ASPECTS OF THE CONTROL OF PREMATURE NUTFALL DISEASE OF COCONUT, *COCOS NUCIFERA* L., CAUSED BY *PHYTOPHTHORA PALMIVORA* (BUTLER) BUTLER

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INTRODUCTION

The coconut palm, *Cocos nucifera* L., sometimes sheds its fruits before they are mature. This phenomenon, often referred to as premature nutfall, can be due to a number of different causes. Normally, many fruit less than 2 months old are shed as a means overbearing (Menon and Pandalai, 1958; Sampson, 1923). Premature nutfall is induced by environtmental stresses such as inadequate or excess soil moisture, especally water logging and deficiencies of major nutrients (Menon and Pandalai, 1958). If fruit bunches are too heavy, their stalks can be damaged under the strain, and even buckle if the bunch stalk is too long and the leaf base too narrow to give them adequate support. The resulting interruption of sap flow leads to nutfall (Samson, 1923).

Pest such as *Amblypelta cocophaga* China (Lever, 1969) and *Eriophyes guerreronis* (Evans, 1973) can cause serious nutfall, and rat damage can have a similar efect. Premature nutfall has been associated with Lethal Yellowing disease (DJP, 1983; 1983a; Maramorosch and Hunt, 1981; Ohler, 1984) and in Indonesia, Natuna Wilt disease (Sitepu, 1979). in the 1920s, from Sri Lanka and India, there were reports of a premature nutfall disease caused by *Phytophthora* sp. (CPCRI, 1979; Menon and Pandalai, 1958) *Phytophthora omnivora* var *arecae* was said to attack not only coconut fruit but also the arecanut palm, *Areca catechu*, causing 'Koleroga' or 'Mahali' disease. Apparently, the leaf base and bunch stalk can also be attacked by *Phytophthora* sp. causing PND (Thampan, 1981). *Phytophthora heveae* causes premature nutfall of West African Tall and hybrid PB-121 coconut varieties in the Ivory Coast (Quillec, Renard and Chesquire, 1984). PND caused by *Phythophthora* sp. has led to heavy losses in the Philippines.

In Indonesia, premature nutfall has been associated with Natuna Wilt disease (Sitepu, 1979) and the presence of some fungi, namely, *Phytophthora* sp. in North Sumatra (Brahmana, 1985; Sitepu, 1984 - personal communication), and *Thielaviopsis paradoxa* (Dade) C. Moreau (DJP, 1983) which, it is thought, was responsible for the shedding of all nuts throughout 160 hectares of coconut-growing area in Bawean island from 1927-1929 (DJP, 1983a). In 1984 a previously unimportant premature nutfall caused significant yield reductions at the Coconut Research Institut (CRI) hybrid seed garden in North Sulawesi. The garden's Nias Yellow Dwarf (NYD) palms suffered the heaviest losses during the latter part of the rainy season. The condition was investigated and shown to be caused by *Phytophthora palmivora* (Butler) Butler. The present paper outlines the current status of research at CRI into this premature nutfall disease, with particular reference to its symptoms and impact, and how it should be controlled in the short and long term.

SYMPTOMS

1. Before Nutfall

1.1. External symptoms

Nias Yellow Dwarf (NYD) nuts (result of NYD x Tenga Tall = KHINA-1) greater than 2 months old are susceptible to PND. The first sign of disease on the nut surface (epicarp) is a small, irregular, light brown patch about 1 cm in diameter and watersoaked in appearance. This patch usually appears about halfway between the stalk end and nut apex. As it increases in size it becomes darker, and eventually sunken and dry, apart from an outer watersoaked area, i.e. the fresh leading edge of the lesion. The darkening lesion is sometimes surrounded by a narrow undulating light brown band. At a later stage, other similar lesion become apparent elsewhere on the nut. Nutfall usually occurs only after the lesion has reached the perianth generally the perianth remains attached to the inflorescence. The time from detection of first symptoms to nutfall is about 3-4 weeks but appears to be proportional to nut age, i.e. the shortes period being in the youngest susceptible nuts. At high levels of infection the entire bunch, including the infected and uninfected nuts and the bunch stalk, may fall.

In tall variety palms and imported hybrids, PB-121 (West African Tal x Malayan Yellow Dwarf), lesion development is commonly confined to the stalk end of the nut. Furthermore, the watersoaked marging of lesion is usually wider and more diffuse.

1.2. Internal symptoms

After initial nut infection, disease spread is more rapid and extensive within the tissues of the husk (mesocarp) than in the epicarp. Invaded husk tissues turn pinkish to yellowy brown and finally dark brown. The development of secondary lesions on the nut surface is often the result of internal infection spreading through the husk and periodically rising to the surface. The nut falls once infection has reached the stalk end of the nut. In nuts less than 9 months old at the time of infection, the developing shell (endocarp) and kernel (endosperm) are also often attacked. The shell turns brown prematurely, the seedcoat (testa) becomes grey and slimy, and the endosperm does not thicken but rimains soft and translucent. Such infection commonly starts between the stalk end and equatorial region fo the shell.

2. After Nutfall

2.1. External Symptoms

Following the first night after nutfall, white, fungal mycelium grows profusely on lesions adjacent to the perianth and within the perianth over the stalk scar. The fungus is virtually pure *Phytophthora palmivora* (Butler) Butler, and produces abundant sporangia and chlamydospores, on average 50-100 propagules/mm². When nuts with infected endosperms are cut open and left in humid conditions overnight, similar superficial *Phytophthora* growth occurs. *Phytophthora* mycelium has not been observed on attached nuts. Two to three days after fallinp, the presence of secondary fungal invaders of the nut becomes evident, e.g. *Colletotrichum* sp., followed by *Fusarium* sp., *Botryodiplodia theobromae* Pat. and *Thielaviopsis paradoxa* (Dade) C. Moreau.

2.2. Internal Symptoms

The endosperm of nuts attacked when 9 months of age of older remains uninfected after nutfall. Over an 8 month period, in an epidemiology trial for PND (see 5 below) endosperm infections were detected in 57% and 87% of 8½ and 6½ month old nuts, respectively, that had been shed prematurely. The infected endosperm of fallen nuts is often secondarily infected by bacteria.

