A REVIEW OF RELATIONSHIPS BETWEEN SHADE TYPES AND COCOA PEST AND DISEASE PROBLEMS IN PAPUA NEW GUINEA

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ABSTRACT

In Papua New Guinea, unlike most other cocoa cultivating countries, the permanent overhead shade is provided mainly by coconuts and/or Leucaena leucocephala *(Lam.) De Wit. Selection of cocoa shade species has been based on agronomic characteristics and there have been few attempts to determine the relationships between cocoa pests and diseases and the shade species.*

This paper outlines the major pests and diseases in Papua New Guinea cocoa plantings and reviews their relationships to the main shade trees used. Evidence is presented to show that many of the present day problems have arisen from the use of leucaena as a shade tree. In contrast, the widespread practice of interplanting cocoa under coconut palms has considerable economic and managerial advantages and the cocoa generally suffers less from insect and disease attack than sole planted cocoa.

It is concluded that recommendations incorporating the planting of high yielding, disease resistant cocoa under high yielding, hybrid coconut palms at least three to four years old, should be formulated and actively promoted in Papua New Guinea.

INTRODUCTION

Cocoa has been grown in Papua New Guinea since the end of the last century and many systems of cultivation have been tried. The crop is generally grown beneath the shade of selectively thinned forest or cultivated shade trees. Young cocoa plants require fairly heavy shade, although this requirement diminishes as the trees age.

In cocoa cultivation, four ways in which shade species are used have been recognised (Green 1938):

1. As a cover crop which protects against soil erosion and reduces weed competition during establishment of seedlings
2. As a temporary or nurse shade before the closure of the cocoa canopy
3. As a windbreak and hedge
4. As a permanent overhead shade.

One of the functions of shade is to buffer against changes in the environment (Murray 1964) and the selection of shade species is based on this and other agronomic or physiological characteristics.

Although there is an extensive literature on these agronomic aspects (eg. Chalmers 1967; Henderson 1954; Murray 1957; Wyrley-Birch 1970) and most authors have reported specific pest and disease problems associated with the shade species, few workers have examined the relationships between shade

This paper was first presented at the 7th International Cocoa Research Conference held at Douala, Cameroon Republic 4-12 December, 1979.

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density or species and the pest and disease incidence in cocoa. The micro-climatic effects on the cocoa ecosystem caused when the shade canopy is changed and the possibility of the shade species itself being an alternative host may influence the incidence of pests and disease in the cocoa.

This review concentrates on the relationships between cocoa pest and disease problems and the species of shade trees and density of shade used in Papua New Guinea and will only briefly discuss the agronomic suitability of the various forms of shade.

GENERAL RELATIONSHIPS BETWEEN COCOA PESTS AND DISEASES AND SHADE

It has been stated that "cocoa trees prefer the type of shade trees which allow the light to filter through, but still protect them from the sun" (Urquhart 1953). This requirement can be provided either by thinned forest trees or by regularly spaced trees planted for shade. However, all the desirable qualities for a permanent shade tree (Henderson 1954; Murray 1957; Urquhart 1961; Wyrley-Birch 1970) are rarely found in one species, and the requirements vary between cocoa growing regions. Tree species which are favoured for permanent shade are usually legumes (which may improve the nitrogen status of the soil), or trees which bear another crop (e.g. coconuts, areca nuts, other fruit or nuts, rubber, oil palm) or become a valuable source of timber.

Since the light requirement for cocoa increases as the tree matures, the density of the shade should be gradually reduced as trees commence bearing to maintain acceptable yields. Caution must be exercised, however, since the removal of shade is frequently followed by increased insect attack (Anon. 1971; Entwistle 1972; Lim 1978).

General principles for reducing the disease incidence in shaded cocoa were outlined by Dadant (1953), who suggested that "a space of several feet should separate the cocoa tree level from the shade tree level". He found that this prevented the low branches of shade trees from intermingling with the upper branches of the cocoa and allowed air movement through the cocoa canopy and the space between cocoa and shade tree thereby reducing humidity.

MAIN COCOA PEST AND DISEASE PROBLEMS

Over 300 insect species (Szent-Ivany 1961, 1963) and 47 diseases (Shaw 1963) have been recorded from cocoa in Papua New Guinea. Fortunately, in most areas there are only six or seven species of pests which regularly cause crop loss or tree damage, but many others may occasionally form large populations and cause loss of production. Throughout the country the two greatest cocoa problems are *Pantorhytes* spp. (Coleoptera: Curculionidae) and *Phytophthora* pod rot disease. Vascular streak dieback disease was a serious threat to cocoa growing in many areas but has now been largely removed by both natural and controlled selection of resistant clonal material (Anon. 1972).

