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ORIGINAL PAPER

Knowledge through participation: the triumphs and challenges of transferring Integrated Pest and Disease Management (IPDM) technology to cocoa farmers in Papua New Guinea

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Abstract Income from cocoa is the main source of cash used to purchase food and services in many communities in the tropical lowlands of Papua New Guinea (PNG). Despite the availability of improved management technology, there has been poor transfer and uptake of these technologies among smallholder cocoa farmers, and potentially high bean yields and farmer incomes remain unrealised. A series of IPDM options that were shown to improve crop management and cocoa bean yield in research trials were demonstrated to farmers using an on-farm participatory approach that enabled farmers to evaluate the costs and benefits of each strategy before committing to adoption. The options were designed to provide several levels of entry to improved management, and ranged from no inputs (Option 1), manual inputs (Option 2: pruning, sanitation, weed management and regular complete pod harvesting), high level inputs (Option 3: pruning, sanitation, weed management, regular complete pod harvesting and fertiliser application), to intensive management (Option 4: pruning, sanitation, weed management, regular complete pod harvesting, and the application of fertiliser, fungicide and pesticide). Farmers from East New Britain, Madang and Bougainville, the three main cocoa growing provinces in PNG, participated in on-farm IPDM training and surveys to monitor changes in knowledge and management practice. Farmers opted in or out of the training as their commitments or level of interest changed, and new farmers joined in after observing changes in the cocoa blocks. Farmers were trained in epidemiology and crop management, were shown how to apply the IPDM inputs in their own cocoa blocks, and were given a simple training manual. Surveys conducted prior to, and 3 years after the training, showed an improvement in the farmers' knowledge of cocoa management and a better understanding of cocoa pest and disease epidemiology. Three years after the training, pest and disease incidence in participating cocoa blocks had declined and cocoa yields had increased by an average of 30%. Trained farmers were encouraged to demonstrate improved management to neighbouring farmers, and the program has now been officially adopted as the national strategy to improve cocoa production in PNG. The participatory approach is an effective way of disseminating information and technology to farmers, how-

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ever, it requires frequent follow-up visits by trained extension staff. We also discuss the significant challenges associated with conducting farmer surveys.

Keywords Cocoa · Integrated pest and disease management · Participatory action research · Farmer training · Learning-by-doing

Introduction

The sustainable generation of income from cash crops is fundamental to food security and access to education and health services for smallholder farmers in the tropics. Agriculture accounts for over 35% of Papua New Guinea's (PNG) Gross Domestic Product (GDP), providing a livelihood for more than 85% of the population (Asafu-Adaje 1996). Cocoa is the third most important agricultural export crop after palm oil and coffee, contributing 14% of the national agricultural export revenue (Allen et al. 2009). Ninety percent of this cocoa is produced by more than 150,000 smallholder farming families, primarily in the tropical lowlands of East New Britain Province (ENBP; 44% of national production in 2006), Autonomous Region of Bougainville (ARB; 31%), Madang Province (MP; 8%) and East Sepik Province (ESP; 8%) (Allen et al. 2009). Production in ENBP declined significantly in 2009/10 due to the incursion and attempted control of Cocoa Pod Borer (CPB; *Conopomorpha crameriella*), although this has been offset by increases in production in ARB and ESP.

Although the smallholder contribution to cocoa production in PNG has increased steadily, coinciding with a decline in the plantation sector since the mid 1980s, the yields experienced by these farmers have remained stagnant at 200–400 kg dry beans ha^{-1}, despite the availability of improved planting material with the potential to yield up to 2500 kg ha^{-1} year^{-1} (Allen et al. 2009; Efron et al. 2005; Godyn 1974). The low yields are, in part, a reflection of inadequate disease control and block maintenance, insufficient inputs, such as fertilisers to replace soil nutrients, limited availability of labour and land, lack of information, few trained extension staff and the failure to effectively transfer and promote the adoption of new technologies (Curry et al. 2007; Omuru et al. 2001; Smith 1981).

Cocoa production is a significant source of cash income for more than 31% of PNG households (Allen et al. 2009). An estimated 24% of food protein requirements in PNG come from imported food, particularly rice and wheat, purchased using income from cocoa and other cash crops (Allen et al. 2009). In addition to the importance of cocoa as a source of income for food purchases, it is often regarded as an 'ATM' (automated teller machine) that is visited when cash is required to meet commitments such as school fees, medical expenses, church contributions, social celebrations and customary obligations. Cocoa is also grown as a means of securing 'ownership' of land and acquiring a social standing or status (Curry et al. 2007). PNG smallholder farmers are price responsive, investing more time and money into cocoa when prices increase. In assessing grower practice, Omuru et al. (2001) reported that many farmers invested few or no inputs towards disease management, and that productivity would be improved by fostering farmer adoption of low to medium cost management options along with the uptake of cultivars with resistance to disease.

Over the past three decades successive surveys and reports have identified constraints to improved cocoa production (Fleming and Lummani 2001; Ghodake et al. 1995; Godyn 1974; Holderness 1992; Omuru et al. 2001; Yarbro and Noble 1989). Despite an awareness of the issues faced by farmers, no new technology has been successfully introduced to reverse the low productivity experienced. Long-term research into cocoa breeding, agronomy and pest and disease management at the PNG Cocoa Coconut Institute Limited (CCIL) has had little impact on improving national cocoa yields, due largely to ineffective extension and consequent low uptake of new technologies (Asafu-Adaje 1996; Smith 1981). Although the national government introduced the Smallholder Cocoa and Coconut Rehabilitation and Expansion Program (SCCREP) in 1987 in an effort to improve cocoa and coconut productivity through the rehabilitation of senile trees, block expansion and a provincial extension package, production did not increase. Clearly, a new approach to technology transfer was needed.

More than three decades ago Godyn (1974) reported that extension officers lacked specialised skills to pass onto farmers and recommended that extension staff should receive specialist training after graduating. Godyn (1974) also recommended that a larger proportion of agronomic research be conducted on cocoa at the smallholder level. Despite years of investment in extension services, there remains a lack of understanding and skills of pruning, shade management and pest and disease control practices amongst smallholder farmers. The role of extension officers has been largely to oversee the logistics of farmer training by research staff, with the extension staff having little idea of what is being taught to the farmers.