CAUSAL ORGANISM

Phytophthora palmivora (Butler) Butler can be readily isolated from the fresh leading edges of husk, shell and kernel infections by means of direct aseptic transfer to tap water agar (CMS, 1983). Koch's Postulates have been established for this *Phytophthora* and Premature Nutfall Disease (PND), using mycelium-sporangia in plugs of potato carrot agar (CMS, 1983) applied to pre - wounded and unwounded healthy nut surfaces. This pathogenicity test was replicated 6 times, and conducted on 6 month old detached nuts, then repeated on attached nuts. Both inoculation techniques successfully led to typical PND symptoms. Lesion development following inoculation of wounded tissues was more rapid adn more often successful than from unwonded tissues. The Commonwealth Mycological Institute in the UK confirmed the identity of the *Phytophthora* and determined that it is morphological Form 1 (MF 1), mating A 1. the relationship between it and the *P. palmivora* causing but rot has not yet been resolved. A paper on the above and other etiological investigations is being prepared by the authors.

CROP LOSS ASSESSMENT

1. Relationship of Disease to Production Losses

Premature Nutfall Disease (PND) causes production loses in at least two ways:

a) The shedding of nuts before they are mature. The younger the nuts are when they fall, the less likely they will be of value for human consumption, copra preparation or seed puposes. Most nuts infected when less than 9 months old will fall prematurely.

b) The spoiling of the kernel. Nuts with infected kernels are unsuitable as seed, and yield inferior copra. They are not used for human consumption. In many nuts infected before they are 9 months old,. the endosperm will become invaded by the fungus.

Those nuts infected with PND but harvested before the infection can cause nutfall, i.e. before it reaches the stalk end of the nut, usually have healthy kernels. CRI is investigating the possibility that the germinating seed growing through and infected husk may be prone to attack by *P. palmivora*. Such a phenomenon might account for the occasional incidences of low seednut viability in hybrid nuts from the Paniki seedgarden.

Individual palms infected with PND may lose more than 75% of annual production, though ~~in~~ a coconut garden there tend to be 'hot spots' of such disease levels and hence lower overall losses. During an 8 month period in the NYD epidemoilogy trial mentioned above (also see 5, below) average losses attributed to PND were 75 nuts per palm (9.1 nuts/palm/month). The mean harvest was 3.8 nuts/palm/mo. Estimated, attainable production for the hybrid-producing NYD is 7-9 nuts per month. During the same period total hybrid seednut production for all 8140 NYD palms (including those of the epidemiology trial) was 177 801 nuts, i.e. 21.8 nuts per palm (2.7 nuts/palm/month). Observations of the seedgarden and comparisons with the epidemiology trial indicated that the principal cause of such low production was PND. It is estimated that PND in the seedgarden has caused production loses of at least 50%, equivalent to Rp 80.010.450, assuming the official sale price of Rp 450 per nut.

In a demonstration plot of 7 yeard old PB-121 hybrid palms at Pandu, North Sulawesi annual loss due to PND was estimated at 10 and 40%, outside and inside disease 'hot spots', respectively. Individual palms have suffered losses in excess of 65%. In the West Coast of Africa, a similar PND, caused by *P. heveae*, results in 10% - 20% annual losses (Manners, 1983) in particular areas.

2. Impact on National Production

At present there is not yet sufficient survey data available for a reliable estimate of the impact of PND on national production. Table 1, below, summarises the current information on the occurrence of PND in Indonesia (Results of CRI field observations).

Tabel 1. Premature nutfall disease attributed to *Phytophthora* sp. Field observations of losses in different coconut varieties.

Location	Coconut Variety	Estimated Loss, 1984 - 1985[1)]
North Sulawesi,	NYD	Heavy
Mapanget	NGD	Moderate
Mapanget	Raja	Moderate
Paniki	NYD (producing KHINA-1)	Heavy
Pandu	PB-121	Heavy
Pandu	KHINA-1	Slight
North Maluku	Local Tall	Moderate
Galela		

1) Losses: Slight = 5%, Moderate = 5 - 25%, Heavy = 25%

Bearing in mind that tall palms tend to be much more resistant to PND than NYD or PB-121 palms and that tall palms still predominate in Indonesia, it is likely that PND is of overall minor significance nationally, though locally it can be very important. In Galela, North Maluku, coconut farmers have described serious outbreaks of premature nutfall on local tall palms which were probably due to PND (Bennett and Hosang, 1985).

In the long term, PND may increase in importance as more of the susceptible PB-121 palms are planted as part of the Smallholder Coconut Development Project. Furthermore, tall palms adjacent to such PB-121 palms may be at greater risk to infection because of the high levels of disease inoculum arising from the more susceptible hybrids (see 1.4.,)..

EPIDEMIOLOGY

In August 1984 an epidemiology trial was strarted using 8 year old NYD palms (producing NYD x Tenga Tall = KHINA-1 hybrid nuts) in the Paniki seedgarden. It will trace the development of PND for a period of 2 years in order to study the effects of environmental factors which influence disease development and spread, e.g. climate, pests and other diseases. 20 palms were chosen at random within a 1 hectare area and all bunches older than 2 months were recorded for PND, pests and other diseases, every two weeks. This on-going trial includes records of nutfall and whether or not the endosperm of infected nuts has been spoiled. Rainfall, humidity, sunshine, and temperature data are collected from the nearby Sam Ratulangi airport meteorological station, and rainfall data also from Paniki itself. Information gathered from the trial should indicate the optimum timing for the application of control practices.

1. Disease Development

1.1 Effect of Climate

Outbreaks of PND caused by *Phytophthora* spp. have been associated with the onset of the rainy season. The 1984 outbreak of PND at Paniki also occurred during the rainy season Fig. 1 shows PND development in 8½ month old nuts over the period from September 1984 to April 1985. This period does not include the driest months of the year from June to August. Nevertheless there appears to be a tendency for the percentage of diseased nuts to increase after high rainfall and numbers of rainy days. Disease peaked in mid-March then declined after the onset of a dry period. The lag phase of disease, i.e. maximum disease occurring after maximum rainfall, may in part, be explaned by the effect of the incubation period for disease. Nutfall incidence peaked in late January. The incidence of infected but on the whole increased, going from 45% to 80% by the end of the 8 month period.