Studies over the past 30 years have indicated that the severity of attack by many of the main cocoa pests is influenced by the density of shade or type of shade tree used.

RELATIONSHIPS BETWEEN COCOA PESTS AND DISEASES AND SHADE

In Papua New Guinea, some 70% of the country's cocoa is interplanted under coconuts (in some cases leucaena is also present) and about 20% is cocoa under leucaena alone. The remainder is grown unshaded or can be found under a variety of shade trees, the most common of which are thinned primary forest or

Erythrina spp. The relationships between shade and cocoa pests and diseases are discussed below, while the main host associations are listed in *Table 1*, and *Table 2* indicates how the population levels of some of the cocoa insects could be expected to vary among the three main cocoa ecosystems of Papua New Guinea.

Temporary shades

Green (1938) discussed the merits of six species used for temporary shade *Aeschynomene americana* L., *L. leucocephala* (Syn. *L. glauca*), *Crotalaria anagyroides* Kunth, *Cajanus cajan* (L.) Millsp. (Syn. *C. indicus*), *Tephrosia candida* (Roxb.) DC. and *Tephrosia vogelii* Hook. f.. The last four species are all susceptible to pink disease (*Corticium salmonicolor* Berk. and Broome) (Green 1938) and *C. anagyroides* is an alternative host for both *Tiracola plagiata* Walker (Dun 1967) and *Zeuzera coffeae* Nietner (Entwistle 1972). *Flemingia* sp. is now used in some areas, but is an alternative host for *Helopeltis clavifer* Walker, the most damaging cocoa mirid in Papua New Guinea (Smith 1978), and for pink disease.

Unshaded cocoa

Although it is difficult to establish cocoa without using shade, mature trees generally gave higher yields if unshaded, provided fertiliser applications were adequate. In Papua New Guinea, highest yields have been recorded in unshaded cocoa (Charles 1961, 1971) but conditions become much more favourable for some insect pests (Byrne 1971). It was suggested by Byrne (1971) that a compromise could be reached between high yields in unshaded cocoa and lower insect attack to shaded trees by the less drastic thinning of shade around the block edges, since "this could assist in keeping down infestation of pests such as *Pansepta teleturga* Meyrick." This system has been tested in Malaysia, where Lim (1978) reported that shade removal, except around the block boundaries, increased the incidence of mirids, thrips and leaf eating pests. He indicated that success from shade removal would require a continuous closed cocoa canopy and the maintenance of a high standard of pest control.

Pantorhytes populations were greater on unshaded than on shaded cocoa trees (Bourke 1971; Hassan 1971), and Smith (1981a) reported that populations of *H. clavifer* were frequently damaging on unshaded cocoa. In addition, increased damage levels of the insect pests *Platyacus ruralis* Faust, *Rhyparida* spp., *Z. coffeae* and *P. teleturga* were all correlated with inadequate shade levels (*Table 2*) and Dun (1951) suggested that "proper control of shade will go far toward lessening the amount of damage" by the latter pest.

It is possible that unshaded cocoa would suffer less from disease since increased air movement and lowered humidity could create conditions unfavourable to fungal pathogens.

Coconuts

This regime has been described as the ideal shade for cocoa (Henderson 1954) and has been used in Papua New Guinea since early this century (Urquhart and Dwyer 1951). Both Godyn (1974) and Henderson (1954) listed many advantages of interplanted over sole planted cocoa and various authors have reported that yields of both crops are equal, if not better than, those in sole planted areas (Barrant 1978; Denamany *et al.* 1978; Henderson 1954; Ramadason *et al.* 1976; Shepherd *et al.* 1976; Urquhart 1957).