In 2003 a National Cocoa Summit of PNG industry stakeholders set a target of 100,000 tonnes of dry bean production by 2012, a significant increase from the plateau level of 40,000 tonnes per year achieved over the previous few decades. The summit considered crop protection as a critical priority for the cocoa industry. A National Extension Summit in 2004 highlighted the broader deficiencies in information dissemination and agricultural extension that have hindered the delivery of improved technologies first reported by Godyn (1974). It was proposed that with an appropriate extension program, tailored to meet the range of circumstances and capacities experienced by smallholders, significant increases in cocoa yield could be realised without the need to increase the area of land under cultivation (Curry et al. 2007). Adapting and disseminating technologies to farmer circumstances has been challenging (Snapp et al. 2002). Understanding the constraints faced by farmers with few resources could improve efforts to develop and disseminate appropriate technology. Extension through participatory research and on-farm demonstrations has been shown to be a practical, cost effective means to involve farmers and disseminate technology (Olanya et al. 2010).

In 2005, with funding from the Australian Centre for International Agricultural Research (ACIAR; www.aciar.gov.au), researchers at CCIL compiled a package of integrated pest and disease management (IPDM) options for sustainable cocoa production by smallholders (Konam et al. 2008). The low, medium and high input options were designed to cater for smallholder farmers from a range of backgrounds and resource capabilities. This package formed the basis of an on-farm training program that aimed to improve cocoa production and farm incomes. IPDM information and technology was extended to farmers using a participatory approach, improving the link between the research institute, extension staff and the farming community. The program aimed to foster the evaluation and adoption of the IPDM strategies in partnership with smallholder farmers. Farmer surveys were conducted in order to gauge the effect of the participatory strategy for technology transfer. This paper describes the changes in farmers' socio-economic and agricultural characteristics, skills and knowledge in the 3 years following the introduction of IPDM options to smallholder farmers in the three major cocoa growing provinces in PNG. The challenges faced in implementing such a program, and conducting surveys, are also discussed.

Methodology

Documentation of industry and farmer knowledge, skills and attitudes

Existing cocoa industry knowledge and farm management practices were documented from consultation, discussion and surveys at a stakeholder workshop held in November 2005 and from in-depth farmer surveys in 2005 and again in 2008.

A stakeholder workshop was held in ENBP over 2 days in November 2005 to identify the key constraints on cocoa production, to ascertain the main priorities of the cocoa industry, and to understand the current level of farmer knowledge and attitudes to disease and farm management strategies. Presentations made by cocoa industry representatives and scientists were followed by small-group discussions, vigorous debate and questions. Current farming practices, constraints to production, the main pest and disease problems, industry priorities, IPDM options and on-farm trials were discussed. At the end of the workshop the key constraints and industry priorities were collated and used to compile IPDM packages and plan for their dissemination.

Farmer surveys

Baseline economic, social and farm management data were collected from cocoa farmers in nine villages, in ENBP (Tokiala, Kareeba, Bitagalip), MP (Galeg, Kaul, Waden) and ARB (Buka, Tinputz, Arawa) prior to IPDM training (Table 1). Survey questions were based on those developed by Omuru et al. (2001) for collection of data from smallholder cocoa farmers in ENBP, with additional pest and disease management questions relevant to the IPDM program. Staff from the Pathology Section of CCIL conducted the farmer surveys, staying with farmers in each village for up to 3 days to obtain data through a combination of observation, unstructured conversation and direct questioning. The baseline surveys determined the farmers' existing level of knowledge of cocoa husbandry, farm management practices, levels of disease in the cocoa block as well as social and economic status. Information from the baseline survey was used to guide the development of strategies to enhance farmer adoption of improved farm management strategies and to select farmers and villagers to be involved in the participatory on-farm trials.

A follow up survey was conducted in each village during November 2008 in ENBP and MP, and in March 2009 in ARB, to evaluate changes in farmer knowledge and practice following the extension, implementation and adoption of the IPDM technology. Comparison of baseline data with data collected in the follow-up survey allowed the short-term changes in socio-economic activities and productivity to be assessed.

Integrated disease management options and establishment of on-farm trials

A 'menu' of disease management options was developed based on research conducted at CCIL (Table 2; Konam and Guest 2002, 2004; Konam et al. 2008). The options were designed so that they would be accessible to farmers facing a range of social and economic circumstances. The application of inputs and activities were scheduled according to the cocoa cropping cycle.

The establishment of on-farm trial plots in the selected villages commenced in March 2005. Following presentations and discussions to inform farmers of improved cocoa management and the IPDM options by CCIL staff, 12 farmers in each village volunteered, or were selected by the village elders, to participate in the survey and in

Table 1 Characteristics and background of sites at which surveys were conducted and on-farm trials were established in each of three cocoa provinces in PNG

Province	Village	Characteristics
East New Britain	Tokiala	Villages were all within 60 min drive of CCIL
	Kareeba Bitagalip	Continuous large investment in cocoa research and development since LAES in 1920s, Department of Agriculture and Livestock (DAL) to the Cocoa Industry Company Limited (CIC; Research Arm of the Cocoa Board, 1983–1986), CCRI in 1986
		Good infrastructure for transport, sale and export of cocoa
		Land ownership is maternal which has led to fragmentation of landholdings
		Production affected following CPB incursion in 2006 and attempted eradication program ("rampasan")
Madang	Galeg Kaul (Kar Kar Island)	Three agronomically distinct localities: Galeg is 40 min by plane or 3–5 h by banana boat on the Rai Coast, Kar Kar Island is 20 min by plane, or 3 h by banana boat and Waden is approximately 2 h by car from Madang town.
	Waden (north coast of Madang)	CCIL's Stewart Research Station (SRS) is mostly focused on coconut research and development
		Infrastructure for transport and sale of cacao beans varies across the Province
		Land ownership is paternal
Bougainville	Buka (Malasang) Tinputz	Villages were located on Buka Island and the northern half of Bougainville Island: Malasang is approximately 30 min drive from the CCIL station on Buka; Tinputz was a cocoa plantation area prior to the Bougainville crisis and is approximately 2 h drive from Kokopau (Buka-Bougainville channel crossing); Arawa was the mining hub in the centre of Bougainville and was the largest town on Bougainville prior to the crisis. It is approximately 5 h drive from the Buka-Bougainville channel. The CCIL station at Buka has a cocoa nursery and sells planting material. CCRI's Duncan Research Station ran on Bougainville Island from 1986–1989 until the crisis. A DPI office was established in Arawa in 2008.
	Arawa	Much infrastructure for transport and sale of cocoa, particularly on Bougainville Island, was destroyed during the crisis (1988–2001).
		Farmers in southern Bougainville more entrepreneurial than Buka Islanders
		Mission schools meant that Bougainvillians were highly educated until the crisis.
		Queen Emma, who introduced cocoa to PNG, had a plantation in Buka

the establishment of participatory on-farm trial plots. Each plot was established in partnership with farmers and provincial extension personnel. They included all four IPDM options and were designed to serve as a focal point for later extension activities (Guest et al. 2010). The four options were established side-by-side, located beside roads, paths or frequently visited sites such as schools and churches, to improve their visibility to the

