolatan gave better control than the wettable powder at the same dilution, although containing about half the amount of active ingredient. The liquid formulation is probably a better bark penetrant.

Of the fungicides tested against mouldy rot, 0.25% Antimucin WBR, 2% Difolatan, 0.5% Benlate (benomyl) and 0.5% Acti-dione (cycloheximide) gave better control than 0.28% Fylomac 90 (tetradecyl pyridinium bromide). The systemic fungicide Benlate eliminated the disease with two applications at weekly intervals. Control was also good with the antibiotic Acti-dione and Difolatan. Antimucin WBR and Fylomac 90 gave good control only when applied after each tapping, the latter being slightly less effective than the former.

Since Acti-dione, Difolatan and Antimucin WBR all control mouldy rot as well as black stripe, they are therefore suitable for use in areas where both diseases occur. The considerably lower mammalian toxicity of Acti-dione and Difolatan however makes them the preferred fungicides.

The present study suggests that by regular applications of a suitable fungicide mouldy rot can be eliminated, and black stripe kept under control, while tapping continues. It is now possible to achieve good control of mouldy rot with weekly applications of newer fungicides such as Benlate and Difolatan, but with black stripe application after every tapping is necessary. The prospect of reducing the frequency of application must therefore await the development of a systemic fungicide which can penetrate the bark, or a formulation of a surface fungicide which would adhere to the panel and yet release the active ingredient slowly. A rate high enough for adequate fungicidal action, but low enough to give a reasonable persistence on the panel and to avoid phytotoxicity, is the objective.

Table 1. Fungicides and adjuvants tested against black stripe

A. The following fungicides gave good control (65% and above) applied after every alternate-daily tapping:

Antimucin WBR (phenyl mercuric dinaphthylmethane disulphonate), 0.5%
LPF XXI (organo-mercury), 0.5%
Difolatan 80 w.p. (captatol), 2%, 5%
Difolatan 4 flowable, 2%, 5%
Mil-col (drazoxolon), 1.0%
Acti-dione (cycloheximide), 0.5%, 1.25%
Kroma-clor (mercuric dimethyldithiocarbamate + potassium chromate + cadmium succinate + malachite green + auramine), 5%.

B. The following fungicides gave satisfactory control (64–55%) applied after every alternate-daily tapping:

Antimucin WBR, 0.25%
Difolatan 80 w.p., 1%
Du-ter (triphenyl tin hydroxide), 0.3%, 1%
Du-ter, 0.3% + Nonidet P. 40, 1%
Du-ter, 0.3% + Stikvel, 1%
Phaltan (folpet), 2%.

C. The following fungicides gave poor control (54% and below) applied after every alternate-daily tapping:

Verdasan (phenyl mercury acetate), 1%
Du-phar 61242* (organo-tin), 1%
Hoechst 6006 (organo-tin), 1%
Brestan 60* (triphenyl tin acetate), 0.5%
Demosan (chloroneb), 0.5%
Brunosol TC (o-phenyl-phenol), 20%
Fylomac 90 (tetradecyl pyridinium bromide), 0.28%
8-hydroxyquinoline, 0.15%.

D. The following fungicides have shown promise when applied at weekly intervals:

K 905 (a zinc fungicide in spindle oil), diluted to 5% in coconut oil.

Tectal T 10 (zinc naphthenate), diluted to 1% in palm oil. This formulation shows promise as a prophylactic applied weekly below the tapping cut.

E. The following fungicides, with or without adjuvants, gave poor control (54% and below) applied at weekly intervals:

Antimucin WBR, 0.5%; 0.5% in Shell panel dressing, Flintkote type 3, palm oil, Otina C, or 1% Mobilcer A or M.

Du-ter, 0.3% in Shell panel dressing, Flintkote type 3, palm oil, Otina C, rubber latex, or Mobilcer A or M.

Difolatan, 10%; 5% + Nonidet P. 40, 1%.

Nectryl (o-phenyl-phenol), undiluted*, 50%*; 10% and 20% in Prorex*, BP 85 spraying oil*, palm oil and coconut oil.

RE 433 (a zinc fungicide in petroleum distillate), 5% in coconut oil.

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* Phytotoxic to bark.

DISCUSSION

Chairman: P. de Jonge

Barnes: In your study of black stripe have you encountered any associated typical symptoms of the disease, such as bark necrosis above or below the panel?

Chee: *Phytopthora palmivora* can cause different symptoms on different clones; for example, the same strain can damage the bark in patches instead of vertical stripes.

Barnes: In North Sumatra, in the 1960s, we had very severe infection, which appeared to be a clonal characteristic. Abnormal *Phytopthora* infections sometimes occurred at the base of the tree, and reached up almost to the first branches. Have you seen this in Malaysia?

Chee: We have encountered cases of infection at the collar and on the virgin bark below the cut, but we have not been able to pin-point the cause. In the literature this has been called patch canker, and is supposed to be caused by *Phytopthora palmivora* or *Pythium*. We have not been able to prove this in Malaysia. In Indonesia, very often both mouldy rot and black stripe occur on the same panel, giving an unusual sort of symptom.

Turner: The sort of lesions which Dr. Barnes was referring to also occur in South Thailand, in the very heavy rainfall areas.

Although you state that fungicidal bark dressings containing Antimucin are ineffective, in high rainfall areas (*e.g.* Trong) they give satisfactory control. A formulation giving a steady release of the fungicide would be of great benefit. Perhaps this would only work in a very high rainfall area, and not at Sungei Buloh.

Chee: I know of planters who have been experimenting with panel dressings containing Antimucin, with apparently very good results, but my own observations do not confirm this. However, I agree with you that in heavy rainfall the active ingredient can probably leach out from the dressing, thereby becoming effective.

Hartley: We have been using Benlate for a short while in the field at 0.1 gm per gallon or 0.05% concentration. We have met with similar results to those reported by Dr. Chee, and in fact on many occasions we have obtained control with one round, either sprayed or painted, though we would prefer to use two rounds. This gives a cost per 550 panel task of about $2.40 for the two rounds.

Chee: The reason that I used 0.5% was that it was the most promising of various concentrations tested in the laboratory.

Vehmendahl: Is it true that Antimucin gives rather a strange reaction when Ethrel is later used on the panel?

Chee: Yes. We have applied Antimucin, Acti-dione, Benlate and Difolatan on clones PR 107 and PB 86, followed by Ethrel. Results with Benlate and Acti-dione are not conclusive, but with Antimucin, some panels temporarily become partially dry. Difolatan had no effect.

STEM ROT OF *HEVEA* CAUSED BY *PHELLINUS NOXIUS*

by

T. M. Lim

SUMMARY

A potentially dangerous stem decay problem caused by *Phellinus noxius* (formerly known as *Fomes noxius*) in mature rubber has been observed. The disease, originating from spores infecting wounds and cut ends of unprotected branches, causes progressive dieback of the whole tree and results in the creation of infection centres for brown root disease.

Spores of *P. noxius* readily colonised slices of wood in the laboratory within 4 weeks, and freshly cut branches in the field in 12 weeks. The rate of penetration of an infected branch is 2.5 cm/month, and its downward growth along the trunk up to 86 cm/annum.

Factors predisposing trees to infection include proximity to a source of spore inoculum, a high degree of susceptibility to wind-breakage and incorrect pruning.

Laboratory and field trials indicate that 20% Izal in a bituminous carrier is effective in preventing spore invasion of cut branches.

INTRODUCTION

Phellinus noxius (Corner) Cunningham (formerly *Fomes noxius*), a wood-rotting fungus of wide distribution in the tropics, attacks trees of at least 50 genera (Commonwealth Mycological Institute, 1968), causing the disease commonly known as brown root disease. As mentioned by Petch (1921), it was first described on breadfruit from Samoa in 1875, and subsequently was recorded on tea in India and coffee in Java; it was reported on *Hevea* rubber in Ceylon and Malaysia in 1905 (Petch, 1921) and 1911 (Bancroft, 1911) respectively.

In Malaysia, brown root disease ranks third in importance as a root disease of immature rubber, following white and red root diseases caused by *Rigidoporus lignosus* and *Ganoderma pseudoferreum* respectively. However, while the latter are entirely diseases of the root so far as *Hevea* is concerned, *P. noxius* infects not only exposed surfaces of newly-felled stumps but also branch wounds (John, 1964) and can thus colonise woody tissues both above and below ground.

Infection by basidiospores of *P. noxius* of an exposed *Hevea* stump surface was first postulated in 1921 by Petch (1921) in Ceylon, and was confirmed in 1968 in Malaysia by artificial inoculation (RRIM, 1969). Sharples (1936) identified a brown wood rot in trunk forks which he attributed to spore colonisation by *P. noxius*. John (1964) reported that pruned branch stubs or the trunks of pollarded trees were liable to invasion by the fungus.

This paper provides evidence of the infectivity of the spores of *P. noxius* to *Hevea*, describes the development of the resulting stem rot and suggests means of preventing it.

INOCULATION EXPERIMENTS

Fruit bodies of *P. noxius* frequently develop on diseased rubber stumps and fallen timber. They produce an abundance of viable basidiospores which are readily dispersed by wind under suitable conditions of temperature and humidity (Hilton, 1961). Experiments were carried out to determine the infectivity of the spores. Some difficulty was initially experienced in obtaining satisfactory spore germination, but this was overcome by using a germination medium prepared from fresh rubber wood. Distilled water (4 parts) was added to wood chips (1 part), autoclaved, filtered, and the filtrate used as the germination substrate. By this means a germination rate >80 per cent was obtained, whereas in water alone it was nil.

Laboratory inoculations were made on freshly sawn wood slices 15 cm in diameter and 10 mm thick, ten of which were inoculated at the centre with 0.05 ml of an extract of fresh rubber wood containing approximately 750 000 *P. noxius* spores, and incubated in plastic boxes lined with damp blotting paper. Trees were inoculated by spraying 5 ml of spore suspension (containing 5.5×10^7 spores/ml) on the freshly sawn stub (60 cm long) of 20 branches 10–12 cm in diameter borne 3–5 m above ground. As a control, a spore-free extract was used, and uninoculated branches were enclosed in polythene bags to exclude accidental natural infection.

Colonisation took place in 70% of the wood slices within 4 weeks, and on 25% of the branch stubs in three months. In a parallel experiment in which the exposed surfaces of 20 branch stubs were left open to natural infection, with a similar number uninoculated and bagged, 15% of the exposed stubs, but none of the covered stubs, were infected one year later. The mean depth of penetration into the branch stub was 30 cm.