As Dun (1967) remarked, the widespread use of coconuts "was probably fortuitous but has proved highly satisfactory since the conditions provided by this combination were entirely unsuitable for the development of the more important (cocoa flush defoliating) species." Most other cocoa pest problems also occur

Table 1.—**Main cocoa pests and diseases in Papua New Guinea and their relationships to shade species**

Pest species	Order: Family	Shade tree as alternative host	Author and date	
Flush and foliage feeders				
Ectropis sabulosa Warrengren	Lep. : Geometridae	*Leucaena*	Smee	1963
Hyposidra talaca Walker	Lep. : Geometridae	*Leucaena*	Smee	1963
Achaea janata (Linnaeus)	Lep. : Noctuidae	*Albizia* spp., *Hevea*	Smee	1963
Tiracola plagiata Walker	Lep. : Noctuidae	*Leucaena, Crotalaria, Hevea*	Catley	1962
Ceroplastes chiton (Green)	Hom. : Pseudococcidae	*Erythrina, Gliricidia*	Shah	1976
Ferrisiana virgata (Cockerell)	Hom. : Pseudococcidae	*Leucaena, Albizia*	Szent-Ivany & Catley	1960
Planococcos citri (Risso)	Hom. : Pseudococcidae	*Erythrina, Leucaena, Tephrosia, Hevea*	Szent-Ivany	1956
Rhyparida spp.	Col. : Chrysomelidae			
Platyacus ruralis Faust	Col. : Curculionidae			
Pod feeders				
Amblypelta spp.	Heterop. : Coreidae	*Cocos*	Brown	1958
Helopeltis clavifer (Walker)	Heterop. : Miridae	*Pueraria, Flemingia, Eucalyptus*	Smith	1978
Pseudodoniella laensis Miller	Heterop. : Miridae			
Pseudodoniella pacifica China and Carvalho	Heterop. : Miridae			
Pseudodoniella typica China and Carvalho	Heterop. : Miridae			
Vertebrate pests				
Flying fox	Chiroptera : Pteropidae	*Ceiba*		
Parrots	Psittaci : Psittacidae	*Cocos*		
Rats	Rodentia : Muridae	*Cocos*		
Woodborers				
Glenea spp.	Col. : Cerambycidae			
Oxymagis horni Heller	Col. : Cerambycidae			
Neotermes spp.	Isop. : Kalotermitidae	*Leucaena, Gliricidia*	Smee	1963
Pansepta teleturga Meyrick	Lep. : Xylorictidae	*Casuarina, Ceiba*	Bailey	1978
Pantorhytes spp.	Col. : Curculionidae			
Zeuzera coffeae Nietner	Lep. : Cossidae	*Albizia* spp., *Crotalaria, Eucalyptus, Hevea*	Entwistle	1972
Pod rots				
Botryodiplodia theobroma		*Hevea*	Shaw	1963
Phytophthora palmivora (Butler) Butler		*Cocos, Hevea*	Shaw	1963
		Leucaena leaflets	Newhook & Jackson	1977

Table 1. Cont. —

Pest species	Order : Family	Shade tree as alternative host	Author and date
Stem cankers and diseases			
Corticium salmonicolor Berkley & Broome		*Cajanus, Cassia, Casuarina, Tephrosia, Erythrina, Flemingia, Leucaena, Hevea*	Shaw 1963; Zaiger 1968
Phytophthora palmivora (Butler) Butler		as above	
Seedling blight			
Phytophthora palmivora (Butler) Butler		as above	
Rhizoctonia sp.			
Vascular streak dieback			
Oncobasidium theobromae Talbot & Keane			
Root rots			
Phellinus (Fomes) noxius (Corner) G.H. Cunningham		*Leucaena*	Thrower 1965
Rigidoporus (Fomes) lignosus		*Albizia, Cassia, Cocos, Hevea*	Shaw 1963

Table 2. — **Expected effect of shade species on population levels of some cocoa insect pests**

Pest species	Coconut shade	Leucaena shade	Unshaded cocoa	Author	Date
Leaf defoliating caterpillars	Almost complete absence of pests	Very damaging levels of all four species	Except for *Achaea*, levels greatly reduced.	Dun Anon.	1967 1966
Rhyparida spp.	Almost absent	Almost absent	Damaging levels	Anon.	1965
Platyacus ruralis	Almost absent	Almost absent	Damaging levels	Dun	1951
Helopeltis clavifer	Populations generally small; causing no economic loss	Generally high and damaging populations	Highest population levels are found	Smith	1972
Neotermes spp.		Attack to cocoa frequently ascribed to presence of leucaena stumps		Anon.	1963
Pansepta teleturga			Damaging levels	Bailey	1978
Pantorhytes spp.	Generally small populations causing no economic loss	Populations frequently high and damaging to cocoa	Populations frequently very high and damaging	Hassan	1971
Zeuzera coffeae			Levels may increase as shade cover is reduced	Anon.	1965

with low incidence under coconut shade. In particular, populations of *Pantorhytes* (Hassan 1971) and *H. clavifer* (Smith 1981a) are generally small and rarely cause economic damage to cocoa. Room and Smith (1975) have demonstrated that a negative association exists between *Pantorhytes szentivanyi* Marshall and coconut shade.