Table 2 Integrated pest and disease management options developed for cocoa farmers in PNG (Konam et al. 2008)

Option	Input level	Activity	Aim
1	Low	• Current practice (little to no input, visit primarily for harvest)	• Convenience, cash when required by farmer
2	Medium	• Cocoa and shade tree pruning	• Increase flowering
		• Regular, complete harvesting • Sanitation	• Reduced disease pressure
		• Manual weeding	
3	High	• Cocoa and shade tree pruning • Regular, complete harvesting	• Increase pod production
		• Sanitation	
		• Weed management	
		• Fertiliser/manure application	
4	Maximum	• Cocoa and shade tree pruning • Regular, complete harvesting	• Protect developing pods
		• Sanitation	
		• Weed management	
		• Fertiliser/manure application	
		• Targeted pesticide applications	

local community. In exchange for training, each IPDM farmer agreed to train a further 12 farmers who were then known as the extended IPDM farmers or ‘disciples’, after which the initial model farmers became ‘apostles’ (these more familiar hierarchical terms were introduced by the villagers). Each village was visited at least once a year, some more frequently, by project and CCIL staff to interact with farmers and offer advice.

Data analysis

Survey data was analysed using IBM SPSS Statistics 18 (SPSS Inc. IBM Company Headquarters, Chicago, Illinois, USA). Data collected from the nine villages in the three provinces were combined for statistical analysis. Where data is presented as a percentage, it indicates the valid percent. This means that where responses to particular questions from a given farmer were not provided for both the baseline and follow up surveys, the data were excluded from the analysis. The McNemar, marginal homogeneity and Wilcoxon signed rank tests were used to test for significant differences between responses in the baseline and follow up surveys at the 0.05 level.

Results

Outcomes of the stakeholder workshop

Over 300 cocoa industry stakeholders from across PNG attended the 2 day workshop, including members of the national industry regulator, the Cocoa Board, representatives from government organisations, private industry and farmers. The key issues that arose from discussions included: (a) a distinct lack of cocoa management skills amongst cocoa farmers, (b) high crop losses despite the existence of recommendations for control, (c) a lack of adoption of new technologies, (d) the requirement for a new method to deliver new information and technology to replace the current ineffective, inadequate or non-existent extension system and (e) that high quality planting material and effective technologies had been developed by CCIL but were not being disseminated to the farmers or extension agencies.

Socio-economic and agricultural characteristics of the survey respondents

A total of 96 IPDM farmers were interviewed during the baseline survey in March 2005. Eighty-eight farmers were interviewed in the follow-up surveys in November 2008 to March 2009. Because of the low number of responses for corresponding questions in both surveys, it was not always possible to analyse the data for each province separately. Of the initial 96 IPDM farmers who participated, 88% were male and 12% were female (Table 3). All surveyed farmers in MP were male, while in ENBP and ARB 89% and 79% of participants, respectively, were male. The dominance of males is consistent with the observation that men tend to focus on cash-generating activities while women concentrate on growing vegetables for domestic consumption.

Farmer age ranged from 19 to 68 years, with the average being 37.6 years (Table 3). The oldest farmers were in ENBP (40 years), followed by ARB (38 years) and MP (36 years). There were six members in an average household, and this did not differ significantly among provinces (ENBP=5.1, MP=6, ARB=5.8; $p>0.05$). The majority of farmers lived on, or within walking distance (20 min), of their cocoa block (Table 4).

Most farmers in ENBP and MP (87.6% and 67.6%, respectively) only owned one cocoa block, while in ARB 25% of farmers surveyed owned a second block. Thirty five percent of all respondents had planted more than 1 ha with cocoa. However, the same percentage of respondents had fewer than 300 trees (the recommended planting density is 625 trees ha^{-1}). The structure of this question and the choice of possible responses on the questionnaire made it difficult to interpret the responses. Thirty-seven percent of the baseline respondents had been farming for less than 5 years, 39% had been farming for between 5 and 10 years, and 24% of respondents had been farming for more than 10 years (Table 4). More farmers in ENBP had been farming for longer than farmers in the other provinces.

Other sources of income

Twenty-six percent of farmers had an occupation other than farming in 2005, including tradesman (electrician, carpenter),

Table 3 Combined household characteristics of smallholder cocoa farmers in East New Britain, Madang and Bougainville in 2005

	Variable	Mean	Median	% Respondents	*n*
Gender	Male			87.9	66
	Female			12.1	
Age (years)	Mean	37.7	36		64
Marital status	Married			80.3	66
	Not married			19.7	
No. of family members		5.8	6		66

Table 4 Combined agricultural profile of smallholder cocoa farmers in East New Britain, Madang and Bougainville in 2005

	Variables	Mean	% Respondents	*n*
Live on cocoa block	Yes		44.6	65
	No		55.4	
Years of farming	<5 years		36.9	65
	6–10 years		38.5	
	11–20 years		10.8	
	all my life		13.6	
No. of blocks owned[a]		1.5		63
	1		66.7	
	2		19.0	
	3		11.1	
	≥4		3.2	
Distance to first block	walking distance (<20 min)		69.4	62
	half day walking		6.5	
	reachable by car		24.2	
Area planted (first block)	<300 trees		35.1	57
	300–500 trees		12.3	
	> 500 trees and <1 ha		17.5	
	>1 ha		35.1	
Planting material	SG1 hybrid seedlings		6.1	66
	SG2 hybrid seedlings		27.3	
	Hybrid clones		10.6	
	Farmers selection		22.7	
	Mixture of the above		25.8	
Occupation other than farming	2005		25.5	51
	2008		17.6	
Intercropping	Yes		80.6	36
	No		19.4	

[a] Owned, leased, or shared

community services (health worker, church leader or teacher, school chair person), fisherman, clerk, and security services (Table 4). Many jobs were unpaid services to the community. Additional jobs were more common in MP (45.9%) than in ARB (36.1%) and ENBP (18.7%). The total number of IPDM farmers that had another occupation declined to 18% in 2008. Eighty-one percent of farmers intercropped their cocoa, providing food or an additional source of income (Table 4). The most common plants that were intercropped were coconut (64%, including fresh coconut and copra), banana (28%) and vanilla (8%). The crops (other than cocoa) that were most commonly grown across all provinces to provide additional income were coconut and copra, food crops for selling at market stalls and betelnut (*Areca catechu*) (Fig. 1). Other crops include banana and fibre crops.