DEVELOPMENT OF THE DISEASE

On a pruned branch stub, decay begins at the exposed surface and spreads slowly into the stub and then into the trunk, appearing after 12–24 months as an extensive rot, which is dry and characterised by brown-coloured fungal plates. At an advanced stage of decay the wood appears as a honey-combed, friable mass. No signs of external growth of the fungus are normally visible, for the pathogen is able to colonise the stem internally, without external mycelial growth. The trunk above the point of entry of the pathogen invariably dies or breaks off (*Fig. 1*), while the fungus continues its downward growth and finally enters the collar and roots, from where root contact enables it to spread to neighbouring trees (*Fig. 2*).

The progress of stem decay in ten naturally-infected 10-yr-old trees was followed over a period of four years. The mean rate of spread down the trunk was 86 cm/year, and in three trees infection reached ground level and infected the roots of neighbouring trees 1.5 m away. Two of the diseased trees eventually carried both the resupinate and bracket-type fruit bodies of the fungus.

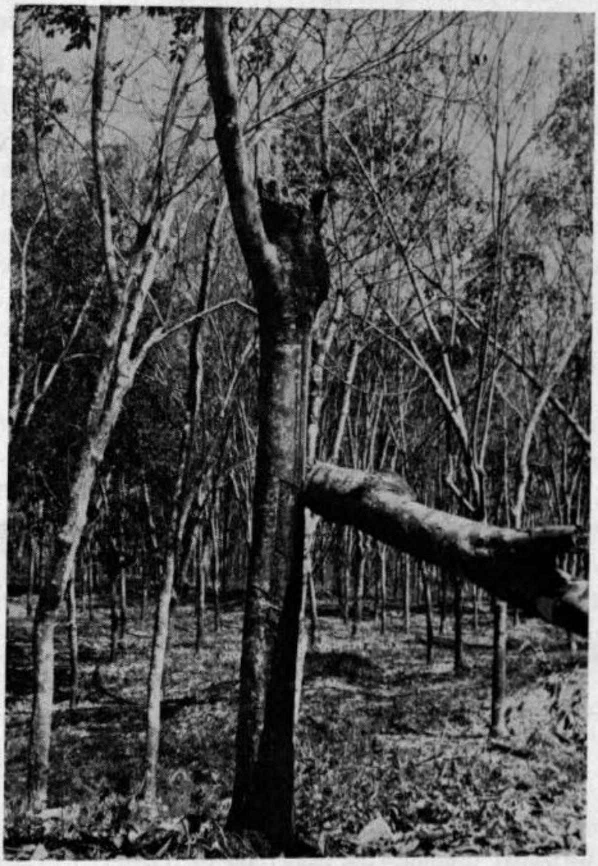


Fig. 1. An 18-yr-old tree infected by P. noxius, *which entered the fork through a pruned branch*

DISEASE INCIDENCE AND PREDISPOSING FACTORS

Field surveys have been carried out on four sites in Selangor and Malacca in order to assess the extent of *P. noxius* stem rot in mature rubber, where the sporadic occurrence of trunk snap and dieback could not be attributed entirely to wind damage or any of the known stem diseases.

Site A (Selangor) comprised a narrow belt of trees of mixed clones about 17 years old forming a roadside boundary, which had previously been pruned to prevent encroachment of the lower branches on to an overhead cable line. *Site B* (Selangor) was a field of 17-yr-old crown-budded trees which had in the past experienced wind damage. On *Site C* (Selangor), 18-yr-old RRIM 501 had been pruned about 10 years previously to reduce its susceptibility to wind damage, while *Site D* (Malacca) was a 19-yr-old field of RRIM 501 which had been extensively pruned or pollarded for the same reason.

Table 1 indicates that 10–30% of naturally wounded or pruned trees were infected with *P. noxius,* in spite of the standard wound dressing (an asphalt/kerosene mixture) having been used. At all four sites, the disease cycle (*Fig. 2*) was well entrenched, as is shown by the fact that recently-established branch infections, as well as older, deeply-penetrated stem rots, were found. At site D, a serious disease situation had developed, with 30.6% of the remaining stand being infected, including 23.1% of root infections. At site C, and particularly at site D, a high mortality rate had resulted in tapping becoming uneconomic. Both stands were therefore prematurely felled.

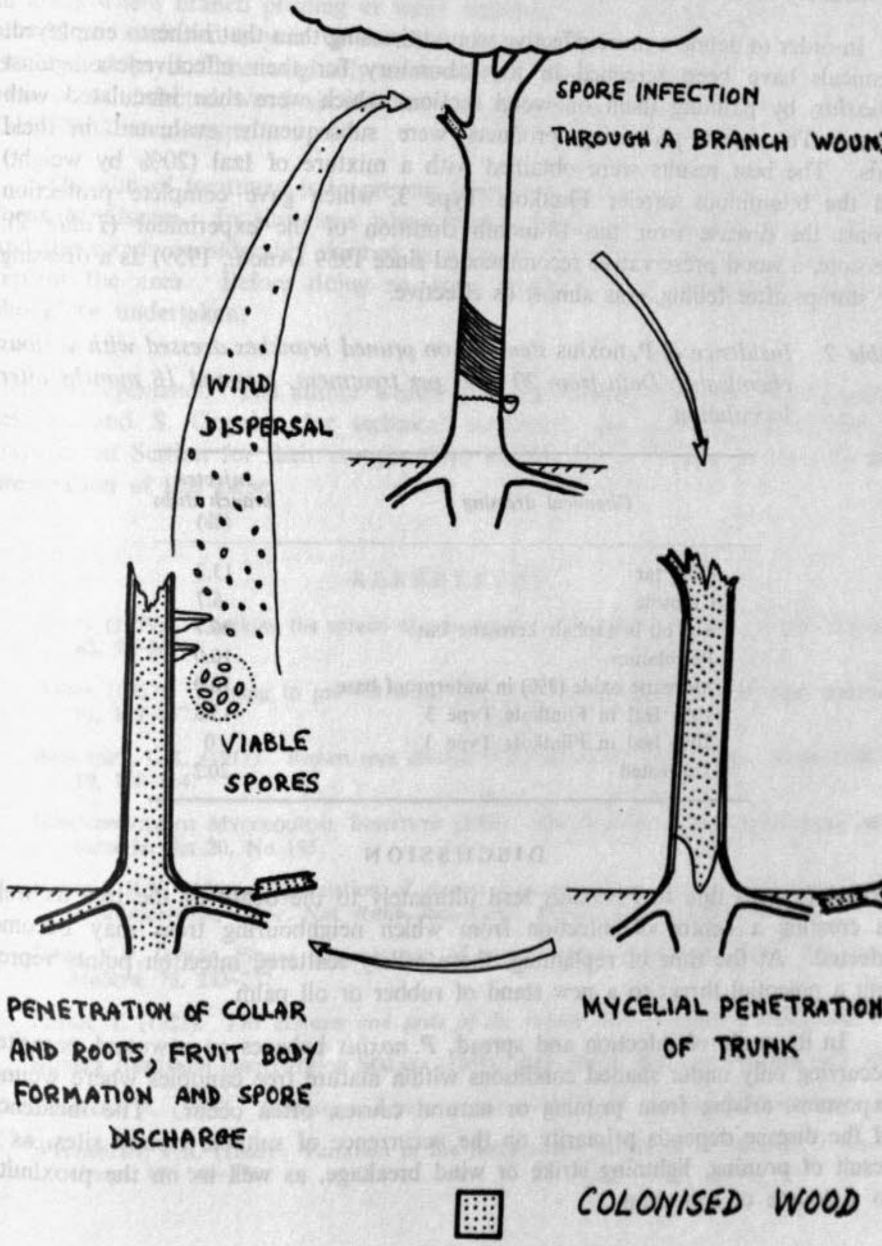
Table 1. Incidence and severity of P. noxius *stem rot on four sites*

Site*	Clone	Age (years)	No. trees inspected	Percentage of trees infected in				Infected trees (%)
				Branch	Upper trunk	Lower trunk	Collar or root	
A	Mixed	16–17	153	3.3	5.9	12.4	0	21.6
B	,,	17	90	5.6	4.4	8.9	6.7	25.6
C	RRIM 501	18	14 544	2.3	5.8	1.1	0.9	10.1
D	,,	19	3 463	1.4	2.1	4.0	23.1	30.6

* A–C = Selangor
D = Malacca

Of the common features shared by these infected sites—a history of natural wounding or corrective pruning—the clone, age of trees, and field topography are also significant in the development of the disease. While pruning or pollarding in immature areas does not constitute an immediate danger from spore infection because of the more open tree canopy, that carried out in a mature stand provides wounds under more suitable conditions for invasion by spores of the pathogen. It is significant that all the infected fields surveyed were close to jungle, from which a supply of spore inoculum of the fungus may have arisen. Local topography is important in that a greater exposure to wind results in more branch breakages. The frequency of wind damage in Selangor is above average (Wycherley, 1963), and the high incidence of trunk infections in sites A–C may well be a reflection of this.

FIG. 2 INFECTION CYCLE OF *P. NOXIUS* STEM ROT OF *HEVEA*



CONTROL

The correct treatment of pruning and other wounds is essential in order to reduce the likelihood of infection by *P. noxius*. Branches should be pruned as close as possible to the trunk, and the cut re-sawn to a smooth sloping surface and immediately dressed with a protectant chemical (Anon., 1967).

In order to define a more effective wound dressing than that hitherto employed, chemicals have been screened in the laboratory for their effectiveness against *P. noxius*, by painting them on wood sections which were then inoculated with spores. The most promising products were subsequently evaluated in field trials. The best results were obtained with a mixture of Izal (20% by weight) and the bituminous carrier Flintkote Type 3, which gave complete protection against the disease over the 18-month duration of the experiment (*Table 2*). Creosote, a wood preservative recommended since 1959 (Anon., 1959) as a dressing for stumps after felling, was almost as effective.

Table 2. Incidence of P. noxius *stem rot on pruned branches dressed with various chemicals. Data from 20 trees per treatment, assessed 18 months after inoculation*

Chemical dressing	*Infected branch stubs (%)*
Coal tar	13.3
Creosote	6.7
Tar oil in asphalt/kerosene base	26.7
Petrolatum	10.0
Mercuric oxide (3%) in waterproof base	10.0
10% Izal in Flintkote Type 3	13.3
20% Izal in Flintkote Type 3	0
Untreated	20.2

DISCUSSION

Stem infections due to *P. noxius* lead ultimately to the death of the tree as well as creating a centre of infection from which neighbouring trees may become infected. At the time of replanting, these widely scattered infection points represent a potential threat to a new stand of rubber or oil palm.

In its mode of infection and spread, *P. noxius* behaves as a wound parasite, occurring only under shaded conditions within mature tree canopies where wound exposures, arising from pruning or natural causes, often occur. The incidence of the disease depends primarily on the occurrence of suitable wound sites, as a result of pruning, lightning strike or wind breakage, as well as on the proximity to a source of inoculum.