The detection of any meaningful trends in PND development with climatic factors will probably not be possible until there is at least a year's data from the trial. It is likely that rainfall interactions with humidity, temperature fluctuations and even sunshine determine both disease development (incubation period, time from first external symptoms to nutfall, infection of the kernel etc...) and spread (nut to nut and tree to tree). Population fluctuations of insect vectors (see 5.2, below) may also have an impact on disease. Data from the nearby Sam Ratulangi airport meteorological station on humidity, temperature and sunshine have not so far revealed a close relationship with disease. However, ideally such data should be taken from within the coconut crown dan the coconut garden area. Field observations together with climatic and disease data and comparisons with other *Phytophthora* diseases indicate that the optimum conditions for PND are cool, predominantly overcast rainy days, with high humidity.

1.2. Effect of Nit Age.

Although nuts older than 2 months can be attacked, and when attacked develop symptoms more rapidly than older nuts, the incidence of infection is higher amongst older nuts (see Fig.2). Symptoms of PND on 2½ month old nuts were uncommon and apparent only during the February recordings. The incidence of infection in 8½ month old nuts was much higher than in 4½ month old nuts. Future inoculation experiments should determine to what extant these age differences are due to inherent nut physiology and environmental factors, e.g. position in the crown or vector preferences (see 5.2).

1.3. Effect of Cultural Practices

The cropping system under coconuts may have an effects on PND spread and development. Mixed cropping with medium-stature perennials ang ground cover with annuals/biennials will increase humidity and therefore allow longer periods of moisture on the nuts, favouring *Phytophthora* infections. A cursory comparison of NYD and PB-121 with *Centrosema* sp. cover crop or general weed growth did not reveal any clear differences in infection levels, though there was a slight indications of lower infection where there was *Centrosema* sp. The effect of different fertilizer regimes on PND has not yet been studied. However, high nitrogen inputs could lead to more PND, but high K might reduce PND severity. Such fertilizer responses have been found in leafspot diseases.