Cocoa planting material

Hybrid planting material, most commonly sourced from CCIL or the Department of Primary Industry (DPI), was the preferred planting material of 70% of cocoa farmers interviewed (Fig. 2; Table 5). In 2005, 22% of farmers reported that they also grew 'bush cocoa', a selection from their cocoa block. By 2008 none of these farmers still grew bush cocoa. A small percentage of farmers planted cocoa from a mixture of sources. The most common reasons why farmers preferred a particular type of planting material were ease of management and high productivity (production) (Fig. 3). 'Production' as a reason for preferred planting material declined as a selection criterion between 2005 and 2008, while growth habit and "other" became more important, reflecting an improved understanding of the importance of good management to yield. Smaller, more easily managed trees have been promoted since the incursion of CPB in ENBP, and many farmers reported higher yields despite the incursion of CPB, because they have improved the management of their trees.

The crop cycle

IPDM training included instruction on the timing of key events in the cocoa crop cycle, such as flowering time and peak harvest, and the timely application of management inputs such as pruning or fertiliser application. Knowledge of the cropping cycle was used as an indication that the farmer was applying IPDM inputs at the correct time. The

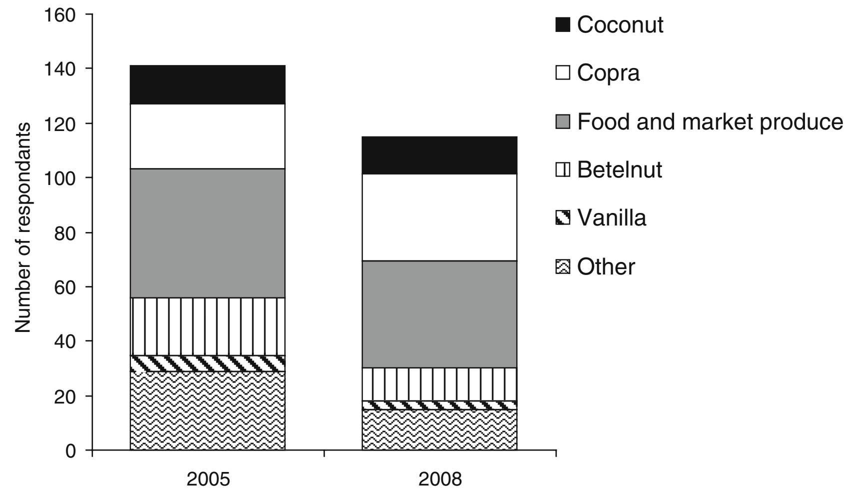


Fig. 1 Cash crops grown as a source of income by smallholder cocoa farmers in East New Britain, Madang and Bougainville (n=66). Data shown is the combined responses of three most common cash crops grown by each respondent so it does not add up to 100. Not all respondents listed three crops as a source of income. Crops recorded as 'other' included banana and fibre crops

number of farmers that understood the cropping cycle increased significantly over time (Table 6; p=0.000).

Pest and disease incidence

The incidence of pests and diseases in the farmer's cocoa block, as assessed by the interviewers, decreased over time with more cocoa blocks ranked as having a low incidence of pests and diseases in 2008 than in 2005 (Table 7). A lower number of cocoa blocks were given a high incidence disease rating in 2008 than in 2005.

Survey participants were shown photographs of a number of insect pests of cocoa and asked if they recognised the insect and if they thought the insect was a problem on their cocoa. The ability to recognise insect pests was significantly greater in 2008 (p<0.05) for all pests. The ability to recognise an insect as a problem to the cocoa crop also changed after training. In the 2005 survey, termites were identified as the most problematic pest, while three years after the introduction of IPDM farmers reported longicorns as being the greatest problem pest in the cocoa block (Fig. 4). As CPB was not recognised as a pest in 2005, and its distribution remains localised, it was not included in the surveys. However by 2008 the CPB insect was widely recognised by farmers in ENBP and ARB, where 44% of surveyed farmers recognised CPB and 37% implemented some sort of control measure.

Transfer of information

Prior to 2005, 46% of farmers knew that pests and diseases contributed to yield losses. However, when asked questions regarding specific diseases, the farmers' knowledge dropped to 12%. In 2005, information was obtained largely by observation (17%), by talking to other farmers (10%) and by attending field days (10%). Thirty-two percent obtained information from a range of sources and 31% reported no source of information.

In the follow up survey almost all farmers (95%) recorded IPDM training as their source of knowledge, most likely because they had all participated in the IPDM training. The second most common source of knowledge was observation. Prior to the IPDM training 52% of farmers knew that black pod, caused by *Phytophthora palmivora*, was a serious disease of cocoa because they had observed it

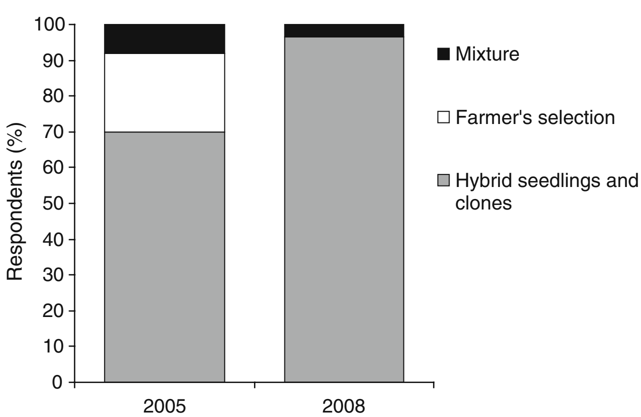


Fig. 2 The type of planting materials preferred by smallholder cocoa farmers in East New Britain, Madang and Bougainville in 2005 and 2008 (n=66)

Table 5 Source of cocoa planting materials of smallholder cocoa farmers in East New Britain, Madang and Bougainville (n=66)

Source	2005 (%)	2008 (%)
CCIL and DPI	60	59.7
Village nursery	14.1	7.0
Own seeds	17.2	3.5
Mixture	7.8	29.8