Effective control of the disease involves surgery to eradicate established infections. New outbreaks can be avoided by preventing spore invasion by treating pruning wounds with a chemical dressing such as 20% Izal in Flintkote. Pruning should be conducted during dry weather, and all diseased timber burnt. Successful treatment depends on early detection of disease by periodic inspection rounds in areas where branch pruning or wind breakage has occurred. Such inspection should be instituted a year or so after pruning. Once the disease has become established beyond the originally infected area, extensive surgery is necessary to remove it: infected wood should be sawn off and the wound painted with the Izal/Flintkote mixture.

The aim of treatment is to prevent formation in the root system of an active focus of disease. In situations where many disease centres have been formed and the stands considerably thinned as a result, the only practicable course is to replant the area. Before doing so, total eradication of all diseased material should be undertaken.

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DISCUSSION

Chairman: R. L. Wastie

Chairman: You described how *Phellinus noxius* can spread from the trunk downwards. Have you also come across instances where the fungus spreads from the root system upwards?

Lim: No, not in my experience, although it has been reported to do so on cocoa in New Guinea.

Turner: I would agree that the importance of this fungus is widely underestimated. In oil palms, for example, it is far more serious than is usually believed, and is probably responsible for some disease attributed to *Ganoderma*.

The annual growth increment of the fungus in the tree was 86 cm; was the rate constant? In oil palm the disease takes a long time to become established but then accelerates.

Lim: The rate of spread down the trunk increases as the tree dies and it becomes less resistant to the pathogen.

Varghese: Have infections by *Ustulina* ever been found in association with *Phellinus noxius?* The two may be confused.

Lim: No. We have found only one disease occurring at a time.

Nesbit: *Phellinus noxius* enters the rubber tree through a wound, but how does it gain access to the oil palm?

Lim: Entry is believed to be through spore infections of pruned frond butts. Dr. Turner has indicated that making the pruning cut as short as possible will reduce the likelihood of such infection.

Singh: Is the lower percentage of infected trees at site C of *Table 1* due to the fact that a larger sample was examined?

Lim: At sites A and B only naturally wounded or pruned trees were examined, whereas at C and D the whole stand was surveyed. The percentage of infected trees at the first two sites might therefore be expected to be higher than at the last two.

INVESTIGATIONS ON THE SPEAR AND BUD ROT DISEASE COMPLEX OF OIL PALM SEEDLINGS IN MALAYSIA

by

George Varghese

SUMMARY

Spear and bud rot of oil palm have been known from the early days of establishment of the crop in Malaysia. The causal nature is not clearly understood, and various existing theories concerning the origin of the disease are reviewed.

The epidemic type of spear and bud rot in young palms was found to be associated with soft rot bacteria, which were pathogenic to wounded seedlings.

It is possible that the entry of the bacteria and the subsequent development of the disease are aided by species of *Fusarium* and *Thielaviopsis*, which are frequently isolated from infected palms.

The relation of adverse environmental factors and genetic make-up of the host to susceptibility is discussed, and certain measures for the control of the disease are suggested.

INTRODUCTION

A disease condition manifested by the death and disintegration of the central leaves and terminal bud of oil palm seedlings is known as the 'spear and bud rot complex'. This disease has been recorded from the early days of commercial planting of oil palm in Malaya. Sharples (1925) reported that young oil palms 2–3 years old showed 10% infection of their central leaves, but his attempts to isolate a primary pathogen were not successful. At present the cause of spear and bud rot is not clearly understood, and this account describes recent investigations into the disease complex.

REVIEW OF THE LITERATURE

In 1907, Butler isolated a pathogenic fungus from a bud-rot disease of palmyrah palm (*Borassus flabellifer*) in India, which he later named *Phytophthora palmivora* (Butler, 1910). This organism was also shown to be the primary cause of bud-rot of coconut palms (Shaw & Sundaraman, 1914). Although *P.palmivora* is now generally accepted as the pathogen responsible for bud-rot of coconut palms, the bacterial origin of the disease is also not entirely rejected (Menon & Pandalai, 1960).

Ghesquière (1935) distinguished two types of bud-rot of oil palm in Congo—one caused by *P.palmivora* and the other by bacteria which he named *Bacillus coli*. Later he suggested that insect-borne nematodes could also be associated with the disease (Ghesquière, 1939). Wardlaw made observations on the disease from 1945; he considered that a wind-borne phytopathogenic fungus, bacteria or insects could infect the bud at various stages and cause the disease. He further suggested that the 'little leaf' condition was another stage of the bud-rot disease (Wardlaw, 1948). Kovachich (1952) agreed with this, although he attributed the cause to a virus or physiological disorder. The 'little leaf' condition was also shown in the Congo to be associated with boron deficiency (Ferwerda, 1954). However, in their review of the little-leaf syndrome, Bull & Robertson (1959) doubted whether spear and bud rot-originated 'little leaf' could be associated with boron deficiency, since severe deficiency of the element in tropical soils was unlikely. In an extensive study carried out in Congo, Duff (1963) concluded that a bacterium of the genus *Erwinia* was associated with the disease, and in subsequent inoculation experiments he found that the bacterium was capable of producing spear and bud-rot symptoms in oil palms.

In Malaya, the literature on the disease is very fragmentary and disconnected. Eaton in 1922 ascribed the disease to a *Bacillus* sp. (quoted by Waterston, 1953), and Thompson in 1937 recorded *Pythium complectans* from bud-rot tissue of oil palm (Thompson & Johnston, 1953). Varghese (1962) isolated coliform bacteria and found them to be consistently associated with spear and bud-rot disease of young palms in the nursery as well as in the field. A number of pathogenic fungi were also associated with the infected tissue, including species of *Fusarium*, *Curvularia* and *Thielaviopsis*.

INVESTIGATIONS

Symptomatology

Observations on the spear and bud-rot complex of oil palm seedlings were made in three oil palm estates in Johore during 1961. The disease had occurred at high levels (the highest incidence being 17% of a one-yr-old field planting) in the nurseries as well as in field plantings. The symptoms of the disease complex are as follows (Varghese, 1962):

i. *The nursery spear-rot*. Usually seen on 6–7 month-old seedlings in the nursery. Necrosis starts as a lesion in the first leaf (the leaf immediately behind the spear) and/or on the unopened central spear leaf. The lesion may originate in the apical region or in the basal portion of the leaf, but gradually spreads over the whole leaf, infected areas of which decay. When the palm is split longitudinally through the bulb, the terminal bud is often found to be intact and free of infection. If the bud escapes infection the palm may survive.

ii. *Spear-rot of seedlings in the field*. This usually occurs in 1–2 yr-old field plantings, and the symptoms are ragged pinnae in the middle portion of the younger fronds immediately surrounding the central leaves. The fronds resemble those seen in crown disease, although without the typical bending of the petiole characteristic of the latter. The central leaves, including the first leaf and spear, also rot, as described for nursery spear-rot.

iii. *Bud-rot of seedlings in the nursery and field*. This is distinguished from the former two syndromes in that the terminal bud and the succulent tissue below become infected. In the final stages of the disease all succulent tissue inside the bulb is destroyed and the palm eventually dies. Infections occur in the nursery as well as in field plantings, usually in a 1–2 yr-old stand.

Aetiology

In a study of the aetiology of the disease, over 50 isolations were carried out from infected seedlings collected during 1961. The microorganisms isolated are summarised in *Table 1*.

Table 1. Microorganisms isolated from infected seedlings from three estates in Johore

Micro-organism	*Spear*	*First leaf*	*Surrounding fronds*	*Bud and succulent tissue*
*Coliform, gram-negative bacteria	+	+		+
Mixed bacteria	+	+	+	+
Myxomycetes (*Stemonites*)	+		+	+
**Pythium* sp.	+		+	
Mucor sp.		+		
**Fusarium* sp.	+	+	+	+
**Thielaviopsis* sp.			+	+
**Curvularia* sp.		+	+	
Botryodiplodia sp.			+	
Nematodes	+			

* Recorded pathogens of *Elaeis guineensis*.

Coliform gram-negative bacteria, similar to soft rot bacteria (*Erwinia*) were the organisms most frequently isolated from an infected spear, first leaf or bud tissue. Other pathogenic organisms included fungi belonging to the genera *Pythium, Fusarium, Curvularia* and *Thielaviopsis*. Among these, *Fusarium* spp. were most commonly isolated from infected parts of the spear, first leaf, frond bases and margins of bud-rot tissue.

Unwounded spears and central leaves of 6-month-old seedlings, inoculated by a suspension of pure cultures of the coliform bacteria, did not become infected.

In 1965 a second series of isolations was carried out to isolate the soft rot bacteria, following the findings of Duff (1963), who had successfully reproduced symptoms in inoculation trials. Bacterial colonies isolated from marginal tissue were plated on a two-layered selective medium with pectate gel as the upper layer, as recommended by Paton (1959) for separating soft rot coliform bacteria. Six bacterial isolates of differing pectinolytic ability were selected for inoculation tests.

One-year-old potted seedlings in insect-proof wire cages were inoculated with an aqueous suspension of the bacteria applied to the spear and bulb region of the plant, and also by inserting sterilized cotton buds dipped in the inoculum in wounds made at the base of the spear. In the latter inoculation two of the isolates produced spear infection, but the others were unsuccessful. Although the necrosis and rotting resulting from the successful inoculations had spread along the edge to the upper portion of the spear, subsequent spread within the spear leaf was soon arrested and the infected palms survived. The results suggest that under field conditions, infection by soft rot bacteria might be aided by other pathogenic organisms such as species of *Fusarium* or *Thielaviopsis*. The disease could also be augmented by conducive environmental factors.

Recently, fresh attempts have been made to isolate phytopathogenic fungi which could be primary invaders of oil palm tissue. By using baiting techniques and antibiotic incorporated media (Ocana & Tsao, 1966) extensive isolation trials were carried out to detect the presence of *Phytophthora* spp., for Kovachich (1957) isolated a *Phytophthora* sp. in one instance of nursery spear-rot in Africa. All attempts to show *Phytophthora* in spear-rot specimens in West Malaysia have so far failed. The fungi isolated were again *Fusarium oxysporum*, *Fusarium solani*, *Thielaviopsis* sp. and *Botryodiplodia* sp. An inoculation trial is currently being laid down to study the pathogenicity of these fungi, alone and in combination with the soft rot bacteria.