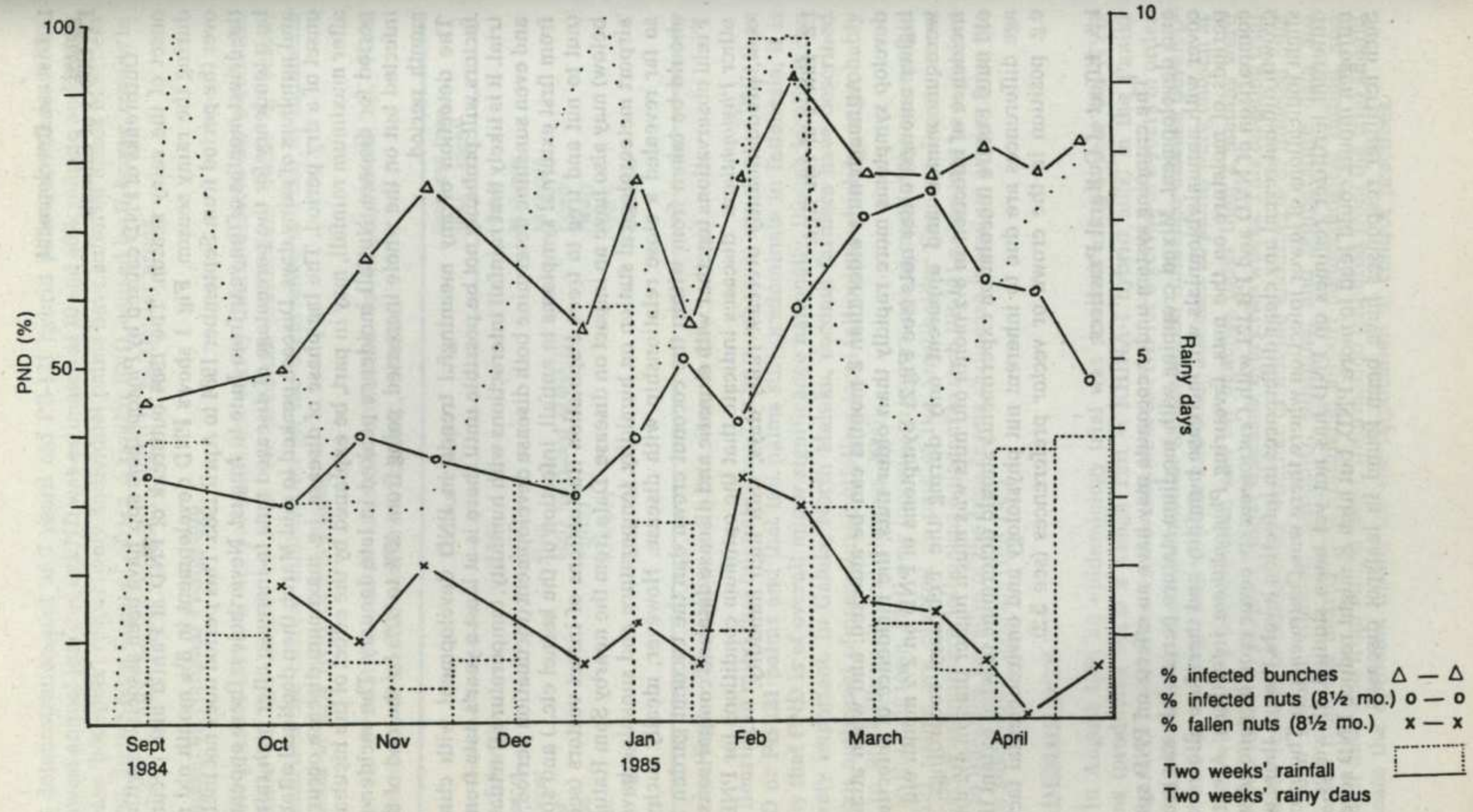

Fig. 1 Relationship of rainfall to the development of Premature Nutfall Disease

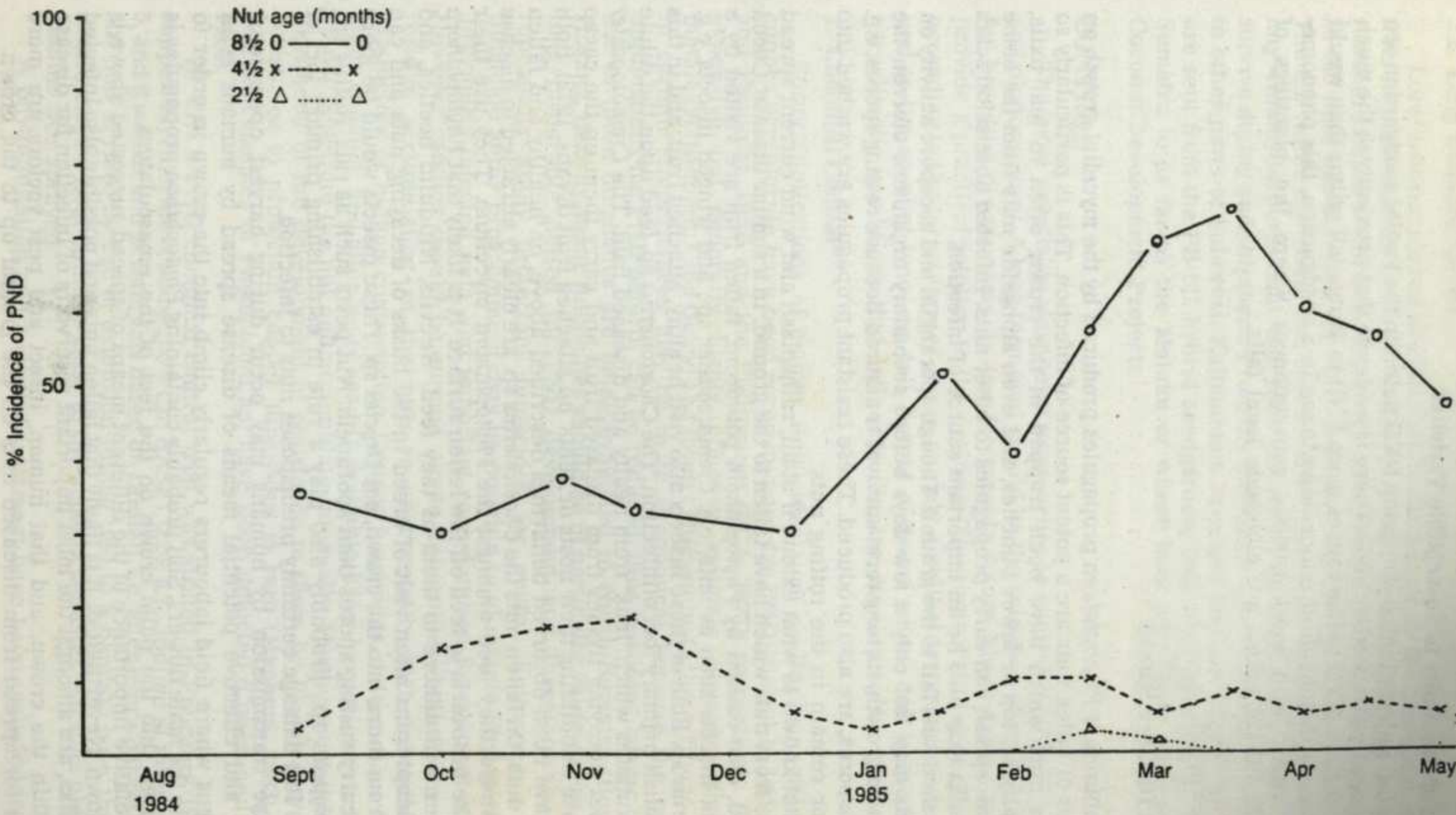

Fig. 2 Incidence of Premature Nutfall Disease in 8½, 4½, and 2½ month old NYD nuts

1.4. Effect of Proximity to Susceptible Varieties

Tenga tall palms planted alongside NYD palms in the Paniki seedgarden are also occasionally attacked by PND. There is evidence that proximity to the much more susceptible NYD palms causes more PND in Tenga tall palms than would normally occur. Although of minor importance in a seedgarden, this phenomenon may recur with more serious consequences where the plantings of susceptible PB-121 palms are alongside local talls.

2. Disease Spread

2.1. Short Distance Spread

The abundant *Phytophthora* propagules produced by the mycelial growth on the lesions of fallen nuts are a potent source of infection. This is particularly so for fallen nuts which have been trapped in the crown, often in leaf axils, occacionally on top of lower bunches, and even alongside nuts from the same bunch. Rainsplash can carry propagules to other nuts. Infected abscission scars on nut stalks may olso be an important source of infection.

Most shed nuts fall to the ground. Though sporangial and zoospore activity on fallen nuts may last only a few days before secondary organisms oferrun the *Phytophthora* growth, its long-term survival is assured because resting spores, e.g. chlamydospores, are also produced. These resistant propagules are washed into the soil or remain in the rotting nuts.

It is not known to what extent, if at all, rainsplash and wind current spread may occur from nuts which have fallen to the ground. In a similar disease, Cocoa Black Pod, also caused by *Phytophthora palmivora*, fallen fruit are visited by a number of insects such as ants, e.g. *Crematogaster* sp., and winged insects, e.g. *Chaetonerius* sp. Both of these insects also visit healthy, attached fruit, and in this way establish primary foci ofinfection. The *Chaetonerius* sp. feed upon the dilute sugary exudates which 'leak' from healty and diseased fruit. The *Crematogaster* ants gather decaying tissues from diseased fruit and carry them up the cacao tree for use in building their nests or 'tents' on attached fruit (Evans, 1973). Both insects have been observed behavings described above, on healthy and fallen diseased nuts. On fallen nuts the *Chaetonerius* sp. are clearly attracted to disease lesions where they feed amongst the *Phytophthora* mycelium. They use their sponge-like proboscis to feed off the lesion surface. It is likely that *Phytophthora* propagules will adhere to them as they feed. Weevils, Nitidulid beetles, and other Coleopterans often visit of breed in the husks of decaying nuts and can migrate from there into the crown, e.g. *Oryctes* sp. These insects would be more likely to carry resting spores than sporangia. Nut pests such as rats, *Rattus* sp., and *Amblypelta* sp., probably also play a role in establishing primary foci of infection. Rat damage certainly predisposes nuts to infection.