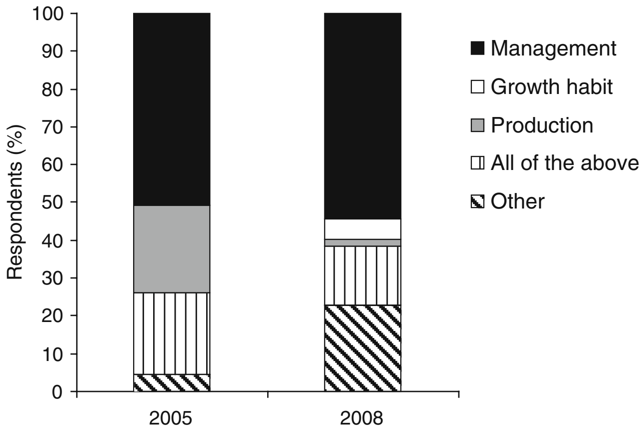


Fig. 3 Reasons for selecting a particular planting material given by smallholder cocoa farmers in East New Britain, Madang and Bougainville (n=66). Data are presented as the percentage of respondents who selected their cocoa based on ease of management, productivity, growth habit, all of the above, or other reasons

(Fig. 5) and 21% had discussed it with another farmer. Fifty two percent of farmers had observed that poor ventilation and high humidity increased the incidence and severity of black pod. It should also be noted that farmers often reported "all of the above" as a source of knowledge, suggesting that their information came from a range of sources (Fig. 5).

Training and extension

Forty one percent of respondents in 2005 had not been visited by an extension agent in the past year, 17% had been visited once, 5% twice and 1% had been visited more than twice in the last year (n=138). Despite this low frequency of visits, 15% of the respondents thought the visits had been good (7%) or very productive (8%), while 13% found the visits to be not productive (n=87). A small proportion of farmers had learnt cocoa husbandry skills such as grafting and pruning through field days held at agricultural research stations (DPI or CCIL) prior to the IPDM program (Fig. 6) but the majority of farmers had no knowledge of these skills. Since all farmers who were interviewed participated in the IPDM training, most reported that they had learnt the skills by the time of the follow-up survey.

Constraints to production

Lack of knowledge was a common constraint for farmers in 2005, however, after IPDM training this declined and lack of time emerged as a more common constraint. While the time available for IPDM activities was limited by the time needed for other activities such as commitments to other jobs, community or family, the change was not statistically significant because few respondents answered both surveys (Fig. 7). Other constraints included land shortages, lack of finance to buy materials for the cocoa farm including tools and planting material.

Cocoa yield

Following the implementation of IPDM training, the average yield of dry cocoa beans on farmer's blocks increased (p=0.052) by 218 kg ha^{-1} from 690 kg dry beans ha^{-1} to 908 kg dry beans ha^{-1}. Thirteen of the 18 respondents reported an increase in yield (72%), and one farmer (0.05%) had no change in yield during the course of the project. Four of the 18 respondents (22%) reported a lower yield in 2008 than in 2005. Three of these farmers were affected by the CPB incursion and eradication attempt in ENBP, while the fourth left his farm in ARB to become a cocoa extension officer.

Investment in cocoa producing tools

The number of bushknives (p=0.028), grassknives (p=0.013), axes (p=0.006) and cocoa hooks (p=0.021) owned by cocoa farmers increased between 2005 and 2008, and was used to indicate an investment by the farmers in cocoa and cocoa farming (Fig. 8), although many of these tools are multipurpose and can be used for other farming activities.

IPDM adoption

Although the participatory on-farm trial plots were established and maintained at no financial cost to the farmers, in several cases farmers were initially sceptical of the new technologies and recruitment of participants for the surveys and training was difficult. Data collected during the surveys was not sufficient to provide an indication of how many model IPDM farmers had

Table 6 Change in farmer's knowledge of the timing of the cocoa crop cycle over time (n=66). All changes are significant (p=0.000)

	2005 (%)	2008 (%)	Change over time (%)
Leaf flush	15.1	87	+ 71.9
Flowering period	23.7	89.1	+ 65.4
Ripening period	32.6	90.9	+ 58.3
Peak production time	34.1	87.5	+53.4

Table 7 Pest and disease incidence in the cocoa blocks of participating farmers over time (n=66). Pest and disease incidence was assessed by staff from CCIL conducting the surveys

	2005 (%)	2008 (%)	Change over time (%)
Low	20.0	47.4	+ 27.4
Moderate	20.0	43.9	+ 23.9
High	30.8	7.0	−23.8
Very high	27.7	1.8	−25.9

trained extended farmers. Many farmers trained their immediate family and friends, possibly as this was their main source of labour or because of cultural factors in the village clan structure. Families also visit each other on their farms, and will invite those with knowledge to train other family members. Other farmers were also keen to see results before they adopted the new technology. We observed that in many villages, additional farmers requested training from the model farmers and from CCIL to adopt the IPDM technology once they had seen the differences in their neighbours' blocks. A farmer in ENBP paid farmers from one IPDM village to come and train him. In Bougainville, two of the farmers who participated in the initial IPDM training have since been recruited by the ARB Department of Agriculture. One field staff member from CCIL in ENBP was recruited by a private company on Bougainville to train farmers in IPDM. Another member of the Plant Pathology Division at CCIL, ENBP, was funded by farmers from East Sepik Province to train farmers there. In this area, the farmers formed groups and trained as a cooperative. There is heavy demand on CCIL Pathology Staff for IPDM training in Farmer Field Schools set up by CCIL to manage the recent CPB incursion in ENBP. At least one private sector stakeholder, Agmark, has adopted IPDM for its "Training by Association" model that offers intensive training to farmers in ENBP, and other community and church groups have adopted IPDM to develop cooperatives to promote better cocoa management to smallholder farmers.