Epidemiology

An aspect of the disease on which more information is required concerns the manner of spread and the environmental factors in relation to disease development. Observations on the part of planters would be of help in this respect. Special attention should be paid to the growth habit and genetic stock of susceptible palms and to field conditions. The epidemic type of spear and bud-rot usually occurs in patches ,and often follows a period of heavy rain after drought. There is also some evidence that susceptibility is higher in progenies of certain genetic lines.

The role of insects and nematodes in the aetiology and epidemiology of the disease has been stressed by many observers. Sporadic occurrences of spear and bud rot in the nursery and in the field commonly follow insect injury. In a specimen recently examined, minute lesions at the base of the petiole of the spear and adjoining fronds were detected, which may have been initiated by insects. The specimen was infested by soil-inhabiting mealybugs (*Geococcus*). Nematodes have frequently been isolated from infected spear tissue.

DISCUSSION

The involvement of soft rot bacteria in the disease complex is evident from work already quoted (Varghese, 1962; Duff, 1963). The role of the fungi associated with infected tissue has however not been established. Soft rot bacteria can normally gain entry only through wounds or through lesions caused by other agents. It is here that *Fusarium oxysporum*, *Fusarium solani* and *Thielaviopsis*, which are frequently isolated from spear rot specimens, may be significant.

The role of insect and nematodes has been mentioned, and spear-rot does occasionally occur after insect and mechanical injury, both in young and old palms. These sporadic occurrences should not be confused with the epidemic type of the disease. Nematodes isolated from infected spear rot specimens in Malaysia were recently found to be saprophagous (Winoto, pers. comm.)

Evidence in Africa and Malaya suggests that the development and spread of the disease are closely associated with environmental factors. These could be adverse physical or nutritional conditions which weaken the plant and hence increase its susceptibility. No attempt has been made in the paper to delineate these factors. Susceptibility may also be associated with progenies of certain genetic lines; the need for further investigations on these aspects is emphasised.

Specific control measures for the disease cannot be formulated unless the aetiological and epidemiological aspects are clearly understood. Turner (1968) found thiabendazole effective *in vitro* against *F. oxysporum* and *F. solani*, and suggested its use for controlling field infections.

Planters are reminded that although the problem has not assumed serious proportions in Malaya, their interest in the disease will assist in finding a solution.

Acknowledgement. The writer thanks the planters and research officers connected with the oil palm industry in Malaysia, who have directed his interest to this disease problem and cooperated with him at the various stages of his investigations.

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DISCUSSION

Chairman: R. L. Wastie

Galpine: In 1960 in some areas we lost up to 10% of the palms a few months after planting. The symptoms were shortening of the spear and young fronds and desiccation of the spear, which eventually dried up. When the palms were split open it was found that they had rotted just below the bud, and this appeared to have cut off the water supply to the spears. In all cases this led to the death of the palm.

Varghese: The marked reduction in spear length may be taken as an indication of the early stages of bud rot.

Awcock: In August our estate had barely an inch of rainfall, followed by about 25 inches in the following six weeks. Several cases of spear rot subsequently developed in our spring planting, totalling about 2–3% of the stand. The disease seemed to occur in patches.

Varghese: My own observations also suggest that the disease appears after drought followed by a burst of rain.

Arasu: In a recent paper* Mr. Soh Kim Gai shows that oil palm progenies differ markedly in susceptibility to crown disease, which often predisposes the palms to spear rot. Using susceptible lines, he has since been able to induce typical spear rot symptoms by inoculating with a *Fusarium* sp. isolated from seedlings suffering from the same symptoms.

Vehmendahl: On one occasion we observed that palms which had collapsed as a result of spear and bud rot had all fallen in the same direction, indicating that wind had played a part in the damage.

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* SOH KIM GAI (1969). Progeny differences in susceptibility of oil palm (*Elaeis guineensis* Jacq.) to crown disease. *Malay. agric. J.* **47** (2), 207–210.

USE OF AERIAL INFRARED PHOTOGRAPHY IN EARLY DETECTION OF PLANT DISEASES

by

N.T. Arasu, C.F. Loh and I.F.T. Wong

SUMMARY

Infrared photography, which records the infrared reflectance of plants, has been used in disease detection in a number of temperate crops. Preliminary results of an attempt to use aerial infrared photography in the early detection of *Ganoderma* infection in oil palms are presented. From infrared photographs of a 12-year-old oil palm planting, 674 palms were scored for disease infection and subsequently examined for visual symptoms of infection. Palms showing visual symptoms of infection could be readily picked out as diseased in the infrared photographs. In addition, many palms showing no visual symptoms of infection appeared diseased in the infrared photographs, and some of these palms were found to be infected on dissection.

Aerial infrared photography promises to be a useful tool in the early detection of *Ganoderma* infection in oil palms. It may also be of value in detecting other diseases of plantation crops.

INTRODUCTION

One feature of plantation agriculture is that large areas are covered by a single crop. While this leads to many advantages in ease and economy of management, it also creates problems in that diseases may spread far and rapidly, causing considerable crop losses. Therefore some importance is attached to the early detection of diseases and to estimating their spread. Current methods of disease survey involve the inspection of individual trees; alternative methods which could save time or permit the earlier detection of diseases or a more accurate estimate of their spread would be welcome. In this paper, the preliminary results of an attempt to use aerial infrared photography in the early detection of *Ganoderma* infection in oil palms are presented.

Infrared photography has been used in disease detection in citrus (Bawden, 1933; Norman & Fritz, 1965); vegetables (Brenchley & Dadd, 1962); cereals (Colwell, 1956, 1964) and forest trees (Meyer & French, 1967). While there appears to be considerable interest in the use of infrared photography in disease surveys in temperate crops, this technique does not appear to have been tested on tropical crops.

Aerial infrared photography was used experimentally in a land use survey conducted by the Department of Agriculture. The areas covered included a 12-year old oil palm planting, in an ex-coconut field, known to have a high incidence of *Ganoderma* basal stem rot. Examination of the photographs indicated that apparently diseased palms could be differentiated from healthy palms. It was therefore decided to see if indications from infrared photographs tallied with results from field surveys.

Infrared photography differs from normal colour photography in both colour sensitivity and colour reproduction. Normal colour photography uses a film with three layers of emulsion, each sensitive to one of the three major regions of the visible spectrum: blue, green and red. The development processes are such that the print or positive transparency reproduces the original colour with some fidelity so that images of blue, green and red objects appear blue, green and red respectively and combinations of these colours cover the rest of the visual spectrum. The print or projected image of a scene photographed with normal colour film thus represents objects in roughly the same colours as seen in life.

An infrared film is sensitive to the infrared region as well as the red, green and blue regions of the spectrum (Fritz, 1967). In practice, the blue is cut out through the use of a yellow filter so that one deals with only three regions of the spectrum: green, red and infrared. The development processes are such that a green object produces a blue image, a red object a green image and infrared rays emitted by an object (and not seen by the eye) would be represented red (see *Fig. 1*). With infrared photography, therefore, we lose some information in that it is "blind" to blue subjects but we gain some information in that the normally invisible infrared subjects are rendered visible. The transformation obtained with views of plant foliage is extreme, as may be expected from *Figs. 1* and *2*. The mere shift from green to blue should make foliage appear blue. However, the amount of reflectance in the infrared region is greater than in the green so that, in infrared photographs, the red largely masks the blue.

Fig. 1. Principles of operation of normal colour film and of infrared film (after Fritz, 1967)

Spectral region	*Ultra violet*	*Blue*	*Green*	*Red*	*Infrared*
Normal colour film sensitivities		Blue	Green	Red	
Colour of dye layers		Yellow	Magenta	Cyan	
Resulting colour in photograph		Blue	Green	Red	
Infrared film sensitivities			Green	Red	Infrared
Colour of dye layers			Yellow	Magenta	Cyan
Resulting colour in photograph			Blue	Green	Red

Infrared light is reflected by the palisade and spongy mesophyll layers of leaves. Although the foliage of different plants appears to the eye and in normal colour photographs as more or less equally green, it may vary considerably in its infrared reflectance and may thereby be differentiated in infrared photographs. Further, the infrared reflectance of a given plant species may vary with soil conditions and nutritional status. Disease infection or pest damage, which lead to a loss of turgidity in the spongy mesophyll, cause a rapid reduction in infrared reflectance. This enables early detection of disease—long before visual symptoms develop.

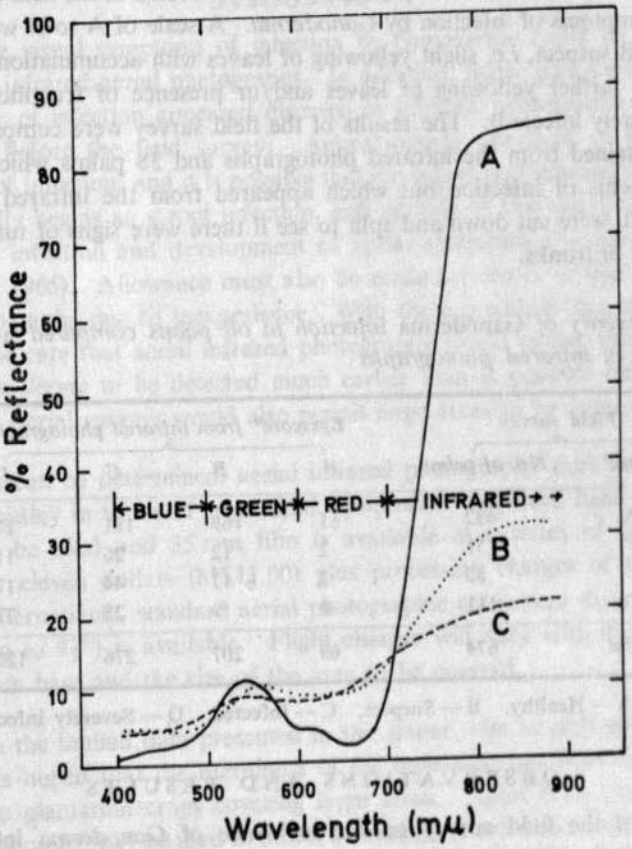

Fig. 2. Spectral reflectance curves of: A grass, B pine trees and C green paint (from Fritz, 1965)

MATERIALS AND METHODS

The aerial survey was carried out in April 1969 from a light aircraft (Cessna 172) flying at a height of 1,000 ft. above ground. The photographs were taken with a hand-held camera (Nikkormat FT) with two interchangeable lenses of focal lengths 50 mm and 105 mm. A yellow filter (Nikkor Y52) was used.