Disease transmission by humans may occur during harvest operations. However, and effective potential means of disease spread by humans is in seedgardens where field labourers regularly climb into the crown in order to emasculate the male flowers. Soil probably containing *Phytophthoa* propagules is often carried into the palm crown on the feet of the emasculators.

The relative importance of the different means of spread suggested above is not yet known. Nevertheless, it is likely that fallen nuts and possibly also infected bunch stalks, are amongst the most important reservoirs of infection for disease spred within the crown, and that human, insect and pest vectors are more important for spread from diseased nuts on the ground up to the crown.

2.2. Long Distance Spread

Long distance spread of PND may be facilitated by the transport of infected nuts from seedgardens. For 3 consecutive harvests at the Paniki seedgarden a random sample of 500 nuts (Snedecor and Cochran, 1973) per average harvest of 28 465 nuts was assessed for PND infection. 35 - 40% of the nuts were infected. Though viable mycelium and sporangia will no longer be present in dried nuts, any chlamydospores and oospores produced by *Phytophthora* will probably survive drying and shipment. From the Paniki seedgarden nuts are regulary sent to other_parts of Sulawesi. Kalimantan. Java and Maluku. If infected seednuts are sent from the PB-121 hybrid seedgarden, they too might spread PND from Sumatra to as far as the Maluku or where ever else there are Smallholder Coconut Development Projects.

CONTROL

The most promising short-term approaches to control of PND are chemical and phytosanitary. A long-term goal should be the selection of resistant varieties for breeding programmes. In the foresseable future bio-control is unlikely to provide a practical solution to the problem. The control strategies should differ according to the target farmer group, namely, smallholder, estate or seedgarden, and to the coconut type, e.g. tall, hybrid of dwarf palms, and to the particular agroclimatic conditions that influence disease development.

1. Chemical Control

Spray applications of copper fungicides such as Bordeaux micture and copper ocychloride have been recommended for PND control in India (Menon and Pandalai, 1958) and the Philippines (PCA, 1977), respectively. The more expensive but generally highly effective systemic phycomyceticides, e.g. metalaxyl (Ridomil: Ciba Geigy) and fosetyl aluminium (Aliette, Rhone-Poulenc), in certain circumstances may be more economical because the number of applications for PND control can be reduced, thus lessening labour costs. The use of these fungicides are being evaluated in North Sumatra (Bennett and Hosang, 1985) Systemic fungicides should be of particular value where there is a long favourable period for PND development and therefore the need to repeatedly apply protectant fungicides for contol. Following a systemic fungicide spray programme it may be possible to eliminate *Phytophthora* from previously infected nuts, and important consideration for seednut production. However, studies should be carried out to determine whether any fungicide residue accumulating in the nuts is unacceptably high for either copra production or human consumption. Copper fungicides, on the other hand, are much cheaper, and often more readily available. They have a long shelf life, but do not penetrate the nut and accumulate internally. Furthermore there is less likelihood of the development of resistance to them by *Phytophthora*. Fungal resistance to protectant copper fungicides is rare (Manners, 1983). Ridomil-resistant isolates of *Phytophtora* sp. have been detected (Cohen and Reuveni, 1983).

At CRI a PND chemical control trial was strated in February 1985, using copper oxychloride (Cobox , 50% Cu; BASF), 0,2% a.i., applied at intervals of 3, 4, 5, and 6 weeks, and at intervals based on rainfall, i.e. after every 200, 300, 400, and 500 mm of rain. By use of extension tubing tied to a bamboo pole, the sprayer nozzle can be held suitably close to the coconut bunches. All nuts older than 2 months are sprayed.

A phytosanitation and a control treatment have been included in the trial.

The palms in the trial are 8 year old Nias Yellow Dwarf planted on the square at 7 x 7 m (204/ha). A lever-operated manual knapsack sprayer (Solo) is used with a cone nozzle (flow rate 15 ml/sec). On average a tree takes 25 seconds to spray (35 seconds including walking between trees) with 1.5 g Cobox in 375 ml water, equivalent to 306 g Cobox in 76.5 litres water per hectare, at a spraying time of about 2 hours/ha, not including refilling and rest periods.

Table 2 shows the current status of the control trial in terms of percentage of infected nuts recorded monthly, starting with the first (pretreatment) record. Even at this early stage a positive effect is already apparent. Although it is too early to come to any definite conclusions, there is apparently a tendency for 3 and 4 week intervals to be more effective than 5 and 6 week intervals. Even only one application has apparently depressed disease development. Results from the epidemoilogy trial (see 5, above) indicated that disease activity declined in March, accounting for the decrease in disease levels in the control and phytosanitation treatments at the 3 rd record. Nonetheless, both are higher than the spray treatments. Positive effects, if any, from the phytosanitation treatment are expected in the longer term.

Spraying with copper fungicides will undoubtedly allow increased yields where PND is a problem. In the past at CRI control of PND on NYD has been reported using about 2.35 g Cobox per tree at a concentration of 0.3% w/v. During such routine spraying 150 palms are sprayed by one man in an effective working day of 5 hours (7.30 am — 12.30 pm). Thus, at Rp 6.500/kg Cobox and Rp 1.500/man day the cost per tree for one application is approximately Rp 25, at current prices and wages. The sale of one nut, Rp 450, will allow 18 applications per tree, i.e. a year of applications at 3 week intervals. (Over the 8 month period from September 1984 to April 1985 an average of 73 nuts was lost per tree in the NYD epidemology trial at Paniki). The total labour and fungicide cost is Rp 5.102/ha./ application.

Table 2. Control of premature nutfall disease with copper oxychloride, 0.2% Cu.