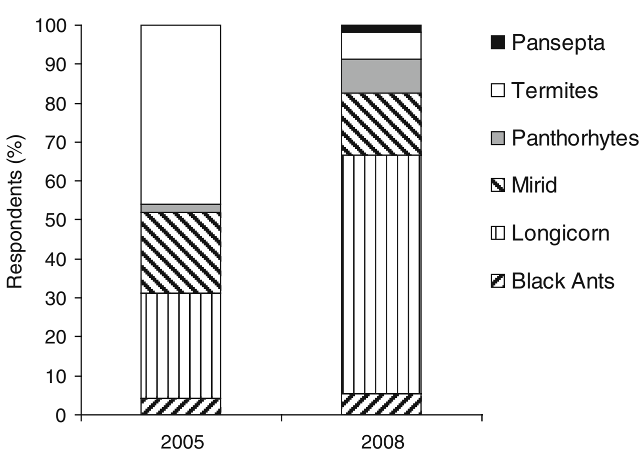


Fig. 4 Most problematic insect pest as determined by participating smallholder farmers (n=66). The insects identified by the farmers as the most problematic in the cocoa block changed significantly (p=0.00; Marginal homogeneity test) from termites to longicorns in the 3 years between surveys

The emergency declared after the incursion of cocoa pod borer in ENBP shortly after the on-farm trials were established led to difficulties with fund transfers to the provinces, disrupting the planned application of management inputs. Rampasan (radical pruning of all cocoa to eradicate CPB) was implemented in infested areas affecting many farmers in ENBP. As a result, apart from the initial establishment training during which Options 1 to 4 were set up and corresponding inputs applied, most participating farmers implemented IPDM Option 2, which did not require the purchase of inputs. Wealthy or entrepreneurial farmers often opted for the higher input options with greater financial commitments that they contributed themselves. In some cases, farmers also applied IPDM Option 2 inputs to those plots initially allocated for Option 1 when they observed that Option 2 resulted in better yields. "Option 5", a modification of Option 4 including targeted pod sprays for CPB, is now recommended throughout regions where CPB is present. These factors meant that corresponding yield data for individual options was not able to be collected and that data presented for disease incidence and yield applies to the overall cocoa block, irrespective of the option applied.

Discussion

Food security in the cocoa-growing provinces of PNG is based on the production of vegetables from village gardens, foraging for wild foods and the purchase of imported foods, particularly wheat and rice (Allen et al. 2009). Rising sea levels and El Niño-related droughts and unseasonal heavy rain shift the balance of food supply from gardening to foraging and imported foods, increasing the importance of cash crops including cocoa.

Despite the large efforts put into the development of new technologies for increasing incomes from cocoa production in PNG, uptake by farmers has generally been poor. Survey results indicate that most smallholder cocoa farmers in PNG lack a basic knowledge of cocoa management, a situation apparently unchanged for over 35 years despite the development of new pest and disease management technologies, the availability of improved varieties (Konam and Guest 2004; Smith 1981) and numerous surveys to identify the issues (Godyn 1974; Fleming and Lummani 2001; Yarbro and Noble 1989). A large part of the problem has been the lack of an effective extension service and the diversity of farmer backgrounds and circumstances. Extension in PNG is hindered by the tendency of staff to remain in their offices rather than actively engage with farmers because of their

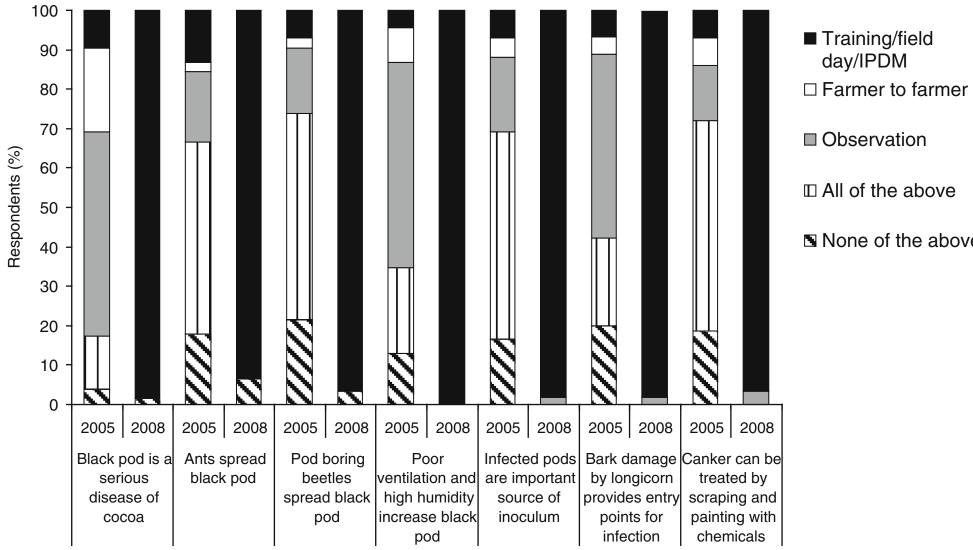


Fig. 5 Case study: The source of farmer knowledge about aspects of black pod disease in 2005 and 2008 (n=66). p=0.000

inadequate technical knowledge, funding shortages and logistical problems. We have shown that the gap between research outcomes and the application of technology in the field can be overcome by providing on-farm training in disease epidemiology and crop management to extension agents and farmers, and by offering a range of management options from which farmers can choose. What is essential is continued regular follow-up training and contact with farmers by well-trained, skilled extension staff. At this stage there is still a heavy dependence on the scientific staff to provide extension services as the IPDM program rolls out.

The start-up workshop provided a highly effective means by which to assess industry attitudes and create an awareness of the IPDM technology. The attendance of over 300 stakeholders from across PNG highlighted the interest and need for new management strategies and a new approach to technology transfer in the PNG cocoa industry. Interest was particularly high from Bougainville, where the civil crisis had recently ended, as well as New Ireland Province, which was not formally included as a project site, but where extension staff went on to successfully introduce the IPDM technology using the same participatory approach and self-generated funds.