The infrared photographs were examined, and individual palms were scored for disease infection on a scale A to D (A healthy, B suspect, C infected, D severely infected) on the basis of colour intensity. With the help of suitable landmarks, 674 palms, previously marked on the photographs, were located in the field and examined for visual symptoms of infection by *Ganoderma*. A scale of A to D was again used (A healthy, B suspect, *i.e.* slight yellowing of leaves with accumulation of spears, C infected, i.e. further yellowing of leaves and/or presence of fructifications at the base, D severely infected). The results of the field survey were compared with the estimates obtained from the infrared photographs and 38 palms which showed no visual symptoms of infection but which appeared from the infrared photographs to be infected, were cut down and split to see if there were signs of fungal infection in their boles or trunks.

Table 1. Severity of Ganoderma *infection in oil palms compared with eyescores from infrared photographs*

Field survey		*Eyescore* from infrared photographs*			
*Score**	*No. of palms*	*A*	*B*	*C*	*D*
A	432	65	169	181	17
B	51	2	12	26	11
C	80	2	17	44	17
D	111	0	9	25	77
Total	674	69	207	276	122

* A — Healthy, B — Suspect, C — Infected, D — Severely infected.

OBSERVATIONS AND RESULTS

The results of the field survey on the incidence of *Ganoderma* infection were compared with the photographic survey (*Table 1*). Of 674 palms examined in the field, 191 were definitely infected; of these 163 appeared to be infected in infrared photographs, 26 appeared suspect while 2 appeared healthy. Apart from the last mentioned two palms, all infected palms could be picked out from infrared photographs. The two anomalous cases may be explained by the fact that there was a lapse of eight months between the aerial and field surveys.

There was a major difference between the field and photographic surveys as to the number of healthy palms. Of the 432 palms recorded as healthy in the field survey, only 65 appeared healthy in infrared photographs while 198 appeared to be definitely infected. In order to determine whether the infrared photographs or the field survey gave a more accurate disease picture, 38 palms scored A in the field survey and C by photographic survey were felled and examined for signs of *Ganoderma* infection. Thirteen palms had light brown necrotic tissue indicative of early stages of *Ganoderma* infection.

DISCUSSION

Palms showing visual symptoms of infection by *Ganoderma* could be picked out as diseased in infrared aerial photographs. In addition, many palms which showed no visual signs of infection appeared diseased in infrared photographs taken some eight months before the field survey. Approximately one-third of these palms showed signs of infection, and it is possible that the others had infected roots. Basal stem rot usually begins as a root infection, and periods of two years or more may lapse between infection and development of visual symptoms (Navaratnam, 1961, 1964; Turner, 1965). Allowance must also be made for errors in interpretation of infrared photographs due to inexperience. With these qualifications, the data can be taken to indicate that aerial infrared photography would enable infection of oil palms by *Ganoderma* to be detected much earlier than is possible through visual examination. Aerial surveys would also permit large areas to be covered rapidly.

As far as can be determined, aerial infrared photography does not entail any large capital outlay in terms of specialised equipment. Standard hand-held 35 mm cameras may be used and 35 mm film is available in casettes of 20 frames at approximately eleven dollars (M$11.00) plus processing charges of three dollars (M$3.00). Alternatively, standard aerial photographic equipment may be used and wider film (up to 9½″) is available. Flight charges will vary with distance of the plantation from base and the size of the area to be covered.

Although the limited data presented in this paper refer to only one disease on one crop, it is hoped that the usefulness of the technique has been demonstrated, particularly to plantation crops covering large areas. Apart from diseases, aerial infrared photography may be used to detect differences in soil conditions and nutrient status (Fritz, 1967) as these factors also affect the condition of the foliage.

Further experimentation aimed at standardising techniques of photography and, with the aid of field checks, building up the required expertise in interpreting infrared photographs will be necessary before the full value of aerial infrared photography in disease surveys in plantation crops can be assessed.

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DISCUSSION

Chairman: C.J. Piggott

Chua: Would the author please comment on the type of equipment used for infra-red photography, the availability of the film and its ease of processing in Malaysia or Singapore?

Arasu: We used ordinary hand-held single-lens reflex cameras. The film is available on order, although there may be a delay of about 6 weeks in delivery. Ordinary processing can be done in the region, but special processing for particular purposes cannot.

Wood: We have developed infra-red films ourselves without difficulty. No special problems were encountered.

Wycherley: The problem with aerial photographs is that a considerable amount of bureaucracy is involved. The Director of National Mapping has to approve the taking of photographs and the films have to be sent to him for developing.

Chairman: Would it be possible to detect deficiency diseases easily at an early stage by infra-red photography?

Arasu: It has been claimed that infra-red photography can be used to detect nutrient deficiencies, but whether it will be possible to detect deficiencies that are so slight that they are not visible to the naked eye and can only be detected by foliar analysis, remains to be seen.

Hubbard: Is there any information on the reaction of this film to transmitted rather than reflected light—for example, on light which has passed *through* a leaf?

Arasu: Healthy leaves reflect most of the infra-red rays, so very little would come through a leaf.

Wycherley: We have taken photographs under rubber trees—*i.e.* by transmitted light—and have not noticed any colour differences compared with photographs taken by reflected light.

Concerning the earlier question on nutrient deficiencies, I would say that this field is probably not one in which infra-red is of any advantage over ordinary colour photography. On the other hand, disease is detected by symptoms of water stress, which do show up on infra-red film.

Arasu: Yes, this reduction in reflectance is associated with water stress, with the collapse or partial collapse of the mesophyll cells.

PLANT QUARANTINE IN WEST MALAYSIA

by

S. J. Navaratnam

(Presented by K. G. Singh)

SUMMARY

Plant diseases and pests account for very large losses in yield throughout the world. Losses from new diseases and pests can be avoided if effective steps are taken to control the importation of crop plants on which the disease-causing organisms and pests travel from one country to another. Control of plants entering West Malaysia is effected by provisions in the Plant Importation Rules. Particular emphasis is placed in the Rules on the control of crop plants. A list of important diseases and pests of crop plants not yet established in Malaysia is provided.

INTRODUCTION

The aim in plant quarantine is to prevent the introduction into a country of agricultural pests and diseases. Economically it is preferable to undergo inconvenience and expense to exclude a pest or disease than to submit to the much higher cost of controlling it for an indefinite period. Plant quarantine did not become of general concern until the beginning of this century, and after the great plant disease and pest outbreaks of the last century in Europe. The catastrophes most often quoted are late blight (*Phytophthora infestans*) of potato in 1845–60 introduced with planting material from South America, and powdery mildew (*Oidium*) in 1850, Phylloxera (*Phylloxera vastatrix*) in 1861 and downy mildew (*Plasmopara viticola*) in 1875, all on grape-vine introduced with planting material from North America (Large, 1940). As a result of the late blight epidemic there was serious famine in Ireland in which 1 million people died and another million and a half emigrated to the U.S.A. Grape growers in France incurred tremendous losses from the outbreaks of the above-mentioned diseases and pest. At that time very little was known of plant diseases, and plant pathology and agricultural entomology were not as yet established as scientific disciplines. Departments of Agriculture with agricultural advisory services were yet to come. Interest was being stimulated however, and investigations, even though of an elementary nature, were initiated as a result of these catastrophes.

Every new disease or pest introduced, though it may not always be disastrous, is likely to increase the cost of production and, in some cases, be extremely difficult to control. Yield may be affected by the new disease or pest and control measures may be needed. The cost of control measures will increase even further if research has to be carried out on the problem or a programme initiated to eradicate the pathogen or pest.

LOSSES FROM PESTS AND DISEASES

Because of the difficulties inherent in assessing damage caused by pests and diseases no accurate figures are available. However, a few estimates have been made: in the United States annual crop losses due to insect pests were estimated at 4 billion U.S. dollars (Anon., 1953), and annual losses due to diseases were reported to be equivalent to 3 billion U.S. dollars (Anon., 1954). The average annual crop and storage losses in India have been estimated to be worth more than 10 billion rupees (Reddy, 1968).

In Malaysia new high yielding padi varieties have been shown to be very susceptible to padi blast (*Pyricularia oryzae* Cav.), and if flowering occurs during a period of cloudy, humid weather, the disease can be devastating. The maize stem borer (*Ostrinia salentialis* Snellen) is the most important factor hindering the expansion of this crop in the country. Yield losses can range from 630 to 1600 lb of dry grain per acre (Yunus & Ho, 1969). In Cameron Highlands the larva of the diamond-back moth (*Plutella maculipennis* Curt.) is the most serious pest of cabbage. Intensive spraying with insecticides has to be carried out to obtain a moderately good crop. Without chemical control of the pest, yields can be reduced by more than seventy per cent (Ho, 1965).

By preventing the introduction of new diseases and pests plant quarantine can ensure that such losses do not occur. The relatively small expense in maintaining a plant quarantine service will be amply compensated by the reduction in crop losses.

PLANT QUARANTINE LEGISLATION IN WEST MALAYSIA

Until 1961 the importation of plants was controlled under the Customs Ordinance, whereby it was possible for the Import and Export Control Officer to refer any applications for licences to import plants to the Director of Agriculture for approval. The Plant Importation Rules, which came into force in 1961, are made under provisions in the Agricultural Pests and Noxious Plants Ordinance 1953. The latter enactment is concerned with the control of outbreaks of pests, diseases and noxious weeds already in the country. In brief the Plant Importation Rules prohibit the importation of plants except under authority from the Director of Agriculture, which is given in the form of a permit. Conditions of import are stated in the permit: all imported plants must be accompanied by a phytosanitary certificate from the exporting country stating that the plants have been examined and found free from pests and diseases. Importations of diseased or infested plants, cultures of pathogens, pests, weeds and soil are prohibited except that the Director may approve their importation for scientific purposes. To economise on the number of inspectors and inspection facilities the number of authorised entry places is restricted. Plants imported by parcel post are directed by the postal department to Johore Bahru, Kuala Lumpur or Penang for inspection. Similarly, plants imported by air are channelled through the airports of Subang and Bayan Lepas. The approved entry places for importation by sea are Port Swettenham and Penang and by land Johore Bahru.

Padang Besar, Changlun, Kroh and Rantau Panjang. It is the duty of the Customs and Postal Departments to redirect or channel plants that do not arrive through approved entry places so that they pass through the quarantine office nearest the importer's address.

SCHEDULED PLANTS

Crop plants are listed in a schedule in the Plant Importation Rules, and the import of these plants is only permitted under special conditions. Besides the usual safeguards of obtaining a phytosanitary certificate and examination on arrival, wherever feasible the import of these plants is restricted to small quantities. In some cases, especially for those vegetatively propagated and thus with a risk of introducing virus diseases, plants are grown in post-entry quarantine for a certain period to ensure that virus diseases are not present. For instance when importing sugarcane planting material, only 4 setts of a variety are authorised. On arrival the introduction is grown in quarantine in a screen house for 3 months and then transplanted to the field and kept under regular observation for a further 6 months. This procedure is adopted to safeguard against the introduction of diseases such as sugarcane mosaic, Fiji, leaf scald and gumming. Similarly, sweet potato tubers are grown in a screen house for 2 months and shoots transplanted to the field and kept under observation until harvest. The chances of introducing internal cork, mosaic and dwarf diseases are minimised by growing introductions in post-entry quarantine.