Two species of nettle caterpillars which feed primarily on coconut fronds have occasionally caused localised (although severe) defoliation to cocoa on the mainland of Papua New Guinea, but these outbreaks have been shortlived and usually of only one generation. Only the vertebrate pests listed in *Table 1* as associated with coconuts have caused significant damage since they can feed on both pods and coconuts. However, the extent of damage has been no more severe than in sole planted cocoa. *Amblypelta theobromae* Brown (Heteroptera: Coreidae) the only coreid to cause significant damage to cocoa has not been recorded from coconuts; while those *Amblypelta* species which do promote coconut nutfall (Brown 1958) rarely attack cocoa pods.

Phytophthora palmivora (Butler) Butler has not been recorded from coconuts in this country since 1940 (Shaw pers. comm.) although the disease was originally described from coconuts and other palms in India (Thorold 1975).

Leucaena

Agronomically, this species appeared to be an ideal cocoa shade in Indonesia and Papua New Guinea, although it was generally unsuited to countries which have long dry seasons, since leucaena then seeds profusely and becomes very dense and difficult to eradicate (Chok 1970; Urquhart 1961). Prior to 1960 there appeared to be few disadvantages of using leucaena in Papua New Guinea, but since then it has become evident that many cocoa pests and diseases are associated directly or indirectly with this shade species.

Table 1 records a substantial list of pests and diseases associated with leucaena, including three defoliating caterpillars, *Neotermes* spp., root rot (*Phellinus noxius* (Corner) G.H. Cunn.) and *P. palmivora*. Dun (1967) reported that "as a result of the association of caterpillars and leucaena shade trees, there is a tendency to remove the latter to varying degrees up to complete removal" to prevent flush foliage damage. In addition, populations of both *Pantorhytes* (Bourke 1971) and *H. clavifer* (Smith 1981a) are at higher and more damaging levels under this shade than under the taller shade given by coconuts, rubber or thinned forest. A significant association between leucaena and *H. clavifer* has been shown (Room and Smith 1975).

Although cocoa swollen-shoot-virus disease has not been recorded in Papua New Guinea, two potential mealy bug vectors (*Planococcus citri* (Risso) and *Ferrisiana virgata* (Cockerell)) are present as minor pests of the crop. The latter has been recorded "in dense populations" from leucaena (Szent-Ivany and Catley 1960), while in Indonesia, Kalshoven and van der Vecht (1950) reported that leucaena was "a favourite host, and that crops grown with (it) are liable to suffer infestations" (from mealy bugs).

Thinned forest

Very few insect pests have been encountered in cocoa grown under thinned forest, but the root rots *Phellinus noxius* and *Rigidoporus lignosus* (Klotzsch) Imaz. spreading from forest trees and decaying stumps have frequently killed cocoa trees. Dun (1967) found that flush defoliating caterpillars were generally absent from the cocoa and populations of *H. clavifer* were very low compared to those under leucaena shade. In other countries however, cocoa pest attacks may be initiated from forest trees which remain after partial clearing (Conway 1971; Dadant 1953; Entwistle 1972;

Urquhart 1953). Growers with small landholdings frequently practice partial clearing since the cost of clearing is then considerably reduced, but the shade density cannot be manipulated accurately and damage to cocoa trees from falling branches is frequently encountered. Competition for moisture or nutrients may also be important and yields are frequently very low.

Gliricidia sp.

Apart from *Neotermes* spp., no important pest and disease associations with this shade species have yet been encountered in Papua New Guinea, but several have been recorded elsewhere (Brown *et al.* 1967; Conway 1971; Entwistle 1972, Shah 1976). This species required a considerable amount of management to maintain suitable shade density and was susceptible to wind damage. It was however highly attractive to *Anoplolepis longipes* (Jerdon), (Hymenoptera:Formicidae) which are recommended in some situations for the control of *Pantorhytes* in cocoa (Baker 1972; Room and Smith 1975; Smith 1981b).