A fundamental component of the participatory on-farm training approach to disseminate the IPDM technology is that the farmers evaluate and discuss the management options at the family and village levels, then select those practices that match their own needs and capacity, a strategy which was very effective. Family and community relationships are an important influence in the dissemination of agricultural technology (Ejembi et al. 2006). The availability of a series of options also meant that the

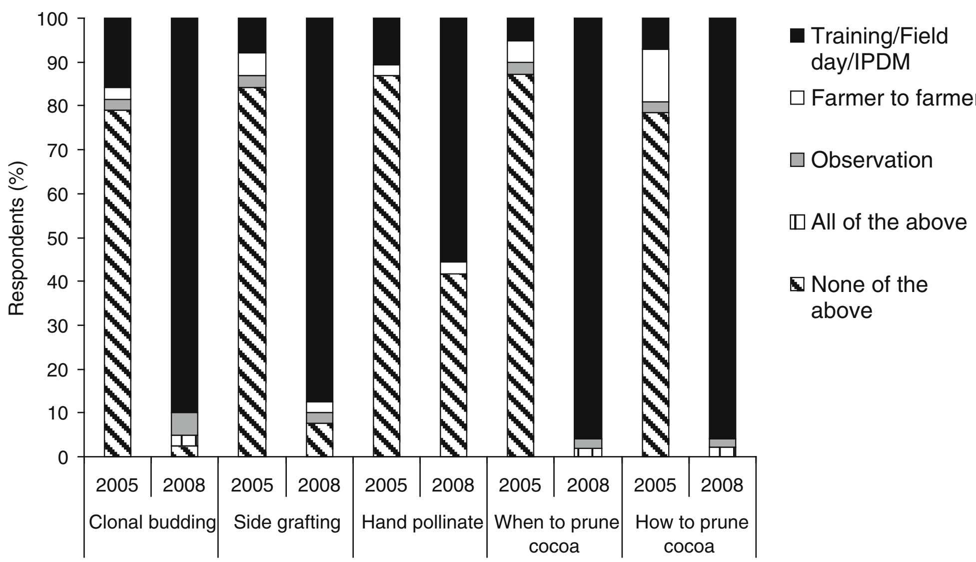


Fig. 6 Sources of information on cocoa management skills for cocoa farmers before and after IPDM training (n=66). p=0.000

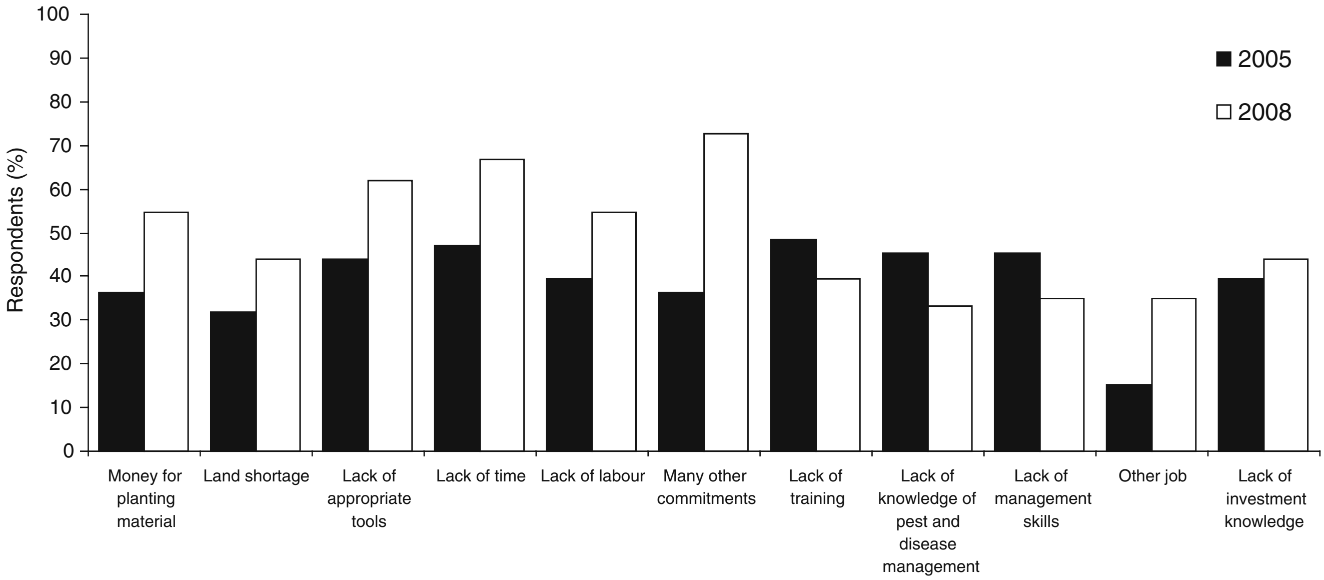
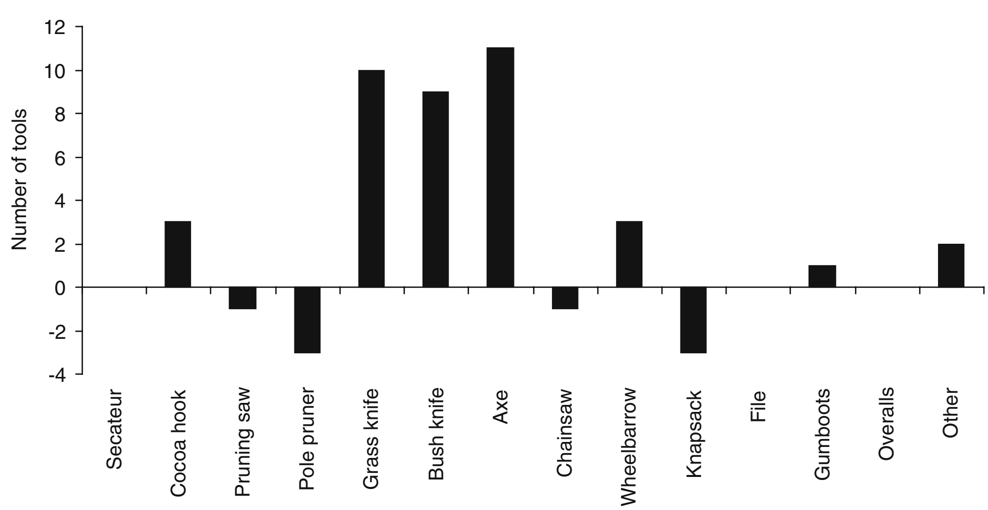


Fig. 7 Constraints to production as identified by farmers. Results presented are from all respondents, not just those who responded to the question in both surveys (n=66). There were no significant differences over time in any of the constraints identified (p=0.5)

farmers did not need to apply all inputs simultaneously to observe a response. When the funding from the central institute ceased due to administrative issues, most farmers continued to implement Option 2 across their block, rather than the full set of all four options initially established, as Option 2 only requires labour inputs. Some wealthier or more motivated farmers invested money to continue managing their entire cocoa block at Option 3 or 4. The fact that farmers continued to implement the IPDM technology even when central support was reduced highlights the success of the strategy to sustainably provide options for farmers to select from to suit their circumstances. The lack of central support for inputs also highlighted the unavailability of certain inputs suggested in the IPDM program, such as chemicals or fertilisers, in more remote villages in Bougainville or Madang. On-going extension support will need to be available to suggest alternative, locally available inputs when these situations arise. Farmer cooperatives established by farmers, or under the guidance of private sector champions and non-government organisations will also assist in providing access to inputs and markets. The on-farm training approach enables more immediate action to be taken as the closer link between researchers and farmers facilitates the assessment of the performance of the technology and farmer perceptions.