NEW LEGISLATION

New legislation to unify the Plant Importation Rules in West Malaysia, Sabah and Sarawak was first proposed in 1965. Although there was unanimous agreement from all states for one law on plant importation to operate throughout the whole of Malaysia, implementation has been delayed because of the need to make a common act—the Agricultural Pests and Noxious Plants Ordinance—under which the rules can be made.

In the unified rules each state will be responsible for enforcing its own plant quarantine. One of the major changes in the new rules will result in the removal of the requirement for an Import Permit for those plants not listed in the schedule. The schedule will consist of crop plants of the South East Asia and Pacific Region and particular care will be taken in their importation. Phytosanitary certificates will be required for all plants with the exception of certain seeds such as vegetables, ornamentals and field crops, and plant products such as cut flowers, vegetables and fruits.

PESTS AND DISEASES NOT KNOWN IN THE COUNTRY

Ever since the Plant Importation Rules were first proposed the aim has been to legislate and make provision for a service which is to be primarily concerned with preventing the introduction from abroad of pests and diseases of our major crops. The ideal is to prevent the introduction of all agricultural pests and diseases, but in practice this is not feasible. For instance there is a considerable volume of viable maize seed being imported from Thailand for preparing animal feed. Groundnuts, peas, pulses, potatoes, vegetables and fruits are being imported in large quantities from all over the world, for local consumption. No doubt these items are introducing diseases and pests. The small risk of introducing new diseases and pests by this means does not justify the extension of the Plant Importation Rules to include such material. Moreover the large increase in quarantine staff, facilities and equipment needed to control these items will not be justified by the small quarantine risk involved.

The appendix to this paper lists a number of economically important diseases and pests which do not yet occur in this country. This list has been slightly modified from Appendix A to the Plant Protection Agreement for the South East Asia and Pacific Region. These diseases and pests have been successfully kept out of the country and it is hoped that this position will be maintained for years to come.

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LIST OF DESTRUCTIVE PESTS AND DISEASES NOT YET ESTABLISHED IN MALAYSIA

BANANA (*MUSA* spp.)

Bunchy top virus	Bunchy top
Pseudomonas solanacearum E. F. Smith	Moko disease

COCOA (*Theobroma cacao*)

Sahlbergella singularis Hagl.	Capsid bug causing die back
Distantiella theobroma Dist.	Capsid bug causing die back
Helopeltis bergrothi Reut.	Capside bug causing die back
Stenoma decora Zell.	Cacao fruit and shoot borer
Marasmius perniciosus Stahel	Witches' broom
Monilia roreri Cif.	Monilia pod rot
Trachysphaera fructigena Tabor et Bunting	Trachysphaera pod rot
Swollen shoot virus complex	Swollen shoot
Cacao red mottle virus	Red mottle
Cacao yellow vein-banding virus	Vein banding

CASSAVA (*Manihot esculenta*)

Phaeolus manihotis Heim	Root rot
Cassava brown streak virus	Brown streak
Cassava mosaic virus	Mosaic

CITRUS

Virus	Exocortis
Virus	Greening
Virus	Xyloporosis

COCONUT (*Cocos nucifera*)

Pachymerus nucleorum (F.)	Coconut borer
Pseudotheraptus wayi Br.	Coreid bug
Rhynchophorus palmarum (Linn.)	Palm weevil
Rhadinaphelenchus cocophilus (Cobb) Goodey	Red ring disease
Oryctes monoceros (Ol.)	Beetle
Cause not established	Cadang cadang

COFFEE (*Coffea* spp.)

Antestiopsis spp.	Pentatomid bug
Leucoptera coffeella (Guer.)	White coffee leaf miner
Planococcus kenyae (Le Pelley)	Mealybug
Omphalia flavida Maubl. et Rangel	American leaf spot
Trachysphaera fructigena Tabor et Bunting	Trachysphaera fruit rot
Gibberella xylarioides (Stey.) Heim et Saccas	Tracheomycosis
Coffee blister spot virus	Blister spot
Virus	Mancha mantecosa

HEVEA RUBBER (*Hevea brasiliensis*)

Leptopharsa heveae Drake et Poor	Lace bug
Microcyclus ulei P. Henn.	South American leaf blight
Pellicularia filamentosa (Pat.) Rogers	Target leaf spot

MAIZE (*Zea mays*)

Diatraea spp. esp. *D. saccharalis* (F.)	Stalk borers
Sesamia cretica Led.	Durra stem borer
Xanthomonas stewartii (E. F. Smith) Dowson	Bacterial wilt
Sclerospora philippinensis Weston	Downy mildew
Dwarf Mosaic Virus	Dwarf mosaic

OIL PALM (*Elaeis guineensis*)

Pachymerus lacerdae (Chevr.)	Kernel borer
Pachymerus nucleorum (F.)	Kernel borer
Pimelephila ghesquieri Tams	A pyralid
Fusarium oxysporum Schl.	Fusarium wilt
Cercospora elaeidis Stey.	Freckle
Coelaenomenodera elaeidis Mlk.	Leaf miner
Rhynchophorus phoenicis F.	Weevil
Oryctes monoceros (Ol.)	Beetle

PAPAYA (*Carica papaya*)

Papaya bunchy top virus	Bunchy top
Papaya mosaic virus	Papaya mosaic die back
Papaya ring spot virus	Papaya ring spot
Virus	Papaya Waialua disease

RICE (*Oryza sativa*)

Diatraea spp.	Stem or stalk borers
Ephelis pallida Pat.	Panicle disease
Rice dwarf virus	Dwarf
Rice stripe virus	Stripe
Rice hoja blanca virus	White leaf (Hoja blanca)

SUGAR CANE (*Saccharum officinarum*)

Diatraea spp., esp. *D. saccharalis* (F.)	Stalk borers
Diaprepes abbreviatus L.	Sugar cane root stalk borer weevil
Clemora smithi Arr.	White cane grub
Fiji Virus	Fiji disease
Sclerospora sacchari Mily	Downy mildew
Xanthomonas vasculorum (Cobb) Dows.	Gumming disease

SWEET POTATO (*Ipomoea batatas*)

Euscepes postfasciatus (Fairm.)	West Indian sweet potato weevil
Sweet potato internal cork virus	Internal cork
Sweet potato mosaic virus	Mosaic
Sweet potato dwarf virus	Dwarf

TEA (*Thea sinensis*)

Exobasidium reticulatum Ito & Sawada	—
Virus	Phloem necrosis

TOBACCO (*Nicotiana* spp.)

Ephestia elutella (Hbn.)	Tobacco moth
Psuedomonas tabaci (Wolf & Foster) Stevens	Wildfire
Peronospora tabacina Adam	Blue mould

DISCUSSION

Chairman: C.J. Piggott

Chairman: There seems to be no provision for preventing the introduction of weeds in the seeds of another crop. I know of one particular case in Sabah where cover crop seed introduced *Mikania* into Sabah, I think for the first time. Is legislation ever likely to be introduced to prevent this kind of thing?

Singh: The import of any potentially noxious plant is naturally not allowed, and we are trying to make the regulations uniform for East and West Malaysia.

Van: The plant introduction regulations apply to all parts of the plant, including seeds. A consignment of seeds must therefore be covered by an import permit, and any seeds which are likely to be a risk will be kept out.

Varghese: Can anything be done about seeds imported in peoples' pockets?

Singh: It is not easy to prevent this kind of thing, although we try to tighten loopholes in the regulations wherever they occur.

Wycherley: I would like to comment on some of the implications of the plant importation rules as far as the introduction of Hevea budwood from the Americas for use in our breeding programme is concerned. Since we do not wish to introduce South American leaf blight, any measures recommended to improve international quarantine services and to encourage official exchanges of planting material, will be beneficial to us. There have been instances of certain companies getting clones ahead of official exchanges, and it is alleged that budwood has been imported in a golfing bag. Although there are two sides to the argument, from the point of view of the plant breeder anything that can be done to ease the safe movement of material would be very welcome.

Turner: Is there any official quality control of seed produced in this country for export to East Malaysia?

Singh: The question of quality control does not concern the Department of Agriculture, but seed consignments for export are normally examined for signs of shrivelling or other damage to the seeds.

Wong: Is there any regulation covering the purity of seeds imported into this country?

Singh: Imported seed consignments carry a phytosanitary certificate from their country of origin certifying that they are free from all diseases. In addition we check the seeds before releasing them.

Chairman: I think the questioner is not referring to diseases but to importing noxious weeds. There seems to be no legislation for this at all.

Singh: The legislation covers noxious weeds as well.

Chairman: But how do you establish whether a consignment of *Pueraria*, for example, contains seeds of *Mikania*?

Singh: We have to depend on the faith of the person who is importing the seeds as well as on the phytosanitary certificate issued by the country of export.

Chairman: But a phytosanitary certificate only says if the seed is free of pests and diseases, not weeds.

Van: The plant importation regulations cover species that are not present is this country, whether pests, diseases or weeds. In the case of *Mikania*, since this is already present in this country, it is up to the importer himself to see that his consignment is free from adulteration with *Mikania* seeds.

Cates: I think the responsibility for cleanliness lies with the Department of Agriculture of the country that is exporting the seed. Screening seed samples on arrival is very difficult.

Hartley: There seems to me to be a lack of publicity given to the general public on the subject of plant quarantine. It is all very well to legislate against people importing seeds and plants in their pockets, but if they knew the damage that it might do to the economy of the country perhaps they would be more careful.

Singh: We have been publicising plant quarantine for a long time, but the public, and even scientists, are rather unresponsive to the subject.

Chairman: Many people take the attitude that importing a small piece of plant material cannot do any harm. This is entirely wrong, for it is these little bits of material which cause the trouble. They certainly caused trouble in Australia, where legislation is very stiff on plant introduction.

Van: A year ago a scientist against our permission imported some plant material in his briefcase. The plant was subsequently ravaged with diseases and pests and this caused quite a problem. We would therefore like to appeal for the co-operation of the planting public, for the importation regulations exist for safeguarding the interest not only of ourselves but of the planting industry as a whole.