Treatment[1] (No. applications to 6 Apr.)	Mean percentage of diseased nuts≥ 2½ months old		
	Record-1 (7-9 Feb.)	Record-2 (8-9 Mar)	Record-3[2] (9-10 Apr.)
Time intervals			
1. 3 weeks (3)	9.4	6.0	2.0 a
2. 4 weeks (2)	9.0	5.4	2.3 a
3. 5 weeks (2)	7.5	5.3	2.4 ab
4. 6 weeks (2)	10.0	6.0	2.8 ab
Rainfall intervals			
5. + 200 mm (2)	6.0	3.7	1.9 a
6. + 300 mm (1)	7.8	6.4	2.6 ab
7. + 400 mm (1)	6.3	4.9	2.6 ab
8. + 500 mm (1)	7.9	5.3	2.9 ab
9. Phytosanitation (0)	6.3	12.0	6.3 c
10. Control (0)	10.0	12.2	5.4 bc

1) First spray application on 19 Feb. 1985.
2) Results of analysis of covariance using Record-1 data as the covariate. At P = 0.05, treatments with the same letter annotation are not significantly different from each other.

Costs could be further reduced by using lower flow rate nozzles, e.g. 1 ml/sec, and hence less water, allowing fewer fungicide mixing and sprayer-refilling times. The use of motorised knapsack sprayers would reduce actual spraying time; ultra low volume (ULV) attachments might also be effective, reducing volumes and even dosages, further still.

PND control by spraying of fungicides is only feasible for seedgardens and estates, and where are young or short-stature palms, such as dwarf varieties and some hybrids. Trunk injection, root infusion of soil applications of appropriate fungicides, e.g. Ridomil (Margot, 1980), are alternative approaches for palms too tall for spraying. Soil application is probably the most suitable chemical approach for smallholder farmers. The use of systemic fungicides to control Bud Rod or serious leaf spot diseases might also lead to PND contol, and vice versa. Attempts to control any one of the above diseases ought also to take into account possible effects on the others and prevent the need for separate control strategie. In most instnces in Indonesia, PND control by spraying from aricraft is unlikely to be cost-effective. Systemic fungicides would have to be used because the target, the nuts, would receive little cover in comparison with the leaves. The high cost could only be justified, if at all, in large estates with high-yielding palms or as part of an already-established programme of spraying from aircraft.

If ohterwise harmless insects are shown to carry disease their control by chemical means is not recommended. In order to be effective such control would probably also kill insect pollinators of the coconut, and other useful insects, e.g. natural enemies of coconut pests.

2. Phytosanitation

The smallholder farmer often has neither the means nor the knowledge to carry out chemical control measures. However, as the bulk of pathogen inoculum comes from within the diseased area and spread does not appear to be very rapid, crop sanitation (Manners, 1983) may provide at least a partial solution to the PND problem. Potential reservoirs of disease infection have been recognised, namely, fallen nuts and bunch stalks. Smallholders should be able to at least partially control disease by destroying or removing these infection sources. In seedgardens and estates this should be integrated with chemical control.

During the harvest, spadices devoid of nuts should be cut down, and fallen nuts trapped in the crown should be removed. The cut spadices and prematurely fallen nuts (split and left to dry beforhand) should be burned, ideally as fuel for copra-production units. Husks from harvested, infected nuts should also be burned. Carrying nuts from the palms to incineration sites may be too time-consuming for unassisted smallholder farmers. In such cases, fallen nuts should be split to encourage more rapid rotting.

3. Quarantine

P. palmivora may be ubiquitous in Indonesia, if different strains exist, shipment of infected nuts from one area to another could result in the introduction or aggravation of a PND problem. However, it has yet to be shown that nuts infected at harvest will remain infective after drying and transport. If such infectivity is proven, consideration will have to be given to ensuring that seednuts transported as whole nuts, are disease-free. Practical guidelines for quarantine may eventually be necessary.

4. Varietal Resistance

Systematic varietal screening for PND will shortly be started at CRI. Field observations have already given indications of resistance to PND. Some local tall varieties, appear to have moderate to high levels of resistance. In the CRI germ plasm collletion at Mapanget, North Sulawesi, NYD palms appear highly susceptible, whereas Nias Green Dwarf (NGD) and King Coconut (Kelapa Raja) are relatively less susceptible. NYD palms bearing KHINA-1 nuts appear to have similar levels of susceptibility as ordinary NYD. KHINA-1 palms, even when growing close to heavily infected NYD palms have not been observed with significant levels of PND. High levels of PND have been recorded on PB-121 hybrids in Pandu, North Sulawesi, in the vicinity of largely unaffected tall and KHINA-1 palms.

No categorical statements of varietal resistance should be made unless based on proper screening trials. These trials should ideally be conducted in the field on attached nuts because the abnormal physiology of detached nuts may influence normal resistance or susceptibility mechanisms. Comparisons should be made, therefore, between palms within statistically-designed trials. At present this is only possible for a limited number of varieties of coconut types. A further, important consideration for future screenig, is that the inoculation technique should be reasonably representative of that in nature.

Germ plasm surveys and collections should include records of any observed susceptibility to PND.

5. Control Strategies.

Based on the results of past and on-going investigations into PND at CRI, the control strategies, below, are suggested for smallholder farmers, estates, and seedgardens, as an immediate approach to PND control. The long terms strategy, also listed below, deals with the lines of investigation which could be pursued. Their overall aim is to determine the extent of the problem and to increase the efficiency of control practices, whilst reducing the reliance on chemical control.

5.1. Recommendations for control of PND in the short term

Type of Coconut Farm		
A. Smallholder	B. Estate	C. Seedgarden
CHEMICAL CONTROL		
1. —	1. Copper-based fungicide spray monthly during rainy season.	1. As 1B.
2. —	2. No systemics until residue aspects known.	2. Systemics may be used.
PHYTOSANITATION		
1. Remove and destroy fallen nuts and spadices devoid of nuts.	1. As 1A.	1. As 1A.
2. Destroy husks of harvested nuts.	2. As 2A.	—
3. Destroy discarded infected kernels and nuts	3. As 2A.	3. As 3A.