Other shade species used

Various other species including *Albizia* spp., *Casuarina equisetifolia* L., *Ceiba pentandra* (L.) J. Gaertner (kapok), *Erythrina* spp., *Eucalyptus deglupta* Blume and *Hevea brasiliensis* (Willd. ex Adr. de Juss.) Muell.-Arg. (rubber) have been tested as a source of permanent shade for cocoa in Papua New Guinea, but each has one or more agronomic disadvantages and is associated with at least one of the major cocoa insect pests or diseases found there. For instance, *C. equisetifolia* is a host of *P. szentivanyi* (Smith 1981b); *E. deglupta* is a host of *H. clavifer* (Smith 1978) and *H. brasiliensis* is a host for two defoliating caterpillars and no less than seven diseases of cocoa (Shaw 1963).

IMPLICATIONS FOR COCOA GROWING IN PAPUA NEW GUINEA

Although economic chemical control of all the pests and diseases mentioned in *Table 1* (with the exceptions of *Pantorhytes* spp. and *P. palmivora*) is possible, it is desirable that input of pesticides to the cocoa ecosystem be kept to a minimum. If populations and inoculum levels of cocoa pests and diseases could be reduced and maintained at a low level by a combination of cultural, and biological controls and limited pesticide useage, then the resultant damage to the cocoa could be below the level at which production loss occurs.

An integrated approach to pest management in Paua New Guinea, which incorporates the selection of shade species and shade densities, the spot treatment of borer channels with penetrant insecticides and the introduction of antagonistic ant colonies was recommended by Smith (1981c) and is being carried out on some plantations on the Gazelle Peninsula.

The information presented in *Table 1* indicates that many of the major pest and disease problems of cocoa in Papua New Guinea have been caused by the use of leucaena as a source of permanent shade and Room and Smith (1975) recommended that this practice be stopped.

The practice of interplanting cocoa beneath coconuts appears ideal for Papua New Guinea and should be actively promoted since general pest and disease problems are fewer in these situations, and the management and economic advantages are significant. Papua New Guinea is currently embarking on a replanting scheme using locally produced, very high yielding hybrid coconuts and selected budded or hybrid cocoa. Research efforts to determine spacing and fertiliser requirements for hybrid palms and the optimum time for interplanting with cocoa should begin as soon as possible.

Current recommendations suggest that growers who are prepared to use fertilisers and are capable of dealing with likely pest problems should remove all shade once the canopy closes, while growers who are not likely to use fertilizer should retain overhead shade of medium densities, eg. leucaena at about 200/hectare. Given the cocoa pest problems associated with leucaena shade, the findings that *Pantorhytes* spp., *P. teleturga* and *H. clavifer* are all most damaging in unshaded cocoa and that the first two pests are so difficult to control, it is suggested that these recommendations be changed and that the replacement system of interplanting cocoa under hybrid coconut palms be intensively investigated.

CONCLUSIONS

Cocoa culture in Papua New Guinea during the past 30 years has been beset with pest and disease problems which were largely unknown, or at least only minor, prior to World War II, when almost all cocoa was planted beneath coconuts. It is believed that many of the present day problems are due to the widespread use of leucaena as a shade tree. Leucaena is a host for many major cocoa insect pests, and being a low growing tree, its canopy is frequently contiguous with that of the cocoa growing beneath it. This allows easy access of pests to the cocoa and reduces the air movement directly above, within and below the cocoa canopy, thus favouring the build up of diseases.

Unshaded cocoa, although known to give maximum yields if fertilised adequately, is very susceptible to attack by several pests which are extremely difficult to control, and should not be recommended except under very intensive management. Although many other species of trees have been tested as cocoa shades, none have been as suitable as coconuts, under which a low pest and disease incidence is generally found.

It is suggested that recommendations to grow cocoa in unshaded or leucaena shaded conditions, should be changed and that new recommendations incorporating cocoa interplanted under coconuts be promoted. Where cocoa is to be planted under older coconuts with large gaps in the canopy, gliricidia should be used, at least as a temporary shade. When more information on optimum spacing and fertiliser requirements for the newly developed, high yielding coconut hybrids is available, recommendations for the establishment of high yielding, disease resistant cocoa under palms three to four years old should be formulated. This latter dual cropping system would appear to be the ideal combination from both the agronomic and the pest and disease management aspect.

ACKNOWLEDGEMENTS

I am extremely grateful to my colleagues at L.A.E.S., Keravat, to J. Van S. Greve and to Professor M.J. Swift for constructive criticism of this manuscript.

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