DISEASE ASPECTS OF REPLANTING OIL PALMS FROM OIL PALMS

by

P. D. Turner

SUMMARY

The incidence of *Ganoderma* infection of oil palms where the former stand was also oil palm is variable and is related to replanting technique. Where stumps alone were left in the ground, subsequent disease levels are low, provided regular sanitation rounds are made to ensure that infectious spread does not occur. At low disease levels it is unlikely that there is any significant effect on yield. Highest losses occur where underplanting is practised, with the old stand later poisoned and left to rot *in situ*. Relative colonisation of the potential infection foci by *Ganoderma* and non-pathogenic microorganisms is offered as the explanation for the differences in disease incidence. Treatment of diseased plantings is discussed, with regular field sanitation being the most important feature. Future plantings are considered in relation to disease aspects, and clean clearing is preferred.

The relationship between the incidence of basal stem rot in plantings of oil palm (*Elaeis guineensis*) and the type of vegetation which formerly occupied the area is fairly well known in most instances. Thus, where oil palm has been replanted from rubber, the incidence of the disease, which is caused by a number of species of *Ganoderma*, remains very low until senescence becomes a predisposing factor (Turner, 1965b). Where the land was occupied by primary or secondary forest, disease levels are also slight, although in coastal areas certain wild palms form a potential source of infection (Turner, 1968b). In fields where oil palms were replanted from coconut and the stumps of the former crop were left to rot away in the ground, disease levels have almost invariably been high and of considerable economic significance. Recognition of this relationship between the type of the old stand and subsequent disease levels has had an important influence on the clearing method used to control the disease, with clean clearing being essential in most coconut areas (Turner & Bull, 1967).

The disease situation where oil palms followed oil palms has remained an anomaly for several years. Wide variations have been observed in disease incidence between fields of the same age, material and apparently grown under the same ecological conditions (Turner, 1965a). This has sometimes raised problems in deciding upon which clearing method to use or whether, like coconuts, to remove stumps remaining in the field after young palms have been planted. The problem may also be complicated by the practice of underplanting the old stand and progressively thinning the latter by one means or another, a replanting method practised especially in Sumatra. This paper summarises investigations into this situation and estimates the disease levels which might be expected using various methods of replanting old oil palm with new oil palm.

CLEARING METHOD AND DISEASE INCIDENCE

When disease statistics for many hundreds of acres from oil palm fields in Malaya and Sumatra which had been replanted from oil palms were examined, there were no indications to account for the differences in incidence in the form of the more usual predisposing factors, such as age and nutrition. However, when the replanting method was studied, the relationship between this and subsequent disease levels became apparent. The most common clearing methods are as follows:

(a) Where the old stand was felled and the stumps were left in the ground to rot, disease levels arising from primary infection foci rarely exceeded 5%. Trunks were either destroyed or left to rot in the interrow. A higher incidence of disease was recorded where inadequate control measures were carried out.

(b) Areas are clean-cleared, with both stumps and trunks destroyed. Disease incidence under these conditions is negligible.

(c) The old palms underplanted and later destroyed either simultaneously or progressively by felling. Again, disease levels are low, as in (a).

(d) In underplanted areas where the old stand was destroyed by poisoning but there was no felling and the poisoned palms were left to rot away *in situ*, disease incidence has frequently been very high, often exceeding 30% after fourteen years.

In one field where the old palm stand was poisoned and left to rot *in situ* at replanting, disease records have been kept over a number of years, and the increase in the appearance of disease symptoms with age is shown in *Fig. 1*. This pattern would appear to be general for many areas in Sumatra and to a lesser extent in Malaya, where underplanting is now far less frequently practised.

The disease situation is superficially less clear in fields where no control measures have been carried out. Thus it is possible to find older replanted areas where palms were felled and the stumps left in the ground but where disease incidence is high. There are two explanations for this, both of which apply in certain circumstances. Firstly, if the few palms which have become diseased as a result of stump infection are not removed when symptoms appear, then it has been shown that disease spread to healthy neighbours occurs (Turner, 1965c). This results in the development of groups of diseased palms, a feature influencing yield in relation to disease incidence. Secondly, in a number of fields replanted from oil palm no attempt was made to remove such *Ganoderma*-infected palms as were present at that time; nor were later attempts made to remove diseased palms. In such fields the primary infection foci were thus of two kinds, *i.e.* old diseased palms, either trunks or stumps, or sectors of stumps healthy at the time of felling but which subsequently became colonised.

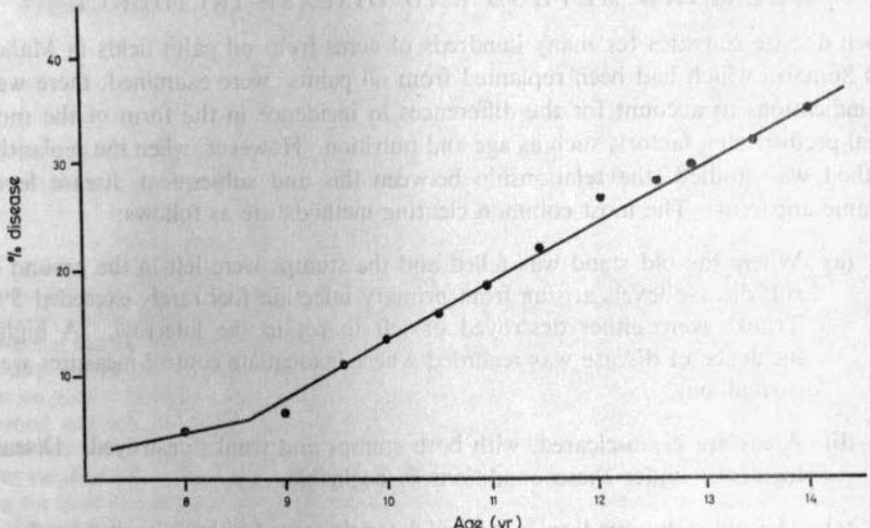

Fig. 1. The incidence of basal stem rot in an oil palm field where the former palm stand was poisoned and left to rot in situ

The influence of a soil factor on disease incidence was noted in two areas of Sumatra. Here the old stand had been underplanted and later poisoned and left standing, conditions which in most circumstances would lead to a high disease incidence. However, in these areas there were peat soils and disease levels were very low. This was a situation similar to that experienced on some estates in Malaya where replanting of oil palm from coconuts on peat soils showed only slight disease despite the coconut stumps remaining in the ground, which would normally lead to a serious disease outbreak. In one Sumatran field the effect was most noticeable since there was a transition from ordinary coastal clay soil to peat, with the disease level being very high in the former sector.

In considering the economic significance of basal stem rot, the influence of disease on yield is of great importance. In fields where disease incidence is low and diseased palms are scattered, such as where the old palms were felled but disease subsequently occurring was promptly treated, there is unlikely to be any significant yield decrease. The yield from diseased palms is lower in both bunch number and weight as infection becomes increasingly severe (Turner, 1966) but when such palms are excavated their neighbours benefit from the removal of competition for available nutrients, *etc*, and their yield is likely to increase slightly for this reason, *i.e.* there is yield compensation. However, as soon as palms become diseased in groups then yield compensation would be applicable only to healthy palms on the edge of the diseased patch, and when large areas become diseased then the effect on yield becomes very significant. It is not known in Malaysia at what level of disease the yield compensation factor becomes operative. This would be expected to vary considerably according to the conditions under which palms are grown, with greater compensation occurring in palms grown under sub-optimal conditions. In Africa, it was observed that vascular wilt disease did not affect yield until some 20–30% of the stand had been attacked (Prendergast, 1957).

INFECTION FOCI

Investigations into the decomposition of oil palm stumps after felling provided an explanation for the various disease situations and also for the generally lower disease incidence than that which normally follows replanting from coconuts, or where the stumps are left in the ground to rot. Twenty-five oil palm stumps of each age were examined by sectioning on an estate in Johore, with observational diagnosis of *Ganoderma* colonisation being based on earlier cultural investigations. After one year from felling, the decomposition of unpoisoned oil palm stumps was found to be quite far advanced in a number of instances, although in the majority little decay had taken place. A rapidly-spreading wet rot was often seen, originating in the centre of the cut surface, first tending to penetrate vertically and then laterally. On the outside, initial decomposition by a *Polystictus* sp. was common. At this stage, little *Ganoderma* colonisation could be found. During the second and third years after felling, rotting took place quickly in many stumps, and a number were found to have been colonised by *Ganoderma*. The degree of colonisation ranged from 5% to 90%, whilst in other stumps no traces of this fungus could be found. By the end of the third year a number of stumps had disintegrated; had the palms been poisoned before felling this number would have been higher. An assessment was made of the potential disease hazard represented by each stump, using the size and location of the area colonised by *Ganoderma* as criteria of the hazard presented to the young palms though their roots coming into contact with the stumps: hazardous 40%, possible hazard 15% and no hazard 45%. With the speed of decomposition being so great at this stage, many potential hazards would rapidly become ineffective. Hazards are likely to be least where felling takes place at ground level, since the amount of bole tissue to be destroyed by microorganisms is much less and the chances of its invasion are increased through soil splash.

Where palms are poisoned and left standing, examination has shown that the amount of *Ganoderma* colonisation is much greater, with large numbers of sporophores developing on the trunk. The amount of tissue invaded by non-pathogenic microorganisms is very much smaller, especially in the absence of the cut surface which marks the point of entry into stumps for many rotting organisms. Breakdown is thus slower, and large infection foci are available over a number of years throughout the field. At the time of poisoning, the root systems of the underplanted palms will already be so extensive as to increase the chances of contact with potential disease sources. In addition, unfelled dead palms frequently become infested in their crowns by *Oryctes rhinoceros*, thus becoming an even more serious danger to the young palms. Sometimes palms have been felled some distance above ground level, and here the potential disease risk is intermediate between that of unfelled poisoned palms and those felled at ground level.

Compared with replanting from oil palm, the main difference in replanting from coconut lies in the much lower rate and degree of colonisation of the coconut stumps by *Ganoderma* (Turner, 1967). The time for stump decomposition is very much longer than that for oil palm, and there is very little colonisation by other microorganisms. There is thus a greater potential for infection, for root contact can be made over a longer period, resulting in the high disease levels frequently experienced in oil palm replantings from coconuts, except where clean clearing is carried out.

DISEASE CONTROL IN EXISTING PLANTINGS

Especially in Sumatra, disease levels have reached very severe proportions in many fields and the future potential incidence is high in many others. Treatment has to be considered as a separate entity in each instance, since economic factors are often of considerable practical importance. Thus, for example, underplanting is not favoured by some plantation companies for agronomic reasons, but income from the stand during the immature period of the underplanting is an essential feature in the economy of other estates; underplanting has also been considered as a very economical method for replanting (Hartley, 1949).