5.2. Long-term research aimed at control measures for PND

A. Smallholder	B. Estate	C. Seedgarden
	Type of Coconut Farm	
CHEMICAL CONTROL		
1. Evaluate fungicide application to soil, roots and trunk.	1. As 1A	1. As 1A
2. Screening of different fungicides Include residue studies for systemics.	2. As 2A	2. As 2A
3. Integration of control of PND and other fungal diseases	3. As 3A	3. As 3A
4. —	4. Evaluate low volume/ low dosage spray methods.	4. As 4B
5. Determine effect of fertilizer on PND.	5. As 5A	5. As 5A
PHYTOSANITATION		
6. Determine relative importances of infection sources, including other possible hosts.	6. As 6A	6. As 6A
7. Evaluate various phytosanitary measures.	7. As 7A	7. As 7A. Investigate infectivity of nuts after long-distance shipment and different storage times.
EPIDEMIOLOGY		
8. Studies to determine optimum timing for control practices.	8. As 8A. Devise observation methods for indications of appropriate control practices.	8. As 8B
9. Study the effect of distinct agroecosystems on PND	9. As 9A	9. As 9A
DISEASE RESISTANCE		
10. Resistance screening of recommended varieties and hybrids.	10. As 10A	10. As 10A. Resistance screening of hybrid parent palms, and palms in germ plasm collections.
SURVEYS		
11. Devise suitable assessment techniques for use in surveys.	11. As 11A	11. As 11A
12. Determine national status of PND by its inclusion in regional routine surveys.	12. As 12A	12. As 12A

SUMMARY AND CONCLUSIONS

1. Premature nutfall of coconut can be due to inherent physiological factors, stress, and attacks by pests and diseases. *Phytophthora palmivora* (Butler) Butler causes a premature nutfall disease (PND) in Indonesia. Its effects are premature nutfall and sopilage of the kernel. It may also lower nut viability. Yield losses from PND can be as high as 75% in individual palms and 50% for an entire garden.

2. Only nuts older than 2 months are attacked. 3 ton 4 weeks elapse from the first appearance of visible symptoms to the premature shedding of the nut. This period is directly proportional to nut age. However, older nuts are more commonly attacked. Nutfall occurs once infection reaches the stalk end of the nut. At high levels of infection the entire bunch, including the bunch stalk will often fall prematurely. The nut and bunch stalk may also be susceptible to attack by *P. palmivora*.

3. The causal organism of PND, *P. palmivora*, is readily isolated from the fresh leading edge of lesions in the husk and from the infected shell and kernel. Koch's postulates for *P. palmivora* and PND have been established, proving the cause and effect relationship between the fungus and the disease.

4. Outbreaks of PND are associated with the rainy seasons . Preliminary findings indicate that it is favoured by periods of overcast, humid, cool rainy days.

5. Sources of infection are fallen nuts, particularly those trapped in the crown, and probably nut stalks which have borne infected nuts. Observations indicate that the most abundant production of *P. palmivora* propagules occurs only after the nuts has been shed. It is thought likely that insects, rats and man can transmit PND. However, rainsplash of propagules from detached nuts probably plays the major role in the development of an epidemic. Long distance spread of PND may occur if infected seednuts are transported between provinces.

6. Chemical control of PND can be achieved by using systemic phycomyceticides, e.g. Ridomil, or protectants such as copper based fungicides, e.g. Cobox. Though systemics offer the greatest potential for disease control they should be used with caution until more is known about possible residue accumulation in nuts. Cobox can be applied as a spray when the nuts are accessible, e.g. dwarf or young palms. The cost per palm per application is Rp 25 in the CRI hybrid seed garden of Paniki where the sale price for one nut is Rp 450. Monthly applications using 0.4% w/v Cobox are recommended during the rainy season. The use of Ultra Low Volume (ULV) techniques, if effective, would reduce costs even further. Soil, root and trunk applications of systemic fungicides should be investigated. Such PND control could be integrated with control measures for other diseases, e.g. Bud Rot and serious leaf diseases. Increase in K fertilizer may reduce the severity of PND.

7. Phytosanitary practices may provide the only short-term solution to PND in smallholder gardens. Shed nuts, especially those trapped in the canopy, should be removed and destroyed, as should bunch stalks that have lost all their nuts. These activities would best be carried out during the harvest period. Discarded, infected husks from harvested nuts should also be destroyed. The plant material

to be destroyed could be used as fuel for copra-producing units. Phytosanitation ought to be integrated with chemical control in estates and seed gardens. The relative importance of different sources of PND infection should be determined. Long-distance shipment of nuts with infected husks should be discontinued if investigations show such nuts to be infective after transport.

8. Field observations have indicated that local tall variety palms have a high level of resistance to PND, as do the KHINA-1 hybrids. High susceptibility has been recorded in Nias Yellow Dwarf palms and imported PB-121 hybrids. PND may become more widespread as more areas favourable to PND development are planted with PB-121 hybrids, under the Smallholder Coconut Development Project. Germ plasm surveys should incorporate PND resistance/susceptibility characters. Resistance screening for PND must be based on the use of inoculation techniques that reasonably reflect the natural means of infection.

9. The economic prospects for coconut production and uses in Indonesia have recently been evaluated and recommendations have been made for strategies aimed at increasing national production and farmer incomes. The recommendations refer to the importance of pests and diseases (Asnawi dan Darwis, 1985). PND should be considered as one of the priority diseases. It is clearly a potentially major disease. PND can be controlled. However, research is needed to improve and develop control practices for the long term, appropriate to smallholders, estates and seedgardens under traditional cultural practices, recommended mixed-farming system and coconut culture in tidal swamp areas.

RINGKASAN DAN KESIMPULAN

1. Gugur buah muda pada tanaman kelapa disebabkan oleh berbagai faktor antara lain keadaan fisiologis tanaman, gangguan (stress) hama dan penyakit. *Phytophthora palmivora* Butler merupakan penyebab suatu penyakit gugur buah (PGB) di Indonesia. *P. palmivora* menyebabkan terjadinya gugur buah muda dan busuknya daging buah. Selain itu mungkin juga menyebabkan rendahnya viabilitas buah kelapa. Kehilangan hasil akibat PGB bisa mencapai 75% per pohon dan 50% untuk seluruh areal tanaman.