The success of the on-farm training approach is reflected in the improvement in farmers' knowledge of the cocoa cropping cycle, a better understanding of pests and diseases, and the reduction in disease incidence in the

Fig. 8 Change in the number of cocoa-producing tools owned by surveyed cocoa farmers over time (n=44)



cocoa blocks. The IPDM training enables farmers to understand why they apply particular inputs at specific times during the year and encourages a targeted approach with fewer negative financial and environmental side effects. Learning by doing has been shown to effectively improve knowledge uptake (Ajayi et al. 2008; Olanya et al. 2010; Snapp et al. 2002). An on-farm approach in Malawi to extend soil fertility technology to maize farmers found that links between researchers and farmers provided feedback from farmers and facilitated priority setting in research and extension (Snapp et al. 2002). The participatory approach is a continuous two-way learning approach, in which farmers, extension staff and researchers together investigate, analyse and evaluate technologies, and direct future research opportunities (Guest et al. 2010).

Engaging farmers in the establishment of on-farm participatory trials fosters the dissemination of information from farmer to farmer in remote villages. In this way, the farmers learn by doing, and impacts are demonstrated to their neighbours within one or two months. Innovations that have rapid demonstrable results are more rapidly adopted than those that are capital intensive or require a long time before results are visible (Ejembi et al. 2006). Trained farmers adopt the new technology and rapidly improve their incomes. Transfer of technology and knowledge between farmers in previous studies has varied. In some cases, farmers preferred to be the primary trainee rather than being trained by other farmers (Ajayi et al. 2008). In PNG many farmers are still requesting training from CCIL Plant Pathology staff rather than extension staff or other farmers. The transfer of information may also depend on financial incentives. In Nigeria, a Farmer Field School approach to transfer technology to cocoa farmers found that 63% of primary trainees transferred knowledge to other farmers when funds were made available by a donor agency (Ajayi et al. 2008).

While it is obvious from the farmer surveys that the extension service in PNG has been ineffective, cultural constraints to production also exist along with the limited availability of labour and land. Many smallholder farmers rely on family members to provide labour, which becomes limiting when there is a conflict with other commitments or the family member leaves the village. Implementation of IPDM involves more time, and potentially some financial investment. As indicated in this survey, competition with other activities became a greater constraint to the implementation of IPDM than a lack of understanding of good farming practices. This shift needs to be taken into account when monitoring the adoption of new technologies.

The availability of land in suitable growing environments has also been reported as a constraint to production (Allen et al. 2009; Omuru et al. 2001). Competition for land means that expansion of cocoa in PNG will need to come from higher yields per tree rather than an increase in the area devoted to cocoa plantings. As indicated by the increase in yields observed in this study, the IPDM technology has the potential to achieve this.

Since the current project, IPDM technology has attracted much debate and support from both government and private industry in PNG, including the adoption of IPDM as the national strategy to improve cocoa production. There is no doubt that the IPDM options are effective. The development of a strong extension network, including private sector "champions", will determine the long-term success of the IPDM technology in PNG. The establishment of outposts of the main private sector agricultural suppliers such as Agmark Pacific and Farmset in the districts would assist farmers greatly by providing access to inputs, infrastructure and transportation of produce. The involvement of both public and private sector stakeholders in the transfer of IPDM to smallholder farmers is a positive sign. The success of this IPDM program will be indicated by how close PNG gets to achieving the target of 100,000 tonnes of dry beans by 2012, but a more detailed impact assessment study might be even more informative in identifying medium- and long-term strengths and weaknesses of this approach.

We can conclude that effective delivery of new technologies depends on a skilled and motivated extension service. Extension staff must be trained in the technology that they are delivering to the farmer. The technology must be delivered to the farmer in the field with regular follow up visits to ensure the practices are being adopted properly. In this way, the farmers become part of the cocoa research program, and can immediately provide feedback to the extension staff to take back to the research institute.

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John-Thomas Vano started working as a field technician with the Plant Pathology Section at the Cocoa and Coconut Institute Ltd Papua New Guinea in 1992. He completed matriculation studies at the University of Papua New Guinea, East New Britain Centre in 2000 while being employed. Mr. Thomas Vano was instrumental in field-testing the IPDM technology, especially in East New Britain Province and the Autonomous Region of Bougainville where he assisted Mr. Paul N'nelau and Mr. Ricky Wenani. He now works with the Simbu Provincial Government where he is promoting the adoption of IPDM by cocoa farmers in the Highlands. Mr. Thomas Vano comes from the Eastern Highlands Province and is married with six children.

Ricky Wenani is one of the plant pathologist/crop protectionist of the Plant Pathology Section at the Cocoa and Coconut Institute Ltd Papua New Guinea, where he manages pests and disease in cocoa in PNG. He took up food technology studies at the University of Technology, Lae and completed 3 years of the 4 year training. Due to university expenses Mr Wenani was unable to return and complete his studies. Mr. Wenani was instrumental in the IPDM technology on farm testing especially in East New Britain and Bougainville. He continues to promote the adoption of the technology by farmers through training of extension officers and farmers. His knowledge on IPDM is evident on his family's cocoa farm. Mr. Wenani comes from the Morobe Province and is married with three children.

Paul N'nelau is one of the senior extension officers of the Industrial Services Division at the Cocoa and Coconut Institute Ltd Papua New Guinea. He is based in the autonomous region of Bougainville and carries out extension services there. He had been with the Agriculture Bank of Papua New Guinea prior to joining the Cocoa Coconut Institute Ltd. Mr. N'nelau was instrumental in the IPDM technology on farm testing especially in Bougainville. He continues to promote the adoption of the technology by farmers through training of extension officers, farmers and school children throughout the autonomous region of Bougainville. Mr. N'nelau comes from Bougainville and is married with children.

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Before awarded John Allwright Fellowship (JAF) from the Australian Centre for International Agricultural Research (ACIAR), he was working at the International Finance Corporation (The World Bank Group) as an operational analyst in the division of agribusiness linkages, and as the Secretary General of the Cocoa Sustainability Partnership (CSP), a public private partnership for sustainable cocoa development in Indonesia.

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