Where large areas of a plantation are affected by basal stem rot, as a general rule attention should first be paid to the younger, least-affected areas, since in such areas the disease can more readily be contained within acceptable limits. Also, as later-planted palms on most estates are often of much higher-yielding material than those planted earlier, the economic significance of disease in the younger plantings is likely to be greatest. Where disease incidence is high through lack of treatment over a long period, the first control round is likely to be both extensive and costly. The next two rounds will also probably be prolonged, although less so than the first round, since a number of palms affected sub-clinically during the first round will show external symptoms during subsequent rounds. However, after the backlog of sanitation has been completed, subsequent rounds at six-month intervals should be both swift and inexpensive. These rounds should be regularly carried out if a build-up of disease is to be avoided.

Unless palms are likely to be successfully treated by surgical methods, they should be removed as soon as the diagnostic sporophores appear, irrespective of bunch production. The longer a diseased palm is allowed to remain in a field, the greater are the chances of disease spreading to healthy neighbours. Where the palms appear to be in good condition, apart from the presence of fructifications, and especially where the foliage is still dark green in colour, significant success has been achieved in treating disease by surgery. The full details of this method have been described elsewhere (Turner, 1968a), but basically it consists of excising all diseased tissues and treating the cut surface with a protectant. It has subsequently been noticed that inspection is necessary after treatment since a number of palms show sporophore development at the base; this is because of the difficulty of removing all diseased tissues at ground level. However, re-treatment is quick, inexpensive and the volume of tissue requiring removal is usually very small. Such small sporophores as develop on the ends of roots severed from the palms can be ignored since they are not in organic contact with the palm.

Palms which cannot be saved by surgery should first be poisoned to accelerate the decay of the tissues. In one experiment in Malaya, comparison was made between paraquat, diquat and sodium arsenite as palm poisons, and arsenite was found to be the most successful and the cheapest. Possibly monosodium methanearsonate (MSMA) would be as effective; it would also be more socially acceptable. When the crown has changed to a brown colour, usually after two to three weeks, the palm is felled and the stump excavated by digging a pit two feet square and deep at the point. The palm remnants can be left to rot away in the interrow; there is no need, as is sometimes practised, to incur the considerable expense of their removal from the field or to burn the trunks. During the first round any vacant points should be inspected for the remains of earlier-diseased palms and, where these are found, they should be similarly excavated.

In fields where disease incidence is very high, replanting may become an economic proposition. However, on some estates it is required to retain as much of the old stand as possible and to interplant. After all vacant points have been inspected and diseased palms excavated, experience has shown that young palms can be planted on the old planting points without fear of disease. Whilst the remnants of the old root system may be infected by *Ganoderma*, they contain insufficient inoculum potential to initiate new disease; in small experimental palms it was shown that a minimum inoculum size of 45 cu in. was required to initiate infection (Navaratnam & Chee, 1965) and experiments by the writer showed that even larger inocula are probably required for mature palms. In fields replanted in this way the need to control disease in the old stand by regular inspection and treatment is considerable if spread to the young palms is to be avoided. Diseased supply palms adjacent to diseased old palms, or at points where insufficient sanitation of disease remains was carried out, have been seen in both Malaya and Sumatra.

In certain areas in Sumatra underplanting followed by poisoning the old stand and leaving it to rot *in situ* has recently been carried out. Where this has been done during the past two to three years it should prove possible to avoid a high disease incidence in future years by immediately felling the poisoned palms and excavating their stumps—the latter being necessary since the stumps are likely to have become large infection foci. Depending on their age, some palms in the replanting are likely to have already become diseased at sub-clinical levels, so regular observation and treatment rounds will be required to remove them when disease symptoms become overt.

DISCUSSION

Considering the practice of replanting oil palm with oil palm from the disease aspect only, it would appear that it is possible to fell the old stand and leave the stumps to rot in the ground, since the low disease levels which subsequently develop may be considered acceptable; they are also readily contained provided regular sanitation rounds are carried out. In assessing costs, however, the necessity for rhinoceros beetle control has also to be evaluated, together with the expenditure on inspection and treatment rounds. With all new replantings, it is advisable to inspect vacant points and dispose of diseased palms before general felling commences, especially if heavy equipment is to be brought into the field.

Frequently, and perhaps desirably, a stand is required to be as disease-free as possible, and clean-clearing is practised. After poisoning the old stand it is best felled by bulldozer, and this can be facilitated in some soils by digging a small trench around the palm base. Where a palm base is split during felling, which is especially common with diseased palms, the remains have to be removed independently. A final plough with tines brings to the surface any potential infection foci. After felling, the old palms can be left to rot in the interrow, necessitating extensive beetle control measures, or disposed of by burning; the latter, although expensive and not easy, is preferable. Disposal of trunks should never be by burial, as carried out on one estate in Sumatra, since this leads to a very high disease incidence.

Clean clearing and disposal of the old stand, in addition to avoiding disease and pest problems, may well be cheaper in the long run than hand felling and leaving the stumps to rot in the ground. Early maintenance is also easier, and should mechanisation of various aspects of estate practice be considered then clean clearing is essential. Where underplanting is still required for reasons of economy, it is expected that poisoning the old stand and leaving it to rot *in situ* will not be practised in future.

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DISCUSSION

Chairman: C.J. Piggott

Stimpson: Burning palms is expensive because of the cost of fuel, and can cost M$6–8 per palm. Our practice is to poison the palms, fell them, cut them up, and cultivate. With the palm material thus left in the inter-row the total cost of clearing is M$160–180 per acre.

Does the author consider it necessary to fallow, or plant dry padi, after clearing an area where disease incidence is high?

Turner: It is not necessary to leave such an area fallow. Normal clearing methods plus ploughing to bring up large potential sources of inoculum should be quite sufficient.

Tampubolon: In Sumatra we excavate the boles of diseased palms before planting, but we are doubtful of the efficacy of this method as 2–3 weeks later sporophores of *Ganoderma* emerge from the ends of the severed roots, with which the roots of surrounding palms may come into contact. If the severed roots are close together a compact inoculum may be formed in this way.

Between 1954 and 1964 isolation trenches were dug around diseased palms to prevent root contact with healthy plants, but the method was found ineffective and was abandoned.

If only 45 cu. in of diseased bole tissue is sufficient inoculum, there is more than enough present whether the palm is poisoned and left standing, felled well above ground level, or felled close to the ground.

Cutting up the bole tissue to hasten its decomposition may not prevent infection, since the roots of the new palms will reach the old stumps quickly, before they decay.

Do you have any data on the minimum period of root contact necessary for infection to take place?

We have found that excising diseased tissue from newly-infected palms does not stop the infection, and we no longer use this method. Since infection originates from the root it is surely necessary to carry out surgery below ground level?

Turner: The sporophores formed on the ends of the roots are very small. You were thinking that perhaps all these roots together would form a large inoculum, but of course there is soil between the roots, and *Ganoderma* does not grow through the soil. So these roots are in fact individual units, and as such I would not expect them to set up an infection. Although Mr. S. J. Navaratnam (Department of Agriculture) reports that a 45 cu. in. inoculum is necessary to infect seedling palms, our own trials suggest that an even greater inoculum is needed for a larger palm.

Concerning trenches, I never held these to be much good because they need constant maintenance, and anyway the roots go underneath them. You say that trenching did not work, but I would suggest that possibly this was because the neighbouring palms were already infected at the time the trenches were dug.

Cutting the stumps close to the ground is beneficial because their decay is hastened by so doing, and the chance of *Ganoderma* colonising the stump is thereby reduced.

It would take approximately a year for *Ganoderma* to grow into a palm from a point of root contact and set up a localised lesion. It would take a longer time again for such a lesion to become lethal.

In our experiments we obtained a worthwhile level of success with surgical treatment of plants which looked reasonably healthy, with dark green fronds. But it is important to follow up with a second round of surgery about 6 months later, to eradicate any remaining pockets of infection.

Wood: Since Dr. Turner has called this the last in his series of papers on *Ganoderma*, I would like to express publicly the view that we owe him a debt for his pragmatic and effective research programme on the topic.

If ground covers are properly managed rhinoceros beetle need not be a big problem. Further, a palm can tolerate limited attacks quite satisfactorily.

Current experiments are investigating close spacing palms at planting to get high crops in early years and then thinning. The problem arises of what to do with the thinned palms. Poisoning and allowing them to rot *in situ* is unlikely to cause a rhinoceros beetle problem because the canopy of the remaining palms will have the "vegetative barrier" effect against infestation by the beetles, but are such thinned palms likely to be sources of *Ganoderma*?

Turner: Much depends on the location, but since *Ganoderma* now appears to be fairly well distributed throughout the country, I would on principle remove the poisoned palms to avoid the possibility of their becoming sources of the disease.

Chairman: Does anyone have experience of different methods of palm clearing? My company has tried using a machine called a fire-fan, which is a small engine with a large propeller blowing out burning kerosene. It had virtually no effect on the oil palms, for it just charred the surface and no more.

Chua: I suggest more research be done on methods of complete clearing of both the palm trunk and the stump in the ground, because by removing all these tissues, breeding places of *Oryctes*, as well as possible sites for *Ganoderma*, are destroyed. We have tried various methods, including burning oil palm trunks by cutting them into small pieces and stacking them into big piles to get plenty of heat generated while burning. This is very expensive, but if losses from *Ganoderma* are likely to be as much as 40% of the stand (as they may be in coastal areas) then it is definitely worth while to clear everything. In our estates in inland areas we do not lose so many palms from *Ganoderma*, and it is probably not economic to use this method of clearing. One method which we have not yet tried is to blow up palm trunks with TNT.

Chairman: People can laugh about blowing up palm trunks, but a lot of explosives are in fact extremely effective, although at the moment they are almost impossible to obtain in this country.

Wycherley: Has any thought been given to the use of palm trunks as a source of carbon? Rubber wood has proved a very good source of charcoal for the blast furnance at Prai. Manufacturing particle board, chipping and pulping are all possibilities for using such material.

Chairman: This has been considered, but selling for such manufacturing processes may turn out to cost more than just leaving the palm on the ground.

Wood: We have made some attempts to get the palm used for paper-making, hardboard, etc., but it is not very suitable.

Galpine: If replanting from oil palm to oil palm is done by felling the palm and leaving the stump in the ground, is it possible that over years of continuous replanting a build-up of *Ganoderma* will occur in stumps left from one year to another? In the first year there are probably only a few stumps infected, but these produce large numbers of spores, and thus gradually a greater and greater intensity of stump infection will develop?

Turner: There is indeed a build-up over the years, but this is inevitable because there are always *Ganoderma* spores in the air. One must therefore expect to have stumps infected. But under circumstances such as you were mentioning one would not expect the subsequent levels of disease to be very high, provided any cases of *Ganoderma* which arose were immediately treated to stop the disease spreading to other palms.

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