2. Hanya buah kelapa yang berumur lebih dari 2 bulan yang terserang. Buah akan jatuh setelah 3-4 minggu munculnya gejala visual pertama. Periode ini lebih pendek pada buah yang lebih muda. Namun demikian buah yang lebih tua yang lebih banyak terserang. Gugur buah akan terjadi setelah infeksi mencapai pangkal tangkai buah. Pada tingkat infeksi yang berat seluruh tangan termasuk tangkai tandan jatuh sebelum waktunya. Tangkai buah juga diduga peka terhadap serangan *P. palmivora*.

3. Organisme penyebab PGB, P. palmivora, dapat dengan mudah diisolasi dari batas perkembangan serangan pada kulit buah, dan dari tempurung atau daging yang tererang. Postulat Koch untuk *P. palmivora* dan PGB telah dilakukan. Hasilnya membuktikan adanya hubungan sebab akibat antara cendawan dan penyakit ini.

4. Menyebarnya PGB berhubungan dengan musim hujan. Kesimpulan sementara menunjukkan bahwa PGB menyebar lebih baik pada keadaan mendung dan lembab, dengan banyak hari-hari hujan.

5. Sumber infeksi adalah buah-buah kelapa yang jatuh, terutama yang tetap pada mahkota, dan kemungkinan juga tangkai dari buah yang gugur. Pengamatan menunjukkan bahwa perbanyakan propagul-propagul *P. palmivora* hanya terjadi setelah buah gugur. Tikus, manusia dan serangga dianggap dapat menularkannya. Percikan propagul-propagul oleh butiran curah hujan memegang peranan yang penting dalam penyebaran penyakit ini. Penyebaran PGB mungkin dapat mencapai jarak jauh bilamana benih kelapa hibrida yang telah terserang penyakit ini diangkut ke daerah lain.

6. Pengendalian PGB seara kimia dapat dilakukan dengan menggunakan phycomeceticides sistemik, misalnya Ridomil, atau protectan seperti fungisida "copper-based", misalnya Cobox. Meskipun fungisida sistemik memiliki potensi/ kemampuan yang besar dalam mengendalikan penyakit, namun dalam penggunaannya membutuhkan penyakit, namun dalam penggunaannya membutuhkan pengetahuan yang luas menyangkut kemungkinan terjadinya akumulasi residu dalam buah kelapa. Cobox dapat digunakan dengan jalan menyemprotkannya bila buah kelapa mudah untuk dicapai, misalnya pada kelapa genjah atau tanaman muda. Biaya aplikasi per pohon di Kebun Percobaan Paniki, Balitka (Balai Penelitian Kelapa, sebesar Rp 25, sedang harga kelapa per butir mencapai Rp 450. Aplikasi bulanan dengan menggunakan 0,4% b/v Cobox dianjurkan pada musim penghujan. Penerapan teknik Ultra Low Volume jika efektif akan mengurangi biaya aplikasi. Penggunaan fungisida sistemik melalui tanah, akar atau batang perlu diteliti. Sebaiknya dalam pengendalian PGB dapat diintograsikan dengan pengendalian terhadap penyakit lainnya, misalnya busuk pucuk. Peningkatan pemupukan dengan Kemungkinan akan dapat mengurangi serangan PGB.

7. Dalam jangka pendek penerapan praktek fitosanitasi di Perkebunan Rakyat merupakan cara utama mengendalikan PGB. Buah-buah kelapa yang telah terlepas dari tandan dan tersangkut pada mahkota pohon harus dikeluarkan dan dimusnahkan, demikian pula tandan yang telah kehilangan seluruh buahnya. Tindakan ini lebih praktis dapat dilakukan pada waktu panen. Sabut dari buah yang telah dipanen harus dimusnahkan. Diusulkan bahwa bahan tanaman yang akan dimusnahkan dapat dipergunakan sebagai bahan bakar dalam pembuatan kopra. Pada perkebunan-perkebunan besar dan kebun-kebun benih, fitosanitasi dapat dilakukan secara terpadu bersama dengan pengendalian secara kimia. Sumber-sumber infeksi PGB lain yang penting harus diketahui. Pengiriman buah kelapa yang telah terserang penyakit pada kulitnya harus dicegah jika penelitian menunjukkan bahwa buah-buah kelapa terserang yang akan diangkut tetap berjangkit sesudah pengangkutan.

8. Pengamatan di lapangan menunjukkan bahwa kelapa dalam lokal memiliki ketahanan yang tinggi terhadap PGB, sebagaimana yang dimiliki KHINA I. Sedangkan kelapa Genjah Kuning Nias dan PB 121 mudah terserang oleh penyakit ini. PGB mungkin akan menjadi masalah lebih penting apabila PB 121 disebar lebih luas penanamannya, sebagai bagian dari SCDP. Survai-survai plasma nutfah pada waktu-waktu mendatang harus terkait dengan pencarian sifat-sifat yang tahan atau tidak tahan terhadap PGB. Pengujian varietas yang tahan terhadap PGB harus dilakukan dengan menggunakan cara inokulasi yang dapat mewakili cara di alam.

9. Prospek ekonomi kelapa dan pemanfatannya di Indonesia telah dievaluasi sehingga berbagai rekomendasi dibutuhkan untuk menyusun strategi peningkatan produksi nasional dan pendapatan petani. Rekomendasi yang ada

menunjukkan pentingnya hama dan penyakit. PGB harus dipertimbangkan sebagai salah satu penyakit potensil untuk menjadi penyakit utama. PGB dapat dikendalikan. Namun, diperlukan penelitian lebih lanjut untuk memperbaiki dan mengembangkan teknik pengendalian untuk jangka waktu panjang yang sesuai untuk diterapkan di perkebunan rakyat, di perkebunan besar dan kebun benih yang dikelola secara tradisional, pola tanam campuran dan pengusahaan kelapa di daerah pasang surut